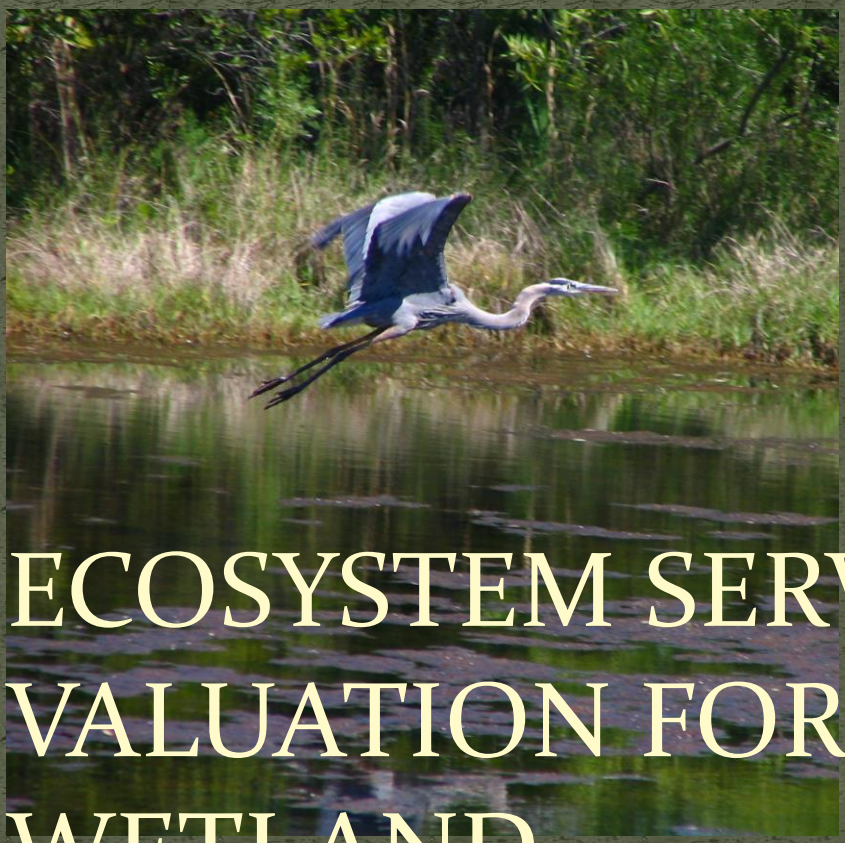

ECOSYSTEM SERVICE VALUATION FOR WETLAND RESTORATION

What It Is, How To Do It, and Best Practice Recommendations

This report is intended to assist those interested in using ecosystem service valuation to promote wetland restoration by: explaining what ecosystem service valuation is; framing it within the history of wetland science and policy; identifying available methods and tools; offering examples of use through case studies of watershed and/or wetland restoration projects that have utilized ecosystem service valuation; and providing recommendations for using ecosystem service valuation within the context of wetland restoration. Five case studies are summarized to provide examples of the use of ecosystem service valuation and the various methods and techniques that can be applied in a variety of settings. A glossary of terms, references, links, and a list of available tools for ecosystem service valuation are provided at the end of the report.

Suggested Citation:

Stelk, M.J. & Christie, J. (2014). *Ecosystem Service Valuation for Wetland Restoration: What It Is, How To Do It, and Best Practice Recommendations.* Association of State Wetland Managers, Windham, Maine.

Photo credit: Jeanne Christie

ECOSYSTEM SERVICE VALUATION FOR WETLAND RESTORATION:

What It Is, How To Do It, and Best Practice Recommendations

By
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Prepared by
The Association of State Wetland Managers

Funding Support Provided by

The U.S. Environmental Protection Agency, Wetlands Division

The McKnight Foundation

Acknowledgements

The Association of State Wetland Managers (ASWM) wishes to thank the McKnight Foundation and the U.S. Environmental Protection Agency for their financial and technical support of this project, and in particular Rebecca Dils, the project manager for EPA. We are also indebted to our reviewers who voluntarily contributed a significant amount of time and expertise in editing, clarifying content, and constructive feedback. Their contributions helped us shape this document and provide a more in-depth understanding of the issues and economic methods. Our reviewers include: Dr. Kenneth Bagstad (U.S.G.S.), Dr. Tom Hruby (Washington State Department of Ecology), Dr. Mary Kentula (U.S. EPA), Maya Kocian (Earth Economics), Dr. Samuel Merrill (Catalysis Adaptation Partners, LLC), Dr. Charles Perrings (Arizona State University) and Martha Sheils (New England Environmental Finance Center).

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INTRODUCTION

A considerable amount of interest has been building over the years in regard to the potential of "ecosystem service valuation" for conservation strategies within the field of natural resource management. However, few natural resource managers understand what it is or how to use it. In fact, the concept of "value" in regard to ecosystem services has become muddied and confusing for even the most acute researchers and practitioners. The concept of "value" to an economist when compared to an ecologist's perspective will more often than not lead to two very different definitions. An economist will generally equate "value" with "market value" - the monetary amount that an individual is willing to pay for a commodity or service. The dollar amount paid is considered equal to the "marginal utility" of the good or service to the individual purchaser, or in other words, the expected level of satisfaction experienced by the buyer in relation to its price.[1] An ecologist might define "value" by ecological function – the ability of specific functions to perform and the ecological value of their contribution to the overall health of the ecosystem. For example, in Vermont, a high-value wetland (a.k.a. "Class 1") is considered to be exceptional or irreplaceable in its contribution to the state's natural heritage by providing one or more "functions or values" at a very high level (Vermont Natural Resources Board, 2010).

To the general public, however, the term "value" is often associated with principles and ethics. For example, a common slogan such as "family values" is intended to convey an ethical position in regard to family structure. At best, the term "value" is ambiguous and it has led to significant debate over what "values" should and can be included in any kind of ecosystem service valuation as well as how to measure them. At worst, its ambiguity has led to the dismissal of ecosystem service valuation efforts that were either not inclusive enough of less tangible values (such as cultural norms and traditions) or produced questionable estimates of economic value due to a lack of explicit market data (Chan, Satterfield, & Goldstein, 2012).

The different interpretations of key terms like "value", coupled with the specialization of professional fields (i.e., the "silo effect"), creates challenges for wetland managers and those in the field of wetland restoration who need to communicate the expected benefits of a proposed wetland restoration project in a language that is meaningful and clearly articulated for a broad audience of stakeholders. Many current decision-making frameworks utilize benefit-cost analysis as a tool to weigh and communicate trade-offs, but it is a process better understood by economists than by many wetland scientists and one that involves several significant limitations and assumptions. It is also incapable of measuring certain values such as "existence value" or "bequest value."[2] In order to approach ecosystem service valuation comprehensively, professionals will have to stretch out of their professional specialties in order to learn new perspectives and new

[1] For a more thorough explanation of the economic principle of marginal utility and ecological economics see "What Have Economists Learned About Valuing Nature? A Review Essay" by Sarah Parks and John Gowdy (available at http://www.sciencedirect.com/science/article/pii/S2212041612000587).

[2] Existence value is the benefit/satisfaction people receive from knowing that a specific environmental resource exists. Bequest value is the benefit/satisfaction people receive from knowing that a specific environmental resource will exist for future generations.

ways to communicate, and to develop creative, standardized, and broadly accepted models for valuation.

The public's knowledge of the benefits of wetland restoration is generally confined to wildlife benefits such as habitat for migratory waterfowl. In fact, seasoned wetland scientists themselves are still trying to understand wetland functions and how they interact within the broader landscape.[3] Wetland restoration is a complicated science and project goals are as diverse as the landscapes and types of wetlands that exist. In addition, many of the intrinsic and implicit benefits of wetland functions to society are unaccounted for in the market system. Therefore, communicating restoration project benefits, and hence, generating financial support for wetland restoration can prove difficult - even more so when faced with a stagnant or bearish economy. Ecosystem service valuation is a technique which can aid in the development of public and political support for wetland restoration projects by deriving monetary values as well as relative value indicators (see discussion on pg. 20 in "Non-monetary Values") for many non-marketed benefits produced by wetlands. Ecosystem service valuation can provide a more balanced perspective of the benefits versus the costs of wetland restoration by providing a dollar and "value" based evaluation of benefits. It also provides, at least in part, a dollar value to compare against other alternatives in a traditional benefit-cost analysis.

There is a rigorous debate among ecologists and economists as to the value of benefit-cost analysis, ecosystem service valuations and their associated methods. The assumptions that need to be made (e.g., the utilitarian framework which posits that the best course of action is one which maximizes the individual's happiness) and the limitations of current science and knowledge of biodiversity have been used to decry the results of ecosystem service valuation studies (Parks & Gowdy, 2013). Additionally there is a secondary, but clearly related, debate regarding whether or not we can or should put a price tag on nature, public goods, and values such as sacredness, cultural identity and the rights of future generations. (Pritchard, Folke, & Gunderson, 2000; Radford & James, 2013; Russi et al, 2013; Searle & Cox, 2009). This paper does not attempt to enter in to either debate nor does it attempt to promote one point of view over any other. However, decisions are being made every day which negatively impact the health of wetlands, which in turn negatively impact society. Whether it is morally right or wrong, unless we include diverse wetland values, including monetary estimates, into the decision-making process we will continue to witness wetland decline and watch their subsequent benefits to society disappear.

Ecosystem service valuation's best attribute may be that it interjects previously under-valued or non-valued public goods (often called "externalities") provided by complex ecosystems such as wetlands into the decision-making process in terms that are consistent with currently used benefit-cost analysis methods. This makes it easier for decision-makers to understand the value of incremental environmental changes, analyze the actual trade-offs, and prioritize wetland

[3] This point has been made explicity clear from the current debate over connectivity of wetlands to the navigable waters of the U.S. For more information go to: http://www.aswm.org/wetlands-law/cwa.

restoration projects. Ecosystem service valuation attempts to connect the broad portfolio of benefits provided by wetlands to those who benefit from them, whether they are the ones directly exploiting the resource or those who indirectly benefit from their services, such as flood and storm surge protection, water quality enhancements, wildlife habitat, etc.

However, because there are values, and therefore trade-offs, that do not necessarily fit within a benefit-cost framework, perhaps the most promising aspect of ecosystem service valuation is that it can expand our perspective of "value" and challenge us to develop more holistic definitions of success. Therefore, the multiple methods of determining value that have been developed through ecosystem service valuation projects are presented in this report and recommendations are offered in regard to effectively designing a comprehensive decision-making context.

The first section of this report begins by explaining the concept of ecosystem service valuation and natural capital. It then provides some historical context for efforts to develop measures of wetland functions, benefits and their value to society within U.S. policy. The authors then connect the use of ecosystem service valuation to contemporary concerns and issues.

The second section explains the valuation process and explains some of the most commonly used methods. Advantages and disadvantages of each approach are illustrated for the reader. The third section provides summaries of five wetland valuation case studies. This leads to the fourth section which outlines best practice recommendations based on the authors' research. The report ends with sections containing information about available decision support tools, methods and software as well as a glossary, a list of other case studies and references.

HISTORY, POLICY, TRENDS & ISSUES

Wetlands and Ecosystem Services

The conterminous United States has lost over 50% of its wetlands since the first European explorers set foot on its shores more than 500 years ago (Dahl, 1990). Despite a slight increase in acreage of certain freshwater wetlands from 2004-2009, coastal wetland acreage substantially declined during those years resulting in a net loss of more than 360,000 acres of coastal freshwater and saltwater wetlands (Dahl, 2011; Dahl & Stedman, 2013). Although wetland conversion has yielded many benefits to society such as agricultural products and development opportunities, these conversions have also negatively impacted and will continue to negatively impact social welfare in numerous ways.

Wetlands provide a multitude of important benefits for society, such as flood attenuation, wildlife habitat, and carbon sequestration. Historically, those benefits were not monetarily valued and therefore they were not accounted for in the market system as a cost of production nor were we able to monetarily quantify the value of their loss or their benefits to production or society. Since many policy and development decisions are based on monetary benefit-cost analysis, the value of wetland benefits (as non-commodities) was absent from policy and development discussions and as a result, wetlands were significantly degraded and destroyed (Springate-Baginski, Allen, & Darwall, 2009; Russi et al., 2013). The destruction of so many wetlands has resulted in losses in wildlife populations, water quality, flood storage and a host of other benefits valued by society. The loss of those benefits has had both environmental and economic consequences. Documenting wetland ecosystem benefits up front provides decision makers with the ability to factor the value of wetlands into the benefit-cost analyses and may ultimately lead to greater emphasis on actions that restore and protect wetlands.

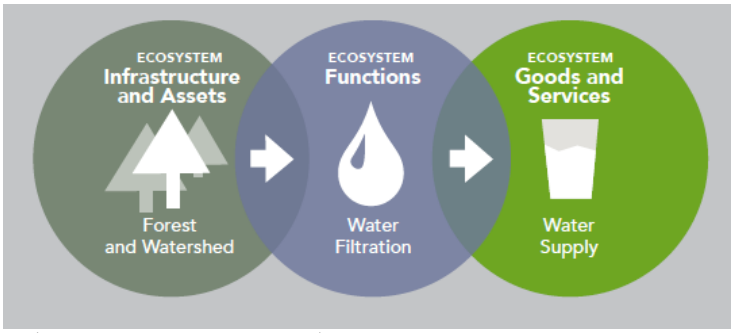
The book *Man and Nature*, published in 1864, is viewed by some as the first modern treatise on ecosystem benefits. Others point back to Plato's descriptions of the effects of deforestation in 400 BC (Gomez-Baggethun, de Groot, Loomas, Montes, 2009). Academics have been publishing research regarding environmental economics since before the 1970s, but the term "ecosystem services" was originally coined by Ehrlich and Ehrlich in 1981 (Gomez-Baggethun et al., 2009; Hermann, Schleifer, & Wrbka, 2011; Liu, Constanza, Farber, & Troy, 2010).[4] "Ecosystem services", more recently referred to as "ecosystem benefits" (please see footnote below)[5], are often confused with the concept of "natural capital." Ecosystem benefits are the goods and services provided by

[4] The first modern statement of the idea of ecosystem services may be by Westman, W.E. (1977) How Much Are Nature's Services Worth? from *Science*, 197, 960-964.

[5] For the remainder of this report, the term "ecosystem benefits" will be used to encompass both ecosystem goods and services. The use of the term "services" to encompass both "goods" and "services" (as explained more thoroughly later in this report) can be confusing and detrimental to valuation efforts. Thus the use of the term "benefits" more adequately represents both, in contrast to when one is discussing just "goods" or just "services." However, when referring to the valuation method, the term "ecosystem service valuation" will continue to be employed due to its universal usage.

the natural functions of nature which contribute to human well-being (Costanza et al., 2011). Or in other words, ecosystem benefits are the annual *flow* of goods and services produced by a *stock* of natural capital (K. Bagstad, personal communication, 2013).

This clarification is illustrated in the image below. The "ecosystem infrastructure and assets" represent natural capital. The natural capital produces ecosystem functions, which in turn, produce ecosystem goods and services (collectively called "ecosystem benefits").



(Source: Earth Economics, 2013)

For example, given 200 acres of wetlands, the total acreage of wetlands would be the stock of natural capital, and the ecosystem benefits would equal the annual flow of goods and services produced by the wetlands such as flood attenuation, carbon sequestration, and wildlife habitat (potentially among others). In an effort to provide a better understanding of ecosystem functions, goods, and services, an international coalition of scientists produced the Millennium Ecosystem Assessment Report (MEA) in 2005. The MEA officially defines ecosystem goods and services as "the benefits people obtain from ecosystems" (MEA, 2005).

The emphasis provided by an ecosystem service valuation perspective is on making an explicit link between the functions of nature (the natural processes that happen regardless of any resulting human benefit) and the subsequent benefits (goods and services) provided to society as a result of those functions. Goods are the tangible end products of ecosystem functions which are marketed and directly useable by humans (such as seafood, forage, timber, biomass fuels, natural fiber). Services are "actual life-support functions, such as cleansing, recycling, and renewal, and they confer many intangible aesthetic and cultural benefits as well" (Brown, Bergstrop, & Loomis, 2007). These aesthetic and cultural benefits are often referred to as "qualitative benefits" (i.e., they enhance one's quality of life).

Some of the goods and services provided by wetlands include:

1. Fisheries Production
2. Habitat for Rare and Endangered Species
3. Water Quality Buffering and Pollution Control
4. Wave Attenuation and Erosion Control
5. Production of Forestry Products and Natural Crops
6. Flood Conveyance and Flood Storage
7. Carbon Storage and Sequestering
8. Groundwater Recharge (Christie & Bostwick, 2012)

A major objective of ecosystem service valuation is to provide a comprehensive estimate of the return on investment in conservation, mitigation and/or restoration efforts. In other words, it can inform wetland managers and decision-makers about whether or not the benefits of wetland restoration outweigh the costs. Valuation efforts have also been used to uncover the external costs of activities that damage wetlands. External costs are not included in traditional benefit-cost analysis models. For example, the recovery costs for residents of New Orleans after Hurricane Katrina was not included in the benefit-cost analysis originally done to determine whether it was cost effective to build navigation channels through the Mississippi River Delta.

The primary goal is to include the important environmental, social and economic benefits and costs within the decision-making framework. The aforementioned Millennium Ecosystem Assessment Report broke down ecosystem benefits into four broad categories: Provisioning Services, Regulating Services, Supporting Services, and Cultural Services (see Figure 1). A brief summary is provided below:

1. **Provisioning**: drinking water, food, raw materials, medicinal resources
2. **Regulating**: gas and climate regulation, disturbance regulation, soil erosion control, water regulation, biological control, water quality and waste processing, soil formation
3. **Supporting**: nutrient cycling, biodiversity and habitat, primary productivity, pollination
4. **Cultural**: aesthetic, recreation and tourism, scientific and educational, spiritual and religious (Kocian, Traughber, & Batker, 2012; MEA, 2005; Perrings, 2010)

Figure 1

Services	Comment 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, fodder
Biochemical	extraction of medicines and other materials from biota
Genetic materials	genes for resistance to plant 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 (hydrological 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; many religions attach spiritual and religious values to aspects of wetland ecosystems
Recreational	opportunities for recreational activities
Aesthetic	many people find beauty or aesthetic value in aspects of wetland ecosystems
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
*While fresh water was treated as a provisioning service within the MEA, it is also regarded as a regulating service by various sectors.	

(Reproduced from: MEA, 2005)

U.S. Policy History

Photo credit: Jeanne Christie

Over the years, wetland scientists have partnered with private landowners, volunteers, engineers, government agencies and businesses to restore lost wetlands in the hopes of reinstating some of the lost wetland functions and associated benefits. In 1989 Congress passed the North American Wetland Conservation Act in response to dramatic losses of migratory waterfowl throughout their flyways in North America. The Act is a grant program that supports the North American Waterfowl Management Plan. Between 1990 and 2014, 2,421 projects affecting 27.5 million acres of habitat, much of it wetland were completed through this grant program (U.S. Fish & Wildlife Service, 2014). Since 1992, the U.S. Department of Agriculture's Wetlands Reserve Program has enrolled over 2.3 million acres in permanent and 30 year easements for wetlands restored on agricultural lands (Natural Resources Conservation Service, 2012). These two programs were created to replace some of the wetlands lost in previous decades with an emphasis on creating habitat for wildlife through voluntary restoration.

Voluntary incentive programs such as the Wetlands Reserve Program and the Conservation Reserve Program (established in the 1985 Farm Bill) are early examples of the economic valuation of natural capital and associated benefits to society (Gomez-Baggethun et al., 2009; Searle & Cox, 2009). Although these programs are not methods of ecosystem service valuation per se, they do provide financial incentives to private landowners to voluntarily conserve, enhance and/or restore wetlands on their property and therefore derive implicit wetland values in regard to ecosystem benefits. For example, while the Wetlands Reserve Program's initial focus was on wildlife habitat, goals were broadened over the years to also include 1) improved water quality and groundwater recharge, 2) flood protection, 3) education and recreational opportunities, 4) carbon sequestration, 5) support for endangered and imperiled species, 6) cultural resources, and 7) open space. Enrollment in the Wetlands Reserve Program provided farmers an alternative for their frequently flooded croplands, and recreational opportunities were created (e.g., hunting, fishing and bird-watching) which provided support for local economies (Natural Resources Conservation Service, 2012).

In 2014, the U.S. Department of Agriculture (USDA) reorganized and consolidated many of its conservation incentive programs. The Wetland Reserve Program and the Grassland Reserve Program were combined with the Farm and Ranch Lands Protection Program into the new Agricultural Conservation Easement Program. Whether or not that decision will positively or negatively impact the success of the USDA's conservation incentive programs is yet to be seen.

The USDA also recently created an Office of Environmental Markets (formerly called the Office of Ecosystem Services and Markets) whose goal is "to develop uniform standards and market infrastructure that will facilitate market-based approaches to agriculture, forest, and rangeland conservation." (USDA Forest Service, 2011)

The Clean Water Act (CWA) of 1972 has had a significant impact on protecting wetlands from destructive dredge and fill activities. Although the original impetus for passing the legislation was to curb the pollution of rivers and streams, it established a broader goal of protecting the physical, chemical and biological integrity of the Nation's waters to accomplish its purpose (U.S. EPA, 2014a; U.S. EPA 2014b). It also provided the basis for policies to avoid, minimize and mitigate wetland losses. Over the past two decades, compensatory mitigation has become a commonly used regulatory tool for wetland restoration and rehabilitation efforts in order to compensate for "unavoidable" wetland impacts by developers and others.

The permitting process outlined in §404(b)1 guidelines for the Clean Water Act states that "significant degradation" includes "loss of fish and wildlife habitat or loss of the capacity of a wetland to assimilate nutrients, purify water or reduce wave energy" as well as adverse effects on "recreational, aesthetic and economic values." (U.S. EPA, 2010) There is clear intent in this legislation to address the ecosystem benefits of wetlands, although when it was drafted, there was no (and still is no) widely accepted method for documenting monetary values or for including them in a benefit-cost analysis for land use decisions.

The requirement for compensatory mitigation was initially focused on permittee responsible actions. But concerns over the lack of mitigation success due in part to either the lack of expertise of permit applicants and/or limited opportunities to meet mitigation requirements onsite led to the development of third party options in the form of in lieu fee programs and mitigation banks. Mitigation banking practices in particular (often referred to as a "payment for ecosystem services, or PES) were one of the earliest forms of accounting for the value of natural capital such as wetlands by creating an exchange market and have been in place for over 40 years (Searle & Cox, 2009).[6] According to the U.S. Environmental Protection Agency (EPA) website, mitigation banking means "the restoration, creation, enhancement and, in exceptional circumstances, preservation of wetlands and/or other aquatic resources expressly for the purpose of providing compensatory mitigation in advance of authorized impacts to similar resources." (U.S. EPA, 2012b) Mitigation banks receive credits then sell the credits to developers who must compensate for having impacted wetlands or other water resources.

[6] An interesting PES case study: Moving from Concept to Implementation: Shabman, L. and Lynch, S. (2013). The Emergence of the Northern Everglades Payment for Environmental Services Program. Resources for the Future, Washington, D.C. http://www.rff.org/RFF/Documents/RFF-DP-13-27.pdf.

The Clean Water Act's narrow focus on water pollution control and abatement, however, has historically ignored the multitude of benefits associated with the biological and ecological diversity of wetlands (Alexander & McInnis, 2012; Russi et al., 2013; Searle & Cox, 2009), albeit with a few exceptions. Our scientific understanding of wetland ecosystems has evolved over the years, and wetland scientists now utilize a watershed approach for wetland restoration and management projects which includes a landscape level assessment of the remarkable breadth of diverse functions offered by healthy wetlands, the complex interplay of their functions and components, and their associated benefits to society. This landscape-level assessment also takes into consideration the type, size and location of the wetland in relation to human and wildlife communities as well as plant and soil types (Windham, Laska, & Wollenberg, 2004).

Even when ecosystem service valuation successfully documents a variety of ecosystem goods and services, many state and federal programs may be limited in the degree to which they can include multiple benefits in a benefit-cost analysis by the specific goals of authorizing legislation (clean water, flood reduction, wildlife habitat, etc.). Integration of federal and/or state and/or local programs to achieve multiple goals of multiple programs is one of many potential solutions to this challenge. There are many examples of where this approach is being pursued through watershed and landscape level projects.

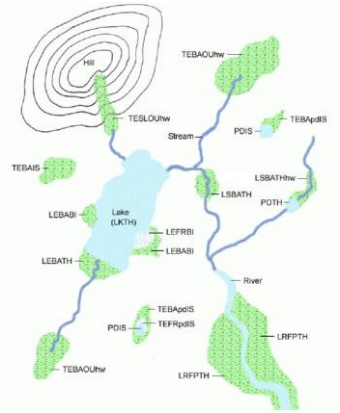
Technological & Policy Advances for Restoration Planning

Landscape level assessments are part of what is known as a "watershed approach." A watershed approach attempts to address the interconnected systems (or issues) that exist within a particular watershed area (i.e., balance the needs of the environment, the economy and social welfare). According to the EPA, a watershed approach is hydrologically defined, involves all stakeholders, and strategically addresses priority water resource goals (U.S. EPA, 2013a). Accurate mapping via geospatial information systems (GIS) and standardized classification methods are integral components of a watershed approach (and thus landscape level assessments) (Morse-Jones, Luisetti, Turner, & Fisher, 2011; Russi et al, 2013). They also provide the basis for evaluating potential ecosystem benefits provided by wetlands based on their location and hydrogeomorphic setting in the watershed.

The U.S. Fish & Wildlife Service (FWS) National Wetlands Inventory (NWI) has been instrumental in providing GIS data and maps showing wetland distribution, type and location. Ralph Tiner, Regional Wetland Coordinator for NWI, describes their approach below:

> To enhance the utility of NWI data for better characterizing wetlands and for preparing preliminary assessments of wetland functions from the NWI database, NWI staff added additional features to the NWI data. Key features included hydrogeomorphic features, specifically landscape position, landform, and water flow path. In addition, it was deemed important to better characterize waterbodies to identify a wide variety of pond types, and to separate natural lakes from created lakes (among other things) so waterbody type was also added to the NWI classification. Collectively, these descriptors have been referred to

as "LLWW descriptors" with the letters representing the first letter of each additional descriptor (landscape position, landform, water flow path, and waterbody type). When standard NWI data are combined with LLWW descriptors, the resultant database is called NWI+ (Tiner, 2012).



Application of LLWW descriptors to a region with nontidal wetlands. Landscape positions: LR – lotic river, LS – lotic stream, LE – lentic, and TE – terrene; Landforms: BA – basin, FR – fringe, FP – floodplain, SL – Slope; Water flow paths: OU – outflow, IS – isolated, TH – throughflow, BI – bidirectional-nontidal; other descriptors: pd – pond (association), hw – headwater; Waterbodies: PD – pond, LK – lake. Note: Landscape position can be added to lakes and ponds if desirable.

The NWI+ database allows for more detailed characterization of wetlands across the landscape and makes it possible to identify potential wetland functions at the landscape-level which can be used to identify potential ecosystem values for both existing and restorable wetlands. This tool and others like it are essential to decision-making efforts which need to prioritize wetland restoration projects based on specific functions that are desired by the particular group of stakeholders. For example, if a community is looking to improve flood attenuation, then the wetland areas that provide the highest potential for flood attenuation would be given highest priority for investment in restoration. NWI+ maps and others like it can help stakeholders identify wetland areas that can or can potentially provide those specific functions to meet those goals.

However, it has really only been over the last ten years or so that the practice of "ecosystem service valuation," has extended beyond the world of academia (Bagstad, Semmons, Winthrop, Jaworski, & Larson, 2012). One could argue that this is due to our increased spatial awareness provided by advances in technology such as ArcGIS, NWI+, and many other spatial models[7] much in the same way that our first view of the earth from the moon changed our global perspective of planet Earth. Today, several Federal agencies (e.g., U.S. Army Corps of Engineers, U.S. Forest Service, U.S. Geological Survey, Federal Highway Administration, National Oceanic and Atmospheric Administration, etc.), international governments worldwide (including China, Syria, and Colombia among many), several well-established for-profit (e.g., UniLever[8], Starbucks[9]) and not-for-profit organizations (e.g., World Wildlife Fund, The Nature Conservancy), are not only developing policies, frameworks and methods to calculate the value of a full range of ecosystem benefits, but they are also using their findings to plan for current and future conservation,

[7] To learn about new innovative spatial modeling efforts being developed, visit the webinar series for the Wetland Mapping Consortium and/or Natural Floodplain Functions Alliance at http://www.aswm.org/aswm/aswm-webinarscalls.

[8] See Unilever's statement of "Protecting Biodiversity" here: http://www.unilever.com/sustainable-living/sustainablesourcing/biodiversity/index.aspx

[9] See Starbuck's "Global Responsibility Report Goals & Progress 2012" here: http://www.starbucks.com/responsibility/global-report

development and growth (Cox, Almeter, & Saterson, 2013; Gomez-Baggethun et al., 2009; Lange, Belle, & Kishore, 2010; Reed, Martin, & Cushing, 2013; Ruckelshaus et al., 2013).

The EPA recently released its "Final Ecosystem Goods and Services Classification System" (FEGS-CS), providing a standardized and comprehensive listing of ecosystem goods and services as a solid foundation for their use nationally and internationally (Landers & Nahlik, 2013). Several intergovernmental agreements have been formed to discuss the "wise use" of wetlands (Russi et al., 2013). And international organizations such as the Intergovernmental Panel on Climate Change (IPCC) and the World Bank Group (WBG) are paying special attention to poor, developing agrarian countries which are rich in natural capital but poor in built and financial capital. These communities disproportionately depend on the public goods and benefits provided by wetlands (and other ecosystems) and they have the least capacity to adapt to the impacts of biodiversity loss and climate change (Alexander & McInnis, 2012; Lange et al., 2010; Perrings, 2010). This situation is not so different in rural America.

Contemporary Issues & Concerns

Public Goods

Ecosystem functions exist whether humans benefit from them or not. Ecosystem service valuation is designed to account for the benefits provided by ecosystems that have not or cannot be directly calculated in terms of dollars because they are not directly bought or sold on the market (Costanza et al., 2011). Historically, benefit-cost analyses performed by economists have only accounted for those ecosystem benefits which could be bought and/or sold in existing markets, e.g., commercial fish or timber. But more recently, and particularly within the last 10 years, after a rapid increase in severe storm events (e.g., Hurricanes Katrina and Sandy), scientists, economists, and policy makers have been trying to understand, measure and account for the benefits to society of non-marketed ecosystem benefits such as the ability of wetlands to reduce flooding, support biodiversity and to absorb excess stormwater (Russi et al., 2013).

Source: Delaware Dept. of Natural Resources & Environmental Control

Typical wetland functions provide these benefits but they are not bought or sold on the market – there is no market-demand for them in the traditional sense because they are considered "non-rival" and "non-excludable." These benefits are what economists refer to as "public goods" since no one directly pays for them and they are non-exclusionary, i.e., anyone can use them and their use, or consumption, by one person does not diminish their benefits for others. For example, a person can enjoy the benefit of flood attenuation from wetlands without excluding anyone from those same benefits and without reducing the availability of it to others. A public good is the opposite of a private good. A private good is one which is privately owned, and once consumed, cannot be used again such as a cord of wood (Costanza et al., 2011). Often, however,

because public goods are not privately owned, it can mean that no one stewards or maintains those public goods and thus, the associated ecosystem benefits become depleted, degraded or destroyed (Searle & Cox, 2009). Garrett Hardin clearly illustrates this quandary in his economic theory, "Tragedy of the Commons."[10]

Environmental Justice & Intergenerational Equity

Environmental justice issues have highlighted the discrepancies between stakeholders and their dependencies on natural capital. For example, many poor agrarian countries receive very little or no monetary compensation for being good land stewards yet their good stewardship practices can provide global benefits. And intergenerational equity issues (e.g., option and bequest values for conserving resources for the next generation) have expanded our thinking from short-term benefits to long-term benefits for future generations to enjoy (The Economics of Ecosystems & Biodiversity [TEEB], 2010). Ecosystem service valuation can provide a more comprehensive process for stakeholders to weigh multiple investment options that evaluate both quantitative and qualitative projected outcomes within a more participatory process framework. A case study report from Natural England found that:

> The key recommendation…is not to put all the emphasis on the numerical results (both quantitative and monetary) but to take note of the entire analytical process from defining the project, the baseline, the impacts of the project, the affected population and valuation. If this whole process were made part of decision-making, stakeholders who may have different interests would find it easier to negotiate about the project and those who design the project may find it easier to strike a better balance between potentially conflicting outcomes of the project. (Natural England, 2012)

Climate Change

Concerns about the impacts of climate change and biodiversity loss have heightened the interest in the ecosystem functions and benefits provided by wetlands, one of the most productive ecosystems of all (Perrings, 2010; Russi et al., 2013). In fact, scientists in China have attributed the increase in droughts, floods and sandstorms in northern China to their shrinking supply of wetlands (Tianyu, 2009). As mentioned previously, wetland functions are the natural ecological processes occurring within wetlands, and wetland benefits (goods and services) are the outputs of these functions that provide benefits for humans. It is now widely recognized that wetlands provide many benefits that are needed to mitigate and adapt to climate change and this reality is fundamentally altering the discussion about why we should preserve and restore them (Christie & Bostwick, 2012; Russi et al., 2013).

Until recently, efforts to address climate change have only revolved around how to mitigate climate change by reducing greenhouse gases through investments in renewable energy, cleaner fuels and more efficient technologies. Most scientists, however, predict that even if we

[10] For those not familiar with this seminal work by Garret Hardin, you can download the pdf here http://cecs.wright.edu/~swang/cs409/Hardin.pdf or here http://www.geo.mtu.edu/~asmayer/rural_sustain/governance/Hardin%201968.pdf.

significantly reduce our carbon footprint immediately, the impacts of our past actions will continue to increase the occurrence and severity of extreme climatic events such as droughts, hurricanes and floods (Pew Center on Global Climate Change, 2006). Wetlands, however, not only absorb carbon, but they also act as sponges to absorb excess floodwater and filter out pollutants in stormwater (Christie & Bostwick, 2012). Strategic wetland restoration efforts will therefore play an increasingly important role in our efforts to not only mitigate (e.g., through carbon sequestration), but to also adapt to the impacts of climate change (e.g., through flood peak attenuation) (Perrings, 2010; IPCC Working Group II, 2014).

It is important to remember, however, that wetlands are also vulnerable to climate change (Kusler, 2006). Climate change is altering the frequency and type of precipitation events experienced around the world as well as global average temperatures (IPCC Working Group II, 2014). When wetlands are exposed to too much polluted stormwater run-off or changes in temperature and hydrology, they can be seriously degraded. When wetlands are degraded or when they are converted to other land uses, their ability to absorb excess carbon is reduced or eliminated and it can also cause them to release carbon. In addition, for certain types of wetlands, warming temperatures and conversion can cause them to release more methane into the atmosphere, which accelerates climate change. Although much is still unknown about the extent of methane releases from different wetland types, what this essentially means is that wetlands can serve as both sources and sinks for greenhouse gases simultaneously (O'Connor et al., 2010).

California Drought Dry Riverbed 2009
Source: National Oceanic and Atmospheric Administration

So even though wetland restoration can assist efforts to mitigate and adapt to climate change, protection of existing wetlands will be an important part of any climate change adaptation plan. Climate change will also lead to changes in habitat and force plant and animal species to migrate to new areas more conducive to their habitat needs. This may result in the spread of more invasive species and/or a need to reevaluate "native" species. Adaptive management and longer term monitoring and assessment of wetland restorations will need to be developed to anticipate and manage climate change risks (Erwin, 2009; IPCC Working Group II, 2014; Stein, et al., 2014).

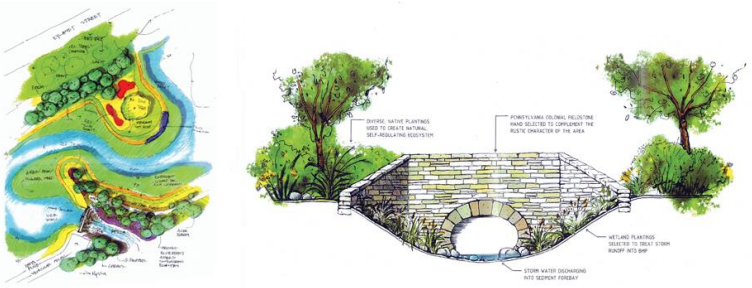
Economic Uncertainty

The interest in and use of ecosystem service valuation has become even more popular lately due to the current state of economic uncertainty in the United States and the large financial investment often associated with restoration projects. With limited financial support available, communities are faced with difficult spending decisions and trade-offs. The use of ecosystem service valuation, however, has revealed that the seemingly large price tag for restoration often does not account for the value of non-marketed ecosystem benefits which sustain life, promote well-being and avoid undesirable expenses. When these "lost" values are accounted for through

ecosystem service valuation, the price tag for restoration, more often than not, is offset by comprehensive accounting of the full range of benefits and costs of alternative choices.

For example, flood attenuation is not a product or service that someone can buy in a store or online, yet it is a very valuable service to those who are concerned about flooding impacts. It is also widely known that flooding can result in substantial financial losses. Ecosystem service valuation can assist in teasing out those implicit monetary and non-monetary values so that they are more explicit and accessible when performing a comparison of benefits and costs. This can lead to a better, more informed, decision-making context for communities with limited financial capacity.

Infrastructure Alternatives



Source: New York City Department of Environmental Protection

Current discussions about "green" infrastructure (e.g., wetlands) vs traditional infrastructure (e.g., wastewater treatment plants) are typically centered around this concept of values being unaccounted for, or lost, in the market system as well as avoided costs (which will be explained further in the "Methods" sections). In fact, several experts contend that "green" infrastructure (also referred to as "natural" infrastructure), such as healthy wetlands, can provide many of the same benefits of traditional man-made infrastructure at a much lower investment and maintenance cost (Kocian et al., 2012; Russi et al., 2013). Several case studies have highlighted the cost-savings of natural vs manmade infrastructure, including the New York Staten Island Bluebelt project where stormwater is controlled using existing natural drainage systems, e.g., streams, ponds, and wetlands. An initial benefit-cost study found that the project would save more than $30 million over a conventional sewer-line approach. The Bluebelt "now includes about 400 acres of freshwater wetland and riparian stream habitat and almost 11 miles of stream corridor…[and]… it has successfully removed the scourge of regular flooding from southeastern Staten Island, while saving the City $300 million in costs of constructing storm water sewers." (Appleton, 2012)

Another great example also comes from the state of New York. New York City undertook several programs to protect and restore wetlands in the New York City watershed. Not only did wetland restoration and preservation efforts in their watershed save the City millions of dollars in water treatment costs for drinking water, but the project also boosted the upstate economy through an increase in recreational opportunities, ecotourism and employment (Colgan, Yakovleff, & Merrill, 2013; New York City Department of Environmental Protection, 2009). Currently, in the Sebago Lake Watershed of the Portland Water District in Maine, land acquisition and conservation easements are being used to maintain source water quality from Sebago Lake and to avoid the bigger costs associated with building additional water filtration facilities (Colgan et al.,

2013). A benefit-cost analysis found that in four out of six scenarios, "green infrastructure represented a cost savings, with the most optimistic case of $111 million saved over 20 years." It was also found that "ancillary benefits in the form of carbon sequestration and Atlantic salmon habitat would make an even more compelling case for investment in green infrastructure. By combining empirical data on the ground with calibrated nonmarket benefits transferred from other settings, we estimate that these nonmarket benefits would amount to $72 to $125 million over a 20-year timeframe. Including these ancillary benefits would make green infrastructure superior in all six scenarios." (Talberth, Gray, Yonavjak, & Gartner, 2013)

In addition, the life span of a healthy wetland can be significantly longer than that of man-made infrastructure, so the cost of each type of solution needs to be weighed in relation to their life expectancy and maintenance costs. Unlike a concrete structure, a successful "green" infrastructure project will most likely not depreciate, and in fact, may actually increase in value over time (Christie & Bostwick, 2012). Applying the correct discount rate is also a challenge due to the fact that discount rates are designed to control for the rate of time preference of individuals, not of society. In other words, an individual will value, say $100, more now than they would value it at a future time. So to account for benefits that wetlands provide to society, a social discount function could be used instead, but there is still a significant amount of debate on the best rate to use. Determining the appropriate discount rate is a challenge and requires making many assumptions (e.g., people's future values) so the choice of discount rate used should be accompanied by clear documentation of the reasoning process and precedent (Costanza et al., 2006; National Research Council, 2004; TEEB, 2010).

Non-Monetary Values

As alluded to earlier, traditional benefit-cost analysis only focuses on established monetized benefits and costs to determine the most economically efficient option. As Drs. Dennis King and Marisa Mazzotta explain, however, this

> may or may not be the same as the most socially acceptable option, or the most environmentally beneficial option. Remember, economic values are based on peoples' preferences, which may not coincide with what is best, ecologically, for a particular ecosystem.[11] However, public decisions must consider public preferences, and benefit-cost analysis based on ecosystem valuation is one way to do so. Often, when actual decisions are made, a benefit-cost analysis will be supplemented with other information, such as equity implications or overriding environmental considerations. (King & Mazzotta, 2000a)

Additionally, recognition of the need to measure qualitative benefits (e.g., aesthetics, cultural history or sense of place, spiritual traditions, etc.) in addition to non-monetary measures of quantitative benefits (e.g., pounds of CO_2 sequestered, volume of water stored or filtered, etc.)

[11] Several works cited in this report (e.g., Pritchard et al., 2000) highlight ecosystem threshold levels and warn against relying entirely on consumer preferences which do not reflect the risk of irreversible damages to life-support systems.

has led to broader and more equitable stakeholder involvement (Bagstad et al., 2012; Liu et al., 2010). The value different individuals and/or different types of communities place on particular ecosystem benefits has also become an integral and influential part of the discussion of what various ecosystems are worth (Alexander, 2012). Values are context specific in space and time and "the concept of value is complex" (U.S. EPA Scientific Advisory Board, 2009). Therefore, broader participatory techniques offer a way to understand the values associated with specific ecosystem benefits within specific contexts.

There are several methods used to derive economic valuation of ecosystem benefits which are not directly bought or sold on the market. The two initial choices are to either estimate a dollar value or to estimate a relative value. Relative value can be either a quantitative or qualitative comparison which compares service X to service Y and considers which is greater in value without necessarily deriving a concrete monetary value. For example, with carbon sequestration, it may be more effective to report results as different amounts (tons) of carbon reduced for different scenarios as opposed to putting a dollar value on the amount of the reductions (Russi et al., 2013). Or it can simply show an increase or decrease in the quality of a particular service due to a policy or management decision in order to highlight trade-offs. Both approaches (dollar value and relative value) can be useful for ecosystem service valuation studies. This report's section on *Ecosystem Service Valuation Methods* under *The Nuts and Bolts of Ecosystem Service Valuation* discusses the different approaches, methods, and provides examples of use.

Establishing Wetland Restoration and Protection Priorities

Documenting the ecosystem benefits provided by specific wetlands may be used as a strategy to include wetland restoration and protection into consideration as alternative approaches to solving a variety of problems, such as: flooding, water pollution, wildlife protection, source water protection, etc. Tools such as NWI+ (and others that use hydrogeomorphic data sets (HGM) and/or Soil Survey Geographic (SSURGO) data[12]) coupled with ecosystem service valuation can identify specific wetlands that provide specific benefits. For example, wetlands can be prioritized for restoration efforts to reduce sediment going into rivers and thus reduce dredging in ports downstream, leading to substantial monetary savings. Wetland protection and restoration combined with stream restoration can raise groundwater tables and support both the quantity and quality of drinking water, thereby reducing the need for drinking water utilities to install expensive treatment systems. Both of these projects may also provide wildlife, recreation and other benefits. In addition, as discussed previously, many federal and state statutes are written to meet certain specific goals and may constrain both the incorporation of the full range of ecosystem benefits provided by wetlands from consideration in the decision-making process and limit the funding available to carry out approaches that achieve multiple benefits. This is a consideration that merits some discussion early in any ecosystem service valuation process, not to discourage a holistic approach, but to anticipate and identify ways to address these challenges as the valuation of benefits is conducted.

[12] SSURGO and gSSURGO are data sets developed and employed by the USDA Natural Resource Conservation Service.

THE NUTS AND BOLTS OF ECOSYSTEM SERVICE VALUATON

The Wetland Valuation Process

This section briefly outlines the recommended steps to take for a comprehensive decision-making process of which ecosystem service valuation is a component. Three particularly useful guides for recommended steps in a comprehensive wetland valuation process helped to guide the development of this report.

1. "Valuing Wetlands: Guidance for valuing the benefits derived from wetland ecosystem services" published by The Ramsar Convention (de Groot, Stuip, Finlayson, & Davidson, 2006)
2. "An Integrated Wetland Assessment Toolkit: A guide to good practice," published by the International Union for Conservation of Nature (IUCN) Species Programme (Springate-Baginski et al., 2009).
3. "Valuing the Protection of Ecological Systems and Services," published by the U. S. EPA (EPA Scientific Advisory Board, 2009)

All three documents highlight the same basic steps, although some vary slightly in order of preference. Essentially, there are seven steps: identify the context; define the boundaries; identify stakeholders; develop a functional analysis; perform an ecosystem service valuation; develop a trade-off analysis; communicate results (see Figure 2, page 23). Proper documentation of the process as it evolves is encouraged in order to keep a record of the methods and procedures used and the outcomes achieved. This will allow others to learn from those experiences and ensure that the field of ecosystem service valuation will continue to improve. Although all seven steps outlined in Figure 2 are essential for a comprehensive decision-making process, this report primarily focuses on Step #5 which involves the actual valuation process.

Ecosystem Service Valuation Methods

Step five in Figure 2, *Perform an Ecosystem Service Valuation*, involves the selection and use of an ecosystem service valuation method(s) which is just one step in the process for implementing a comprehensive approach to wetland valuation as described in the section above. The type or types of ecosystem valuation method selected will vary depending on the specific site and situation. It may often be advantageous to use more than one method to illustrate different scenarios and/or to evaluate different ecosystem benefits. This section explains the most common techniques and methods, outlines the strengths and limitations of each, provides examples of their use, and a matrix is provided at the end for further clarification. The section is intended as a guide to assist in deciding which method(s) may best suit your particular situation. It may also be used as a resource for those responsible for reviewing permits which include an economic valuation. Additional data and research for each method will likely need to be gathered such as demographics, GIS maps, surveys, market data, wetland quality, plant types, soil analysis, connectivity, etc. Additionally, there are several software tools available as well as integrated methods and toolboxes which can assist in the valuation process. A list of these is available at the end of this report.

Figure 2

Essentially, wetland ecosystem benefits can be measured monetarily or non-monetarily through various economic techniques or through the use of indicators which can involve quantitative and/or qualitative analysis. There are four commonly used techniques for ecosystem valuation which can employ various methods. The four techniques are: market-based (which includes market price and productivity methods); revealed preference (which includes the avoided cost, replacement/substitution cost, travel cost, and hedonic pricing methods); stated preference (which includes contingent choice and conjoint analysis methods); and benefit transfer.

Market-Based

Market-based techniques for ecosystem valuation measure the "willingness-to-pay" (WTP) by consumers for benefits that contribute to the provision of marketed goods and services (U.S. EPA Scientific Advisory Board, 2009). Market-based techniques include the Market Price method and the Productivity Method.

Market Price Method

The Market Price Method is commonly used when the ecosystem good or service provided is a product that is bought and/or sold in commercial markets, e.g., commercial clams or lumber. This method calculates the changes in consumer or producer surplus of the product using market price and quantity data. The surplus is the amount that either the consumer enjoys above what he/she paid for the product (the difference between what they paid and what they are willing to pay) or that the producer enjoys beyond what he/she paid to produce the product (the difference between total revenue and total cost). This method is reliant on calculations of supply and demand.

Photo Credit: Oregon Department of Fish and Wildlife

The primary objective is to measure the total economic surplus (consumer and producer) that would result due to the change in the quality or quantity of a final good or service. For example, the market price method can be used to evaluate the benefits of restoring a tidal flat area because market data is available for commercially sold clams that are harvested in the tidal flats. The increase in the healthy clam harvest resulting from the restoration would increase the net surplus (consumer and producer) and the value of that increased net surplus can be used to reflect the value of the restored tidal flat (for this singular activity).

Productivity Method

Productivity in economic terms is the ratio between the inputs and outputs of production and is therefore a measure of the efficiency of production. The Productivity Method can be used to estimate the economic value of ecosystem benefits that are used in the production chain (inputs) for commercially marketed goods (outputs). When natural resources are a component of production, then any changes in the quantity or quality of the resources will change production costs which, in turn, may affect the price and/or quantity of the final product. This method uses the value of the marginal changes to determine the value of the ecosystem good or service. For example, a consistent supply of groundwater is required for agricultural irrigation. The economic benefits of groundwater storage (provided by healthy wetlands) for a farming community struggling with drought can be estimated by the increased revenues from greater agricultural productivity which would result if they had a continual quantity of groundwater for irrigation.

Drs. King and Mazzotta provide an example of this method from the Peconic Estuary in Long Island, New York which measured the increase in species productivity due to marginal changes in

food and habitat. In this case study, extensive development had degraded water quality and reduced the quantity of wetlands. As they explain on their website:

> The study focused on valuing marginal changes in acres of wetlands, in terms of their contribution to the production of crabs, scallops, clams, birds, and waterfowl. It was assumed that wetlands provide both food chain and habitat support for these species. First, the productivity of different wetlands types in terms of food chain production was estimated and linked to production of the different species of fish. Second, the expected yields of fish and birds per acre of habitat was estimated. Finally, the quantities of expected fish and bird production were valued using commercial values for the fish, viewing values for birds, and hunting values for waterfowl. (King & Mazzotta, 2000b)

Eelgrass and marine life.
Photo credit: NOAA, National Marine Fisheries Service

The study results were annual per-acre monetary values for eelgrass, saltmarsh and intertidal mudflat per year in terms of increased productivity of crabs, scallops, clams, birds, and waterfowl. Based on the results of this study, managers were able to measure the economic value of productivity benefits for use in a decision-making context for preserving or restoring wetlands in the Peconic Estuary.

Revealed Preference

Revealed preference techniques ask individuals to make choices based on real-world settings and individual responses are used to infer monetary value. This technique includes the following methods: avoided cost, replacement/substitution cost, travel cost, and hedonic pricing.

Avoided Cost, Replacement Cost and Substitution Cost Methods

The Avoided Cost (also referred to as Damage Costing), Replacement Cost and Substitution Cost Methods estimate the values of ecosystem benefits based on the dollar value of avoided damages, the cost of replacing ecosystem benefits or the cost of providing substitutes. These methods are not direct market valuation methods because they are not based on people's willingness to pay for a service or good. They are based on the costs people may incur to avoid damages or to replace or substitute ecosystem benefits that have been destroyed. Therefore, they are most useful in cases where damage avoidance investments, or replacement or substitution expenditures have already been or will be made.

The aforementioned Staten Island Bluebelt Project is a good example. Researchers were able to monetarily value the water purification services of wetlands by measuring the cost of operating manmade water treatment plants (filtration and chemical treatment expenses) in the absence of healthy functioning wetlands (**substitution**). They were also able to estimate the value of wetlands through the **replacement** costs of building, operating and maintaining new green infrastructure (i.e., replacing the services provided by wetlands). Another example might be a coastal community that develops a monetary value of the storm protection services offered by coastal wetlands by measuring the cost of building seawalls (**substitution**). King and Mazzotta (2000c) point out that the monetary value of providing **substitute** flood protection services (such as a levee) "provide an estimate of the flood protection benefits of restoring the wetlands, and can be compared to the restoration costs to determine whether it is worthwhile to restore the flood protection services of the wetlands."

Photo credit: FEMA/Mark Wolfe

In a **damage cost avoided** scenario, a community could potentially estimate the value of having healthy coastal wetlands through the lens of the costs incurred from a recent storm event. For example, Hurricane Sandy cost $50 billion in damages and 147 direct deaths (Blake et al, 2013). In this situation, one could theorize that a healthy natural coastal infrastructure (such as wetlands) could have avoided $50 billion in damages plus the loss of life. In other words, the value of coastal wetland protection and restoration along the New Jersey and New York coastline could be worth around $50 billion in avoided future damages if the coastal areas are rebuilt. Or the costs incurred to avoid future damages (e.g., the costs for floodproofing, relocation, compliance with new building codes, etc.) could also be used as an indicator of the value of restoring wetlands and their subsequent flood protection benefits. Unless it costs more to restore coastal wetlands, change land use patterns and implement new building codes, there should be a net savings over time produced by the future benefits of those restored coastal wetlands based on avoiding future expenses associated with another natural disaster.

Most often, however, in an avoided cost scenario, a community would estimate the value of their current built environment and use that as an indicator of what they risk losing due to a destructive storm event. The value of restoring wetlands could be estimated as the value of what they stand to lose without healthy wetlands to buffer the impacts. To use a real world example, in a report released in May 2013 by the University of Southern Maine and the New England Environmental Center, they found that "possible reductions in flood damages [through the use of natural infrastructure in three York County watersheds] would yield over $275 million in present value benefits over a thirty-year period. These savings are compared against the cost of conserving land to mitigate flood damages, an estimated $15.0 million." (Colgan et al., 2013)

Travel Cost

Photo credit: US FWS/Tina Shaw

The Travel Cost Method is used to estimate the value of an ecosystem which offers recreational benefits to humans. The value is derived from the time and travel cost expenses that people incur to visit a site. Thus, the amount of money that people are willing to pay to visit the site (e.g., how much their time is worth; how much it will cost to travel to the site; how much it will cost to get in to the site) can be used to estimate its monetary value. This approach is very similar to the neoclassical economic principle of market value being based on peoples' willingness to pay for a marketed good (based on the quantity demanded at different prices).

For example, the value of restoring a wetland could be estimated by surveying birdwatchers or hunters and asking them how far away they live from the wetland, what their travel costs would be to get to the wetland, how often they would use the site for recreation and/or how it compares to other possible substitute sites. This method can be challenging to employ, however, in a large area with no fixed point of entry. For example, a large restoration area with multiple points of access will make the travel costs variable depending on where the visitor is coming from and at what point they choose to enter the recreational site.

Hedonic Pricing Method

The Hedonic Pricing Method most commonly reflects variations in housing or land prices which reflect the value of local and/or nearby environmental attributes such as open space, water bodies, wildlife sanctuaries, hiking trails, etc. It can be used to estimate economic benefits or costs attributed to air pollution, water pollution, noise, views of or proximity to recreational areas. For example, if a house is placed somewhere desirable (such as a lot with a pleasant water view that offers recreational opportunities), the price that people are willing to pay for the exact same house in an undesirable location (such as next to a landfill or airport) will be significantly less even though it is the exact same house.

Photo credit: Pam Brophy

In a case study printed in the Agricultural and Resource Economics Review in 2013, the researchers used hedonic pricing to measure the value of a multi-use urban wetland in Southern California. They calculated the economic benefit of living near the Colorado Lagoon, a tidal lagoon with a salt marsh, and found that the Colorado Lagoon not only provides essential ecosystem benefits such as water quality improvements and biodiversity, but also supports many types of recreational activities for the surrounding population. Through the use of two hedonic models (one that used sales prices of homes over time and another that used Zillow.com's estimated housing values at a single point in

time), their analysis used data on prior home sales to assess the value of proximity to the lagoon. The results of their study show that residents positively value living closer to the lagoon based on the market value of their homes compared to the market value of comparable homes located further away (Frey, Palin, Walsh, & Whitcraft, 2013).

Stated Preference

Stated preference techniques ask individuals to respond to hypothetical situations and individual responses are used to infer monetary value based on demand. Stated preference techniques include: contingent valuation and conjoint analysis.

Contingent Valuation

The Contingent Valuation Method can be used to estimate use and non-use values for ecosystem benefits. Use value is the benefit people derive from using a service or good. Non-use value is the value people assign to goods and services that they never have or possibly never will use. Contingent valuation is the most commonly used method for estimating non-use values (such as preserving a scenic vista, saving whales, or preserving wilderness for the next generation) but is also a fairly controversial non-market based valuation method. This method involves surveying people's willingness to pay for ecosystem benefits based on hypothetical situations, or, how much they would (hypothetically) want to be compensated to give up an ecosystem benefit. Since the method is based on asking people how much they would pay for a non-marketed ecosystem good or service (as opposed to observing their market behavior), this method is subject to a significant amount of criticism. Critics often express the following concerns:

Photo credit: USGS Sirenia Project

- People cannot estimate the monetary value of something for which they have never paid before
- People may be dishonest due to personal or political views
- People may overestimate or underestimate the amount they would be willing to pay because they want to impress or do not want to offend the surveyor
- People's values will differ depending on their demographics, educational background, immediate needs and location
- People's stated intentions do not always match their actions or choices
- Surveys can be biased and misleading

For these reasons and more, there are many skeptics who claim that results generated via contingent valuation are unreliable (Hausman, 2012; King & Mazotta, 2000d). Surveys also require a significant amount of time, oversight and expense. Other experts will point out, however, that explicit guidelines have been developed for contingent valuation which address each of the above bullet points and lead to defensible estimates (Carson, Flores, & Meade, 2001). It is recommended that if contingent valuation is used, that it is used in combination with other valuation techniques in order to reinforce your findings.

Conjoint Analysis

Conjoint Analysis (also referred to as **Contingent Choice Valuation**) is similar to Contingent Valuation in that it presents people with a hypothetical situation, but it does not ask people to derive an explicit dollar value for an ecosystem benefit. Instead, people are asked to choose or rank various scenarios in terms of trade-offs which can often elicit monetary values for a whole suite of ecosystem benefits. Statistical models are then developed using multiple regression or Bayesian analysis techniques to reveal preferences and priorities. Contingent choice is "especially suited to policy decisions where a set of possible actions might result in different impacts on natural resources or environmental services." (King & Mazotta, 2000e) Therefore, it is particularly useful when deriving the value of potential improvements to ecosystems such as wetlands, given that several ecosystem benefits are often impacted simultaneously, e.g., flood water attenuation, wildlife habitat, clean water.

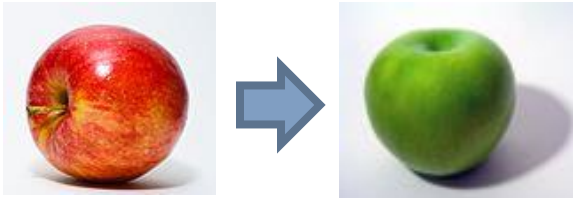
Photo credit: DE Department ofNatural Resources and Environmental Control

OR

Photo credit: Jenny Downing

Benefit Transfer

Benefit Transfer is a widely used technique, particularly by organizations and agencies with limited time and budgets. However, like contingent valuation, it is fairly controversial and is often challenged in court. It involves finding research and studies already performed for similar projects in different locations (aka "study sites") and applying the economic values estimated from those previous studies for your particular situation (aka "policy site"). For example, if there is interest in eliciting the value for a particular wetland restoration proposal, but the cost of a primary valuation study is prohibitive, researchers can find a study from a similar project in a similar location with similar attributes and use those valuation results to estimate the value of wetland restoration for the current project. It is strongly recommended that study sites selected for benefit transfer are as similar to the policy site as possible. So, for example, if the current wetland area is isolated and about 10 ha in size and is located in a rural part of Michigan, it would be considered best practice to find a wetland project with similar attributes, of similar size, and which is located in another rural area of the Midwest such as Ohio (among other attributes to consider). It is also important to review the quality of the study site process and data to check that the results were properly vetted to ensure the highest accuracy of comparisons.



Source: Wikimedia Commons

Advantages, Limitations & Examples of Each Approach

	METHOD	ADVANTAGES	LIMITATIONS	EXAMPLES
MARKET BASED	Market Price	Uses standard, accepted economic techniques. Price, quantity and cost data are relatively easy to obtain for established markets.	Market prices are subject to market imperfections and policy failures and may only be available for a limited number of goods and services provided by an ecological resource.	Marketed consumer goods – fish, lumber.
	Productivity	Relatively straightforward and the relevant data may be readily available, so the method can be relatively inexpensive to apply.	Double counting of benefits is a common pitfall and it is limited to valuing those resources that can be used as inputs in production of marketed goods.	Water quality improvement increases commercial fish catch and fishermen's incomes.
REVEALED PREFERENCE	Hedonic Pricing	It can be used to estimate values based on actual choices. Data are readily available and method can be adapted to consider several possible interactions between market goods and environmental quality.	Very data intensive and only captures people's willingness to pay. The housing market may also be affected by outside influences, like taxes, interest rates, or other factors.	Water and wildlife views increase the market price of nearby property.
	Replacement, Substitution & Damage Cost Avoided	These methods provide surrogate measures of value that are as consistent as possible with the economic concept of use value, for benefits which may be difficult to value by other means. Less data and resource-intensive than some other methods.	The costs to avoid damages or to replace or substitute services may not match the original benefit. These methods do not consider social preferences for ecosystem benefits, or individuals' behavior in the absence of those benefits. Substitute goods are unlikely to provide the same types of benefits as the natural resource.	Building water treatment plants vs restoring wetlands. Costs incurred or avoided from storm damage vs wetland restoration.
	Travel Cost	This method is based on actual behavior instead of a hypothetical situation. Uses available market prices to establish economic values.	If a trip has more than one purpose, the value of the site may be overestimated. The availability of substitute sites will affect values. Provides information about current conditions, but not about gains or losses from anticipated changes in resource conditions. Those who value certain sites may choose to live nearby. If this is the case, they will have low travel costs, but high values for the site that are not captured by the method. It cannot be used to measure nonuse values.	Collect information on the number of visits to the site from different distances. Calculate the average round-trip travel distance and travel time and multiply by average cost per mile and per hour of travel time.

Advantages, Limitations & Examples of Each Approach

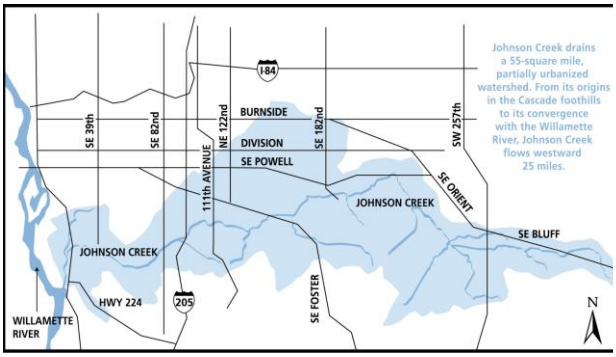
STATED PREFERENCE	Contingent Valuation	Enormously flexible - can be used to estimate the economic value of diverse non-market goods and services. The most widely accepted method for estimating total economic value, including all types of non-use, or "passive use", values.	Sources of bias often appear in interviews and responses may also be biased due to its hypothetical framework. Contingent Valuation assumes that people understand the good in question and will reveal their preferences in the contingent market just as they would in a real market. However, most people are unfamiliar with placing dollar values on environmental goods and services. Therefore, they may not have an adequate basis for stating their true value. Can be very expensive and time-consuming, because of the extensive pre-testing and survey work.	Design and implement a survey asking participants whether they would pay more on their water bill, so that natural flows could once again go into a remote lake that provides habitat and food for nesting and migratory birds.
	Conjoint Analysis	Allows respondents to think in terms of tradeoffs, which may be easier than directly expressing dollar values although dollar values are often used. Minimizes many of the biases that can arise in open-ended contingent valuation studies where respondents are presented with the unfamiliar and often unrealistic task of putting prices on non-market amenities.	Hypothetical method so answers may be unreliable. Conjoint Analysis may extract preferences in the form of attitudes instead of behavior intentions. By only providing a limited number of options, it may force respondents to make choices that they would not voluntarily make. Requires more sophisticated statistical techniques to estimate willingness to pay.	Design and implement a survey that asks residents to choose between pairs of hypothetical sites and locations for a new landfill, described in terms of their characteristics and the natural resources that would be lost. Each comparison gives the cost per household for locating a landfill at each hypothetical site or location.
BENEFIT TRANSFER	Benefit Transfer	Typically quicker and less costly than conducting an original valuation study. Can be used as a screening technique to determine if a more detailed, original valuation study should be conducted.	Values are very site and context dependent and may not be transferable. There may be unacceptably high transfer errors due to subjectivity involved in the selection of the candidate site. It may be difficult to track down appropriate studies, since many are not published. Adequacy of existing studies may be difficult to assess.	A valuation study for proposed coastal wetlands protection and restoration in Michigan uses values of benefits identified in a previous study done of Ohio's Lake Erie coastal wetlands.

CASE STUDIES

There are myriad case studies which have employed one or more ecosystem service valuation methods to varying degrees and with varying success. Five of these case studies have been selected for this report as examples of the use of ecosystem service valuation and the various methods and techniques that can be applied within diverse settings. These studies were specifically selected because they represent a broad geography (i.e., they are from different regions of the United States) and because they illustrate the use of diverse methods, tools, techniques, and objectives. The last case study from the San Pedro River Watershed in Arizona was selected primarily because it offers a comprehensive review of several of the ecosystem service valuation tools and software programs available as of 2012. There are many more case studies available for review, both nationally and internationally, some of which are included in the references section at the end of this report. Each of the five selected case studies is briefly summarized below and a link is provided at the end of each summary which directs the reader to the original online document. References and links are also provided at the end of this report to provide the reader with avenues for more in-depth research and evaluation as well as a list of available software tools.

An important consideration to keep in mind while reviewing some of the monetary estimates below is the contentious issue of aggregation of value at a high magnitude. The practice of aggregating values over a large scale has been criticized as inappropriate for marginal analysis which is necessary to do trade-off analyses (K. Bagstad, personal communication, 2013). Reports that have aggregated wetland values at the state, national, and international level have been criticized as both misleading and grossly inaccurate due to the site specific nature of wetlands (and their associated benefits/values), their often overlapping benefits, lack of primary data and assumptions made regarding values being constant across a land cover type (Eigenbrod et al., 2010). These kinds of estimates can either overestimate by double-counting benefits or underestimate because not all benefits could be accounted for. Others criticize this approach as being completely inadequate at communicating the true impacts of the loss of an entire ecosystem (National Research Council, 2005).

Lents Project Case Study, Oregon (2004)



Source: The City of Portland Oregon

The Lents area of Portland, Oregon faced a high risk of flooding each winter from Johnson Creek. At the time of the study (in 2004), there were 37 flooding events recorded since 1941. Of the 37 flooding events, 21 were considered "nuisance" events which were the focus of the Johnson Creek Restoration Plan developed by the Bureau of Environmental Services in 2002. **The project was part of a larger initiative, the Portland Development Commission Lents Urban**

Renewal Project, which sought ways to store flood waters for the improvement of the environment while simultaneously expanding options for community redevelopment. The Lents flood abatement project included "enhanced wetlands and floodplains in a redevelopment setting."

The project was also part of an initiative to develop the Comparative Valuation of Ecosystem Services (CVES) tool, aimed at quantifying changes to ecosystem benefits resulting from specific projects or programs and to assign economic values to those changes. The tool was developed through the support of the City of Portland, Oregon by an interdisciplinary team (including ecologists, environmental planners and scientists, natural-resource policy advisors, and natural-resource economists from David Evans and Associates, ECONorthwest, and the City) for quantifying the economic values associated with riparian restoration projects. **The CVES values were derived using three economic valuation methods: hedonic value; contingent value; and avoided cost/replacement value.**

This CVES analysis used systems dynamic modeling software called STELLA to estimate the return on investment in the protection and/or restoration of ecosystem benefits. To compare relative values of different management decisions using STELLA, stocks (representing the condition at a point in time) and flows (representing the actions that occur over time) were conceptualized to represent different elements and thereby isolate certain effects. Low and high estimates were derived, reflecting changes in biophysical characteristics or the upper and lower bounds of the range in estimated values of ecosystem benefits, which enabled the development of different scenario models.

The City of Portland's Water Management Program had three objectives for use of the CVES tool:

1. Identify the return on investment in an ecosystem service-oriented (ESO) project versus a single-objective project (e.g. flood storage).
2. Identify the relative return on investment in different types of ESO projects or similar ESO projects in different locations.
3. Identify the return on investment for an ecosystem protection policy such as riparian buffers.

The following five ecosystem services were quantified:

1. Flood abatement
2. Biodiversity maintenance (including avian and salmonid habitat improvement)
3. Air quality improvement (through the removal of ozone, sulfur dioxide, carbon monoxide, carbon and particulate matter)
4. Water quality improvement (through the reduction of water temperature)
5. Cultural services (including the creation of recreational opportunities and an increase in property values)

Several assumptions were outlined in the report. Future values were discounted at various declining rates. Values that would accrue in the near future (6-25 years) were discounted at 3%; values that would accrue in the mid-future (26-75 years) were discounted at 2%; and values that would accrue in the distant future (76-100 years) were discounted at 1%. These discount rates were based on an analysis of the appropriate discount rate for the analysis of natural resource projects with long time horizons, performed by Martin Weitzan in 2001 (Weitzman, 2001).

The values of ecosystem services selected for the analysis were individually compared and the total sum of all ecosystem benefits were compared to a single-objective approach for flood storage. The former comparison, the total sum of services (e.g., bundling of benefits), resulted in an estimate showing twice as much value for an ecosystem service-oriented (ESO) approach as would be generated by a single-objective flood storage approach. Gross benefits accrued over 100 years (in 2002 dollars) totaled $31,274,639.

- Flood Abatement: $14,694,387
- Biodiversity Maintenance: $5,706,064
- Air Quality Improvement: $2,544,635
- Water Quality Improvement: $2,388,982
- Cultural Services: $ 5,940,571

Several observations and lessons were learned during the CVES analysis. Constraints on data prevented a full benefit-cost analysis of ESO projects (i.e., the ripple effect of any action or project may have unexpected impacts – both good and bad). Local information and data were used as much as possible, however, since information and data from other sources were used, the level of confidence in various results varied. Discounting accuracy was a primary concern, therefore it was emphasized that it is important to recognize that the future values that humans place on ecosystem benefits is key to the total estimated values of those benefits over the long-term. The analysis also provided an additional opportunity to identify stakeholders.

To view the report in its entirety, go to http://www.portlandoregon.gov/bes/article/386288.

Wetland Ecosystem Services In Delaware (2007)

Delaware has lost an estimated 54% of its wetlands since the 1780s (Tiner, 2001) with a significant rate of loss of vegetated wetlands occurring between the years 1992-2007. Wetlands cover more than 25% of the state and are among the most valuable natural resources for Delaware. The majority of Delaware wetlands are either estuarine emergent wetlands or palustrine forested wetlands. Wetland ecosystems throughout the state of Delaware continue to be lost to expanding development and a growing population. (Tiner, Biddle, Jacobs, Rogerson, & McGuckin, 2011)

Source: Delaware Department of Natural Resources & Environmental Control

To derive a deeper understanding of the expected economic benefits of wetland conservation and management and to prioritize wetland conservation efforts, the Delaware Department of Natural Resources and Environmental Control (DNREC), initiated an ecosystem service valuation study. To establish a baseline scenario of the current distribution of wetlands across the state, the DNREC developed enhanced NWI+ maps for their state using LLWW descriptors. Then the DNREC created a future scenario by applying data on historic trends in wetland loss for the state to forecast potential losses over 15 years, from 2007 to 2012 (assuming no change in wetland conservation and management). The InVEST model, developed by the Natural Capital Project (a partnership among Stanford University, The Nature Conservancy, the World Wildlife Fund, and the University of Minnesota) was the tool used for valuation. Its spatial analysis capabilities enable users to compare ecosystem benefits across the landscape. For example, a wetland surrounded by agricultural land may be more valuable for filtering nutrients than a wetland surrounded by forest.

The objective of this study was to analyze the value of the changes in ecosystem benefits that would happen as a result of continued trends in wetland loss in Delaware – specifically the net change resulting from a 1.2 percent decline (determined by comparing baseline and future scenarios) in wetlands over a 15 year time period. Their "net loss" approach accounted for the fact that in cases where wetlands were replaced by agricultural use, there is a reduction in the amount of carbon sequestered, but not a complete loss. The wetland ecosystem benefits considered were: carbon storage; water purification; inland flood control; coastal storm protection; and wildlife protection. They did not account for other categories such as recreation, commercial fishing, and aesthetic or cultural values due to data and modeling limitations.

Overall, an annualized net loss of approximately $2.4 million was estimated for the ecosystem benefits analyzed. The results are broken down below:[13]

- Carbon Storage: 194,417 metric tons of carbon storage are lost
    - Economic value **(based on social cost of damages associated with climate change)** for the difference in carbon storage capacity: $19,900,000 in present value ($1,590,000 annualized)
- Water Purification: 1.2% increase in nitrogen, 0.9% increase in phosphorous and 1.3% increase in sediment delivered to waterways
    - Economic value **(based on municipal water treatment costs)**: $9,670,000 in present value ($770,000 annualized)
- Inland Flood Control: resulted in increased flood heights (variable across Red Clay Creek)[14]
    - Economic value **(based on avoided damage costs)**: $720 - $21,200 in present value ($57 - $1,690 annualized)

[13] Present and annualized value calculations applied a 3% discount rate. Value estimates were rounded to three significant digits.

[14] Results represent damages to flooded residences identified in a Red Clay Creek case study only – not statewide.

- Coastal Storm Protection: resulted in increased flood heights (variable across the landscape statewide) damaging residential units
    - Economic value **(based on avoided damage costs)**: $47,600 - $301,000 in present value ($3,790 – $23,900 annualized)
- Wildlife Protection: resulted in direct habitat loss and increased habitat degradation
    - The economic value was not estimated due to the "difficulty in establishing quantitative relationships between the projected wetland decline and species populations."

To view the report in its entirety, go to http://www.dnrec.delaware.gov/Admin/DelawareWetlands/Documents/Economic%20Evaluation%20of%20Wetland%20Ecosystem%20Services%20in%20Delaware.pdf.

New Jersey's Natural Capital Project (2007)

Wetlands in Cape May, New Jersey
Photo credit: USACE/Anthony Bley

In April of 2007, the State of New Jersey released a report following a two-year study by Robert Constanza et al., on "The Value of New Jersey's Ecosystem Services and Natural Capital." The study was produced through a partnership between the New Jersey Department of Environmental Protection (NJDEP), the Geraldine R. Dodge and William Penn Foundations, and the Gund Institute for Ecological Economics at the Rubinstein Institute of Environment and Natural Resources at the University of Vermont. **The purpose of the study was to develop a comprehensive assessment of the economic benefits provided by New Jersey's natural capital that could be integrated into land-use planning decisions.** This effort was partly in response to stated concerns about issues involving development and land use by residents of New Jersey. Rapid development between the years 1986 and 1995 resulted in the conversion of almost 4.4% of New Jersey's forests, farmlands and wetlands to other uses. Concerns regarding the future of New Jersey's remaining natural resources prompted the state government to pursue this study. The NJDEP planned to use the findings to inform rulemaking, establish priorities for land acquisition and for interaction with regional and local planning entities.

The valuation methods employed include benefit transfer, hedonic pricing, and spatial modeling.

1. Benefit Transfer

Researchers used a total of 100 earlier studies which established dollar values for the various types of ecosystems found in New Jersey – 94 of which were original research published in peer-reviewed journals. The values of each ecosystem benefit within the various ecosystems identified (a total of 210) were translated into dollars per acre per year and then the average

value for each ecosystem was multiplied by the statewide acreage for each type of ecosystem. They did not include ecosystem goods (commodities) or any secondary economic activity into their calculations.

According to their research, wetlands provided the biggest dollar value of bundled ecosystem benefits provided by any ecosystem in New Jersey. In 2004 dollars, freshwater wetlands contributed $9.4 billion/yr and saltwater wetlands contributed $1.2 billion/yr. According to their report:

> The most valuable services were disturbance regulation ($3.0 billion/yr), water filtration ($2.4 billion/yr), and water supply ($1.3 billion/yr) for freshwater wetlands, and waste treatment ($1.0 billion/yr) for saltwater wetlands. (Disturbance regulation means the buffering of floods, storm surges, and other events that threaten things valued by individuals or by society as a whole).

To make these estimates more compelling and useful for local decision-making, the statewide results were transferred into local values. The aggregate values of ecosystem benefits were mapped by county, by watershed, and by sub-watershed. Not surprisingly, the maps showed significant differences in ecosystem benefit values according to the predominant land cover in different parts of the state, and areas which had wetlands, estuaries, tidal bays and beaches received the highest ratings.

2. Hedonic Pricing

Researchers also used the Hedonic Pricing Method to estimate the value of New Jersey's natural capital. Researchers adjusted for other factors which could influence housing prices/value such as lot size, number of rooms, local property taxes, etc. Resource limitations required them to focus on only seven local housing markets (as opposed to the entire state) although efforts were made to select markets which reflected the demographics of the state in aggregate. They performed two analyses: the first estimated values according to whether a home was near an amenity (e.g., beach, water body, open space, etc.). In the second analysis, researchers estimated values according to the distances between houses and natural amenities. They found that, in general, houses located near environmental amenities are worth more on the market than houses which are not, all else being equal. Wetlands, however, had virtually no strong market effect on property values. The researchers also concluded that the Hedonic Pricing Method resulted in higher estimates of value/acre than the Benefit Transfer Method and, therefore, the latter method may be considered more conservative.

3. Spatial Modeling (Relative Value)

To complete this study, researchers used landscape level functional simulations of the response of ecosystems and the production of ecosystem benefits in response to various land-use planning scenarios over time. They tracked two variables: concentration of nutrients (as

an indicator of water quality) and Net Primary Productivity (NPP) (as a measure of the amount of plant growth and thus, the health of the plant communities on which many animals depend). The researchers found that forests located close to a river's estuary zone contributed to greater water quality than forests located further away. They also discovered that small river buffers are fairly ineffective in enhancing water quality and that they need to be fairly significant in size to make a difference. However, they also found that small, dispersed forest patches improve water quality more than large forest clusters.

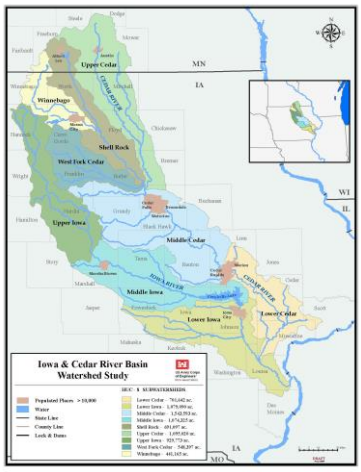
Overall, the study found that the value of the benefits provided by New Jersey's natural capital were worth $8.6 -19.4 billion/year at minimum. The researchers concluded that the present (2007) value of New Jersey's natural capital was $288 – 660 billion, not including marketed ecosystem goods or secondary economic impacts. Although the practice of aggregating values at this scale has been criticized as inappropriate for marginal analysis (which is needed to do trade-off analyses) the authors of this case study argue that it is not meant to be reflective of exchange value. Instead they view it as a useful insight into the state's inventory of ecosystem benefits. Regardless, aggregation at this scale can distort market values by amplifying site specific uncertainties.

They also discovered that wetlands (fresh and saltwater), estuaries/tidal bays, and forests together account for over 90% of the total estimated value of New Jersey's ecosystem benefits. The authors of this report suggested some potential uses of this study, including: discussion framing; priority setting; open space acquisitions; conservation planning; budgeting; pollution control; risk management; municipal zoning; sustainability measurements; ecosystem management; cost allocation; tax policy; eminent domain; and natural resource damage assessment.

To view the report in its entirety, go to http://www.state.nj.us/dep/dsr/naturalcap/nat-cap-1.pdf.

The Middle Cedar River Watershed, Iowa (2011)

The Middle Cedar River Watershed was ground zero of the devastating Cedar River flood in 2008. The total losses statewide for the month of September 2008 were estimated at $3.5 billion and, in some places, the river crests exceeded 500-year heights. The area has also been plagued by droughts - two of the most severe were in 2008 and 2012. Most of the wetland loss in the area is due to agricultural expansion and most agriculture in the Middle Cedar River Watershed is dominated by row crops of corn (for ethanol production) and soybeans. Due to climate change, annual precipitation rates are expected to increase and more frequent flooding is expected in the near future.



Source: Iowa-Cedar Watershed Interagency Coordination Team

In light of the increased frequency and severity of natural disasters in the Middle Cedar River Watershed, a study was commissioned to evaluate ecosystem benefits in the

watershed to make better informed plans to mitigate and adapt to forecast weather patterns. According to the project brochure, the study was developed to

> support flood-risk management in the basin and the work of the Iowa-Cedar Watershed Interagency Coordination Team that was created following the 2008 flood. This team includes federal, state, and local agencies, NGOs, and universities committed to creating a sustainable Iowa-Cedar River Basin. Several ecosystems, such as wetlands, naturally manage floodwater, which generates economic benefits in the form of reduced flood damages. This analysis is a first step towards understanding how the Middle Cedar's floodplains, wetlands, and other ecosystems contribute towards the economic wellbeing of the region.

The valuation method used in this case study was the **Benefit Transfer Method** which was employed by Earth Economics through the use of their newly developed software tool, SERVES (Simple, Effective Resource for Valuing Ecosystem Services). There were basically three steps involved:

1. Quantification of Land Cover Classes:
   This step required the use of Geographic Information Systems (GIS) data to calculate the acreage of each land cover class in the watershed. Aerial and/or satellite photography was used to gather the data. The watershed was divided into 12 final land cover classes based on the U.S. Geological Survey 2006 National Land Cover Database: deciduous forest, evergreen forest, mixed forest, forest buffer, wetland/marsh buffer, emergent herbaceous wetlands, woody wetlands, rivers, lakes, grasslands, agriculture, and pasture. The land cover classes were selected from a database of peer-reviewed valuation studies organized by land cover class.

2. Identification of Ecosystem Benefits and Valuation of Land Cover Class:
   Ecosystem benefits were identified in the watershed and then a range of studies was selected from a database of peer reviewed valuation studies which offered the best geographic and land-cover matches to the site. A low and a high range of values per acre were selected from the studies for each ecosystem benefit provided by each land cover class which was identified in the Middle Cedar River Watershed. Then the low and high value for each ecosystem benefit was summed as a total low and total high value of the sum of ecosystem benefits for each land cover class. For example, wetlands (a land cover type) offer multiple ecosystem benefits such as water regulation, wildlife habitat, recreation, etc.

3. Valuation of the Middle Cedar River Watershed:
   Total high and low annual values of each land cover class from Step 2 were multiplied by the total acreage of that land cover class existing within the Middle Cedar River Watershed. The new low and high values were then summed to get a total annual value of ecosystem benefits within the entire watershed for both the low and high range. Net present values of future flows of benefits were calculated over 100 years at two discount

rates: 0% and 4% (which was used by the Army Corps of Engineers) to assess future value. All values were standardized to 2011 dollars using the Bureau of Labor Statistics Consumer Price Index Calculator.

In total, the study identified 14 categories of ecosystem benefits valued across eight land cover classes. It was estimated that ecosystem benefits in the Middle Cedar River Watershed generate between $548 million to $1.9 billion in goods and services. Wetlands only cover about 2.3% of the land cover in the watershed, yet they were found to contribute between 16.5% - 30.1% of the total value. The top ranking ecosystem benefit provided by wetlands was determined to be flood risk mitigation, valued between $2544 - $3,651/acre/year. To view the report in its entirety, go to http://www.eartheconomics.org/FileLibrary/file/Midwest/Earth%20Economics_Middle%20Cedar%20River_ESV_2012.pdf.

San Pedro River Watershed, Arizona (2012)

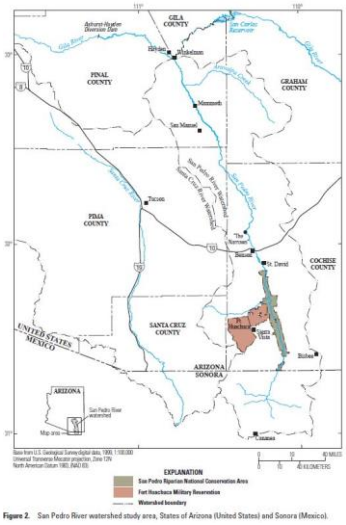


Figure 2. San Pedro River watershed study area, States of Arizona (United States) and Sonora (Mexico).

Source: USGS

This case study (and subsequent report) was produced by the Bureau of Land Management (BLM) and the U.S. Geological Survey (USGS) **to evaluate the various tools and methods available for ecosystem service valuation as well as their "fit" for BLM and/or USGS specific projects.** Using various tools, **they quantified gains and losses in ecosystem benefits** under three types of scenarios: urban growth, mesquite management, and water augmentation.

The study area was the San Pedro River watershed in northern Sonora, Mexico and southeast Arizona, which includes the BLM-managed San Pedro Riparian National Conservation Area (SPRNCA). This area was selected because it is a focal point for conservation activities and scientific research and includes BLM managed lands. **The purpose of this study, however, was to evaluate the readiness and usefulness of ecosystem service valuation in BLM decision-making, particularly in light of the federal shift toward inclusion of non-market values such as socioeconomic and environmental effects, highlighted in policies such as the National Environmental Policy Act (NEPA).** Thus the results of this study are not intended to guide specific management decisions per se, but to guide BLM on the overall use and selection of ecosystem service valuation tools and methods in management decisions.

The tools and methods identified in the report are:

1. Primary Valuation: using past ecosystem service valuation studies at the specific study area (involving contingent valuation, conjoint analysis, travel cost, hedonic, avoided or replacement cost approaches etc.) or creating new primary valuation studies
2. Value Transfer (i.e. Benefit Transfer): using previously estimated economic values from another study site and applying them to the current study area

3. Wildlife Habitat Benefits Estimation Toolkit: Defenders of Wildlife
4. Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) tool: Natural Capital Project
5. Artificial Intelligence for Ecosystem Services (ARIES): The University of Vermont's Ecoinformatics Collaboratory at the Gund Institute for Ecological Economics
6. Multiscale Integrated Models of Ecosystem Services (MIMES): developed by the University of Vermont's Ecoinformatics Collaboratory at the Gund Institute for Ecological Economics but managed by AFORDable Futures, LLC since 2010
7. EcoMetrix: EcoMetrix Solutions Group
8. EcoAIM: Exponent
9. ESValue: Entrix
10. Natural Assets Information System (NAIS): Spatial Informatics Group
11. Simple, Effective Resource for Valuing Ecosystem Services (SERVES): Earth Economics
12. Social Values for Ecosystem Services (SolVES): developed by the USGS in partnership with Colorado State University.
13. Envision: developed by the Oregon State University, the University of Oregon and Common Futures, LLC
14. Ecosystem Portfolio Model (EPM): USGS
15. EcoServ: developed by the USGS and the Chinese Academy of Sciences
16. Investing in Forests (InFOREST): under development at Virginia Tech University
17. Ecosystem Services Review (ESR): developed by the World Resource Institute, the Meridian Institute and the World Business Council for Sustainable Development
18. United Nations Environment Programme – World Conservation Monitoring Centre Ecosystem Services Toolkit (UNEP-WCMC)[15]

A broad group of stakeholders, as well as the managers of the SPRNCA and the Gila District, were convened to identify relevant resource management issues. Four broad categories of ecosystem benefits of interest for the study area were identified, including: water (quality and quantity); biodiversity; carbon sequestration and storage; and cultural values. The above list of methods and tools are described in the report. However, tools which were propriety or place-specific, which required the use of a consultant or academic research group, or which were at too early of a stage in development (at the time of the study) were not used.

Key findings:

- No tool performs well in all categories, suggesting that each tool is more appropriate to specific settings and that more than one tool may need to be used to fulfill different ecosystem service valuation needs.

[15] This toolkit has subsequently been rebranded as Toolkit for Ecosystem Service Site-based Assessments (TESSA): developed by the University of Cambridge, Anglia Ruskin University, the Tropical Biology Association, the Royal Society for the Protection of Birds, Bird Life International, UNEP, and WCMC.

- The time required to apply a particular tool relative to the depth of information it can generate is an important trade-off to consider in selecting the appropriate tool(s).
- It is difficult and potentially risky to transfer values between study sites (where the primary data was collected) and policy sites (where the study site data is applied to avoid the expense of doing primary studies) and therefore value transfer requires an in-depth consideration of the similarity of ecological and socioeconomic factors.
- There are significant limitations in applying economic values and utilitarian assumptions when considering values of indigenous cultures, therefore "important cultural ecosystem features, whether expressed in monetary terms or not, are best considered essential to any planning or evaluation exercise."
- Carbon markets are relatively immature and market caps are not tied to ecological thresholds for climate change, therefore market prices are a less appropriate measure than the social cost (e.g., health impacts) for estimating value of carbon sequestration and storage.
- The benefits of ecosystem goods and services accrue at various spatial scales and thus, analysis of a broader geographic region may allow for a more comprehensive analysis.
- Spatial ecosystem benefit models should be run at the highest feasible spatial resolution - overly coarse scale analysis may lead to incorrect conclusions.
- It is important to clearly communicate uncertainty due to the limitations of models, economic values and discount rates – reporting a single value can "inspire false confidence in the certainty of results."
- Maps of impacts, trade-offs and values can facilitate clearer communication to stakeholders.
- Models that "better quantify ecological end-points will generally be more useful for economic valuation" (e.g., EPA Final Ecosystem Goods and Services Classification System, 2013) and avoid the pitfall of double counting of benefits.
- Consistency in using data sources, approaches and reporting of results is critical.
- A centralized source of spatial data and underlying ecological and economic knowledge would greatly reduce resource requirements for ecosystem service valuation studies and enable more complex ecosystem benefit models.
- Two modeling tools, ARIES and InVEST were selected for direct comparison as well and key findings include that both tools demonstrated similar gains and losses of ecosystem benefits and conclusions, although they were more closely aligned for landscape-scale urban-growth scenarios than for site-scale mesquite-management scenarios (Bagstad, Semmens & Winthrop, 2013).

To view the report in its entirety, go to http://pubs.usgs.gov/sir/2012/5251/sir2012-5251.pdf.

BEST PRACTICE RECOMMENDATIONS

Photo credit: NRCS

Due to the immense diversity of wetland types and functions as well as the diversity of landscapes (environmental, cultural, and economic) within which they are nested, there is no magic "how to" book for wetland valuation that will address every issue practitioners come across. Because this report is broadly aimed at addressing how to employ ecosystem service valuation methods as a tool for wetland restoration prioritization, it is confined to offering best practice recommendations that are relatively general in nature. Additionally, the use of ecosystem service valuation as a tool for wetland restoration decision-making is a relatively new practice, therefore lessons continue to be learned even while this report is written. It is vitally important to the advancement of these techniques that lessons learned are recorded and shared for the benefit of all. The following list of best practice recommendations were selected based on case studies, scholarly articles and agency reports, and consists of recurring themes found throughout the literature.

Communicate Assumptions and Uncertainty

Any assumptions which must be made to utilize a method, such as best professional judgement, and any uncertainties, such as limitations of current scientific knowledge and available data or possible modeling errors, must be clearly articulated by those who are reporting the results (U.S. EPA Scientific Advisory Board, 2009; National Research Council, 2005). These recommendations follow the White House's Office of Management and Budget revised Circular A-94: Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs in 1992, which reads:

> **Treatment of Uncertainty**. Estimates of benefits and costs are typically uncertain because of imprecision in both underlying data and modeling assumptions. Because such uncertainty is basic to many analyses, its effects should be analyzed and reported. Useful information in such a report would include the key sources of uncertainty; expected value estimates of outcomes; the sensitivity of results to important sources of uncertainty; and where possible, the probability distributions of benefits, costs, and net benefits (The White House Office of Management and Budget [OMB], 1992).

However, as the Scientific Advisory Board advises in their 2009 report to the U.S.EPA, "the mere existence of uncertainty should not be an excuse for delaying actions where the benefits of immediate action outweigh the value of attempting to further reduce the uncertainty. Some uncertainty will always exist." (U.S. EPA Scientific Advisory Board, 2009) Scenario-based planning can address the issue of uncertainty (although it will not resolve it) and assist in prioritization of

wetland restoration projects by providing a broad range of potential outcomes based on changing assumptions (e.g., whether or not population growth is assumed to remain constant over time), similar to a risk analysis (Glick, Hoffman, Koslow, Kane, & Inkley, 2011; Stein, Glick, Edelson, & Staudt, 2014).

Include Threshold Effects

If possible, threshold effects (the point at which an ecosystem may change abruptly and irreversibly), which are of primary concern to climate change scientists and ecologists, should also be considered in any valuation exercise. The nonlinearity of ecosystem benefit provision contributes further complexity into any ecosystem valuation. Thresholds are typically not known until they are crossed, although advanced warning signs may occasionally be visible. The possibility of abrupt climate change could tip the capacity of many wetlands to function properly. The development and use of indicators can assist with any assessment of the capacity of the restored wetland to meet the project goals. Examples of ecosystem indicators that can be used include biophysical indicators such as an increase or decrease in fish population, or water quality measurements. Depending on the types of indicators selected, experts from various fields (ecologists, risk analysts and others) may need to be included in the restoration project planning and monitoring phases (de Groot et al., 2006; Turner, Morse-Jones, & Fisher, 2010). In general, "if you are assessing the risks associated with changes in the state of a wetland, you need estimates of both the value of possible outcomes and the probability that they will occur" (C. Perrings, personal communication, 2013).

Bundle Benefits

Wetlands do not just produce a singular ecosystem benefit. They produce multiple ecosystem benefits which interact with each other in a dynamic way. These "bundles" of benefits are important to account for and to communicate to stakeholders during consideration of restoration priorities and trade-offs. Bundling of benefits has generated much scientific discussion recently (Costanza et al., 2011), particularly in agricultural communities who are struggling with maintaining their way of life while simultaneously learning how to farm in concert with nature. Agricultural expansion has been the largest driver of wetland loss historically, however, the agricultural sector holds potential as a strong ally to wetland restoration efforts. Farmers are, after all, "the largest group of ecosystem stewards on earth." (Meacham, 2013) Farming practices impact the productivity and status of the environment, and the environment impacts farming practices and success. Bundling benefits illustrates the interplay between these social systems, economic systems and ecosystems. This approach is supported through comprehensive ecosystem service valuation processes which enable stakeholders to evaluate and weigh various scenarios and their variable outcomes and trade-offs (Russi et al., 2013).

For example, Bali's traditional rice terrace farming system (subak system) exemplifies the symbiotic relationship between social, economic and ecosystem health. Farmers collectively manage their shared irrigation infrastructure, coordinate rice planting at different times throughout the season, and utilize the gravitational effect provided by the terrace system, thereby

effectively and efficiently managing water and pests. This approach produces numerous benefits: food provision; water availability; pest control; wildlife habitat; climate control (cooling); erosion control; and cultural benefits. Because this type of agricultural management practice provides a bundle of benefits, it is more resilient to changes and disturbances, such as climatic variability and natural disasters (Water Land Ecosystems, 2013).

Photo credit: Jeanne Christie

Bundling benefits, however, can also be employed in a strategy for communicating wetland restoration benefits (with or without an agricultural component) due to the multitude of interdependent ecosystems at play in a healthy wetland and/or watershed. For example, in using a watershed approach, which highlights connectivity and system interplay, we can illustrate most of the benefits of a healthy wetland which, in turn, may encourage broader objectives in the decision-making process. It can also help to prevent the development of "dysfunctional incentive systems" which focus only on one benefit at the risk of damaging other benefits not actively identified (Costanza et al., 2011; Pagiola, 2008).

Bundling benefits reflects a systems dynamics way of thinking - as opposed to linear, singular objective planning – which is more in line with the non-linear nature of natural ecosystems which naturally bundle these benefits already. Similarly, efforts are underway to integrate agricultural and conservation objectives which have led to the recognition of other ecosystem benefits at play such as the benefits provided by birds and bees for crop production, e.g., pest control and pollination (Declerck, 2013). In a study done in Costa Rica, birds which were protected through habitat conservation and forest corridors in coffee farms controlled the coffee boring beetle population thereby reducing the need to apply pesticides (Martínez-Salinas, DeClerck, Garbach, & Estrada-Carmona, 2013). Care must be taken, however, to avoid the common pitfall of double-counting addressed in the section below.

Avoid Double Counting

It is vitally important to accurately present net values and avoid double counting benefits or, if unavoidable, to clearly communicate overlaps (Turner et al., 2010). Double counting most commonly occurs when an intermediate ecosystem *service* is valued separately and then aggregated with values estimated for final ecosystem benefits. The EPA developed their Final Ecosystem Goods and Services Classification System specifically to address this issue. The authors explain that "common categorization schemes for ecosystem services, such as "supporting", "regulating", "provisioning", "cultural" (MEA, 2005) are heuristically relevant but do not provide a rigid framework in which ecosystem services can be identified on the landscape and explicitly

associated with people." (Landers & Nahlik, 2013)[16] Fisher, Bateman and Turner explain this concern in a paper to the United Nations Environment Program in 2011:

> For example, in the MEA [Millenium Ecosystem Assessment], nutrient cycling is a supporting service, water flow regulation is a regulating service, and recreation is a cultural service. However, if you were a decision maker contemplating the conversion of a wetland and utilized a cost-benefit analysis including these three services, you would commit the error of double counting. This is because nutrient cycling and water regulation both help to provide the same service under consideration, providing usable water, and the MA's recreation service is actually a human benefit of that water provision. An analogy is that when buying a live chicken you do not pay for the price of a full chicken plus the price of two legs, two wings, head, neck etc… you simply pay the price of a whole chicken (Fisher, Bateman, & Turner, 2011).

Other ecological economists, however, argue that this reasoning is flawed because, although there is a market for chickens, chicken legs, and chicken wings, etc., ecosystem functions and services (intermediate services such as maintaining biodiversity) do not have a market and therefore it is not double-counting. For example, if bees provide a pollination service but the pollinating bees are not purchased, then it is not considered double-counting (M. Kocian, personal communication, 2014). Clearly, it is a complicated issue and as yet, still generates a considerable amount of discussion and debate. Communicating the systems dynamics of wetlands and their overlapping benefits is one way to at least inform stakeholders of the potential for double-counting, and all reasonable efforts should be made to avoid it.

Account for Differing Values

Not all wetland services can be quantified monetarily, however, and there will be values such as existence value, spiritual value, community identity value or option value which are difficult or impossible to quantify. Intergenerational equity issues and other socio-cultural benefits will also be challenging to quantify but they should not be left out of the discussion. Simply showing an increase or decrease in the existence of these attributes in combination with monetary valuations for other quantifiable benefits may be sufficient for weighing resource management options. The kind of information needed will vary depending on the nature of the policy problem, i.e., water quality, biodiversity loss, habitat destruction, etc. Participatory assessment techniques which involve a diverse group of stakeholders and local experts are imperative in these types of less quantifiable valuations (Alexander & McInnis, 2012; de Groot et al., 2006; Russi et al., 2013). It is recommended, in light of environmental justice concerns and equity, that any analysis should identify who the winners and losers are from any potential policy or management decision and

[16] Other sources that address this issue include:

- Boyd, James and Spencer Banzhaf, 2007. *What Are Ecosystem Services? The Need for Standardized Environmental Accounting Units*. Ecological Economics, 63(616:626).
- Haines-Young, Roy and Marion Potschin, 2011. *Common International Classification of Ecosystem Services (CICES): 2011 Update*. Centre for Environmental Management, Nottingham, U.K.

how costs and benefits will be ultimately distributed, both temporally and spatially (Alexander & McInnis, 2012; OMB, 1992; Landers & Nahlik, 2013; Pagiola, 2008).

Differences in values for wetlands can vary spatially and temporally, and these differences can be significant depending on whether they are located in a rural or urban area, in an arid versus humid environment, if they are scarce or plentiful, if they are near residential property or on agricultural land (Fisher et al., 2011; Radford & James, 2013). All of these differences will factor into differing value systems for the people who are judging the benefits provided by a particular wetland restoration project (Alexander & McInnis, 2012; Windham, et al., 2004). This reality also creates a strong argument against relying solely on land cover-based benefit transfer methods. Spatial mapping of this nature which transfers values from study site to policy site based on land cover identified via geospatial mapping creates crude estimates of actual distributions of ecosystem benefits. This can lead to magnification of errors and invalid assumptions, and thereby create unreliable estimates of value (Eigenbrod et al., 2010; Troy & Wilson, 2006).

Provide a High-Low Range of Values

No method currently exists that can quantify all of the ecosystem benefits provided by complex systems such as wetlands and therefore estimated values are typically conservative (Perrings, 2010). However, estimates derived should reflect a range of values for each ecosystem benefit identified to illustrate the range of possible outcomes and to reflect the uncertainty of future events and current scientific knowledge. The values derived through any method will necessarily vary significantly by site (Radford & James, 2013).

Plan for Monitoring & Adaptive Management

Monitoring and assessment of restored wetlands is imperative to ensure that projects are implemented and managed efficiently and effectively, and to track the long-term success of restoration efforts (MEA, 2005). This step allows for adaptive management of restored wetlands and enables wetland professionals to enhance their understanding and knowledge of wetland ecosystems, restoration techniques and best practices. It also enables wetland scientists and academics to compare restoration projects and evaluate differing factors which may have enhanced or impaired a sites ability to recover (Windham, et al., 2004). Finally, this step also enables management plans to evolve in light of new scientific discoveries, information, technological advances and/or changing societal needs and values (Pritchard et al., 2000).

Photo credit: Jeanne Christie

Current and future vulnerabilities to climate change should be identified in this step in order to plan for management responses that will be consistent with restoration goals. It is important to

account for systems dynamics when assessing vulnerabilities in order to predict direct and indirect impacts (Glick et al., 2011). The Climate-Smart Conservation report published by the National Wildlife Federation states that in the future, "monitoring and evaluation strategies will need to be designed to better anticipate climate-driven changes and identify new challenges and opportunities." To accomplish this, they suggest that managers will need to be more strategic and employ "multi-scale monitoring efforts that track shifts in landscape-scale ecological conditions as well as the effectiveness of adaptation actions at specific sites." (Stein et al., 2014)

The EPA's 1-2-3 approach to wetland monitoring provides a cost-effective way for wetland managers "to reduce the cost of monitoring and obtain reliable results when assessing wetlands." (U.S. EPA, 2012a) This three step approach begins with simple methods to assess areas of potential concern, such as a rapid assessment technique, and then progresses to more complicated methods as specific issues are identified. As explained on their website:

> The first level, and most general method, is an assessment of the entire landscape using generally available maps and digital and aerial photography. The second involves the use of rapid methods that produce more information than Level 1 and requires some work in the field. These methods are used to evaluate aspects of the ecological features of the wetlands - the soil, water, and biota - and to assess impacts of human activities that stress the local ecology. The most comprehensive level, Level 3, involves an assessment using the most intensive methods to collect data on the biological, physical, chemical, and hydrologic attributes of a site (U.S. EPA, 2012a).

Monitoring and assessment costs must be included in any economic analysis when considering long-term maintenance expenses (such as invasive species control), although they are typically less for wetland restoration than other traditional infrastructure projects.

Provide Financial Incentives

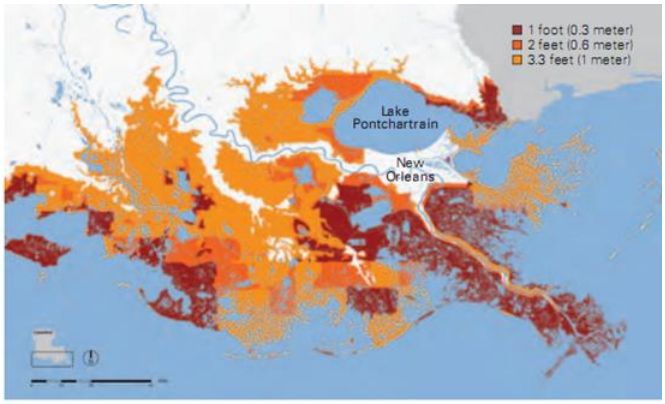
One of the biggest challenges in developing wetland restoration programs in the United States is "approximately 75 percent of wetlands are privately owned, so individual landowners are critical in protecting these national treasures." (U.S. EPA, 2012c) Since the market fails to account for most of the benefits provided by ecosystem functions, many landowners are forced financially to maximize the value of their investment in their land by producing commodities traded on the market such as agricultural crops (MEA, 2005). This often leads to over extraction and destruction of natural resources and their ecosystem benefits that are not monetarily valued as a consumer product or accounted for as a cost of production.

Valuation of wetland ecosystems can be a way to identify appropriate incentives for landowners who voluntarily restore wetlands through programs that provide defined public benefits. Voluntary incentive programs, such as the Wetlands Reserve Program, and compensatory mitigation programs, such as the Clean Water Act, provide alternatives for landowners who cannot afford to give up the marketable use of their land without financial assistance. Some Payment for Ecosystem Services (PES) programs are beginning to refine their practice through

"targeting" in order to focus programs on lands that have a higher likelihood of being degraded or destroyed – in other words, get a bigger bang for their buck – in order to avoid paying for benefits which may not actually be in jeopardy (Alpizar, Blackman & Pfaff, 2007).

By providing financial incentives through public revenues or through regulatory fees, policy makers are ensuring that those who benefit from the ecosystem benefits that contribute to or constitute consumer goods, as well as the general public who benefit from services such as flood attenuation, carbon sequestration and biodiversity are contributing their fair share to restoring, preserving and maintaining these wetland benefits which sustain and enhance human life (Russi et al., 2013; Barnes, 2014). The cost of any financial incentives, however, should also be included in any benefit-cost analysis.

Communicate Effectively & Transparently



Sea level rise scenario modeling for New Orleans, LA.
Source: Natural Resources Defense Council

Awareness raising and knowledge sharing thorough education and illustrative scenario models are essential for effectively communicating the results of any ecosystem service valuation study (Russi et al., 2013). In most multi-stakeholder decision-making contexts, it is best to use simple, transparent tools that illustrate easily understandable trade-offs and opportunities. By using simple, low-barrier tools, local experts can be trained to use them for future decisions and develop a sense of ownership for local communities in regard to data, findings, scenario models, and ultimately land use decisions. Joint fact finding is also recommended and broad participation should be encouraged at the very beginning of the process. The communication strategy used will have to be tailored to the targeted audience. In many cases, providing both biophysical metrics (e.g., tons of carbon sequestered) and monetary metrics (e.g., commercial fish revenues) was the most successful approach since it provided meaningful results for those who prefer either monetary or non-monetary measurements (Ruckelshaus et al., 2013). As mentioned previously, qualitative benefits such as preserving or restoring wetlands for the welfare of future generations can also be effective depending on the decision-making context.

CONCLUSION

This report has attempted to provide a basic overview of ecosystem service valuation, the methods available, and its potential application in the context of wetland restoration projects. It provides suggestions for recommended steps and best practices when using ecosystem service valuation as part of a decision-making framework for wetland restoration projects. The information provided in this report could also be used for prioritization of wetland protection efforts.

The use of ecosystem service valuation offers a way for stakeholders to better understand how healthy ecosystems improve their quality of life and well-being and, hopefully, to gain a deeper appreciation for the interdependencies between humans and nature (Searle & Cox, 2009). Wetland valuation can be used as a way to improve deliberative decision-making processes that include: prioritization of wetland restoration projects, land-use decisions, watershed planning, water quality planning, stormwater planning, habitat conservation, climate change adaptation planning and as a way to communicate often overlooked values that can be used to gain support for policy and financial incentives that conserve wetlands. Values attained should be communicated as being the best estimates available and should be spatially and temporally specific.

Wetlands are diverse and valuable ecosystems which offer multiple benefits for human well-being. Wetland restoration efforts offer society the chance to restore some of the lost benefits provided by wetlands such as reduced risk from storm damages caused by extreme weather events, improved food and water resources, and the capacity to both mitigate and adapt to climate change. Restoration should never be considered as a substitute for wetland protection and conservation, however, since the science and understanding of the complexity of wetland ecosystems is still evolving as is our understanding of how to successfully create or restore wetlands. Avoidance of wetland degradation and destruction should always be considered first in any land use decision (Alexander & McInnis, 2012).

Although the use of ecosystem service valuation can be extremely beneficial and its use should not be discouraged, it is still an evolving field. Caution should be exercised by those who choose to use it for decision-making to ensure that: they use the best available science and data; they include broad stakeholder involvement and establish clear goals at the very beginning; and they include monitoring and maintenance as part of their restoration plan (Russi et al., 2013). Consultation with others experienced in the use of ecosystem service valuation is strongly recommended before embarking on wetland valuation effort. This can be accomplished by developing an interagency and/or interdisciplinary team.

The practice of ecosystem service valuation is inherently interdisciplinary and pluralistic. Depending on the project site and project goals, it may require the participation of a diverse group of experts in the fields of ecology, wetland science, hydrology, economics or more as well as stakeholders from the community. Some academics call for it to evolve into a transdisciplinary practice with synthesized tools and methods. There is no one “correct” method – in fact the use of

multiple methods is highly recommended. The "very objective and virtue of ecosystem service valuation is to make policy objectives and decision criteria explicit (Liu et al., 2010)." To do so, we must: use the best information available; make all assumptions and uncertainties explicit (but not overwhelming); understand to the best of our ability the complex interplay between actions, impacts and policies; communicate information and trade-offs clearly; provide for adaptive management; and be explicit about our goals for wetland restoration projects (Liu et al., 2010).

It is important to recognize that ecosystem service valuation will be only one of the tools that provide the basis for decision-making about a specific wetland restoration site. For example, landowner willingness, adjacent land uses, changes anticipated from climate change and other factors will influence whether and what kind of wetland restoration occurs. However, having an understanding of all that we risk losing through a continued rate of wetland conversion is essential to communicating the benefits of wetland protection and restoration.

Photo credit: Jeanne Christie

Ultimately, ecosystem service valuation offers a common language and a meaningful way for ecologists, economists, engineers, landscape architects, communities, and other stakeholders to communicate values and it also offers a contextual way for decision-makers to weigh future scenarios and impacts of policy decisions (or of the status quo) as well as to prioritize restoration projects. However, policies must be developed to allow greater consideration and use of ecosystem service valuation and to incorporate those values into legislative and regulatory frameworks and decisions. The scenarios and models developed can highlight stakeholder values, illustrate the trade-offs involved, and can therefore fundamentally improve strategic planning with a more comprehensive natural resource management and development decision process. Climate change is emphasizing the importance of these conversations and has brought to light the significant contributions of wetlands to our mitigation and adaptation efforts. Wetlands can provide a wealth of benefits to humankind and ecosystem service valuation is a promising method to communicate those benefits and gain additional support for protection and restoration efforts.

GLOSSARY OF TERMS

In order to help readers understand some of the economics terms and principles in this report, a glossary has been provided. Although a few of these definitions are provided by the authors, most of the definitions were taken from www.ecosystemvaluation.org and a few were gleaned from various U.S. EPA websites, www.investopedia.com, and other online dictionaries.

Bayesian analysis: a statistical procedure which endeavors to estimate parameters of an underlying distribution based on the observed distribution.

Benefit-cost analysis: a comparison of economic benefits and costs to society of a policy, program, or action.

Bequest value: the value that people place on knowing that future generations will have the option to enjoy something.

Consumer surplus: the difference between the price actually paid for a good, and the maximum amount that an individual is willing to pay for it. Thus, if a person is willing to pay up to $3 for something, but the market price is $1, then the consumer surplus for that item is $2.

Discount rate: the rate used to reduce future benefits and costs to their present time equivalent.

Ecosystem benefits: the goods and services provided by an ecosystem function or functions that benefit people.

Ecosystem functions: the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of the ecosystem.

Ecosystem goods: the tangible end products of ecosystem functions which are marketed and directly useable by humans (such as seafood, forage, timber, biomass fuels, natural fiber).

Ecosystem services: the actual life-support functions (such as cleansing, recycling, and renewal) provided by ecosystem functions - they may also confer many intangible aesthetic and cultural benefits.

Environmental justice: the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

Existence value: the value that people place on simply knowing that something exists, even if they will never see it or use it.

Externalities: uncompensated side effects of human actions. For example, if a stream is polluted by runoff from agricultural land, the people downstream experience a negative externality

Interdisciplinary: integrating knowledge and methods from different disciplines, using a real synthesis of approaches.

Intergenerational equity: a fairness concept that confers responsibility on the current generation to administer and/or preserve resources for future generations.

Marginal change: small incremental adjustments to a plan of action or status quo.

Marginal utility: the additional satisfaction or benefit (utility) that a consumer derives from buying an additional unit of a commodity or service. The law of diminishing utility implies that the utility of an item declines in relation to the amount already acquired. For example, the satisfaction of eating the first slice of pizza is typically greater than the satisfaction of eating an additional slice after one has consumed enough to satisfy his or her hunger.

Multiple regression analysis: a technique used for predicting the unknown value of a variable from the known value of two or more variables- also called the predictors.

Natural capital: the stock of natural ecosystems that yields a flow of valuable ecosystem goods or services into the future.

Neoclassical economics: an approach to economics that relates supply and demand to an individual's rationality and his or her ability to maximize utility or profit.

Non-use value: also referred to as “passive use” values, non-use values are the values that people assign to economic goods or services even if they never have and never will use them.

Option value: the value that people place on having the option to enjoy something in the future, although they may not currently use it.

Policy site: in Benefit Transfer, policy site refers to the current site where the values from a previous study site are being used to estimate ecosystem values for the current site.

Private goods: products that must be purchased in order to be consumed, and whose consumption by one individual prevents another individual from consuming it. Economists refer to private goods as "rivalrous" and "excludable". If there is competition between individuals to obtain the good and if consuming the good prevents someone else from consuming it, a good is considered a private good.

Producer surplus: the difference between the total amount earned from a good (price times quantity sold) and the production costs.

Public goods: goods that may be enjoyed by any number of people without affecting other peoples’ enjoyment. For example, an aesthetic view is a pure public good. No matter how many people enjoy the view, others can also enjoy it.

Relative value: in contrast to absolute value which measures the dollar value of X or Y, relative value measures the value of X in relation to the value of Y – in other words, is X greater or less than Y?

Social discount function: the discount rate used in computing the value of funds spent on social projects. The social discount rate can appear in both calculations either as future costs such as maintenance or as future benefits such as reduced pollution emissions.

Stakeholders: any individual or group of individuals who are involved in or affected by a course of action or policy decision.

Study site: in Benefit Transfer, study site refers to the site of a previous primary valuation study.

Transdisciplinary: creating a unity of intellectual frameworks beyond the disciplinary perspectives - approaches that transcend boundaries of conventional approaches to get around the issue of methods of thinking completely by working from the problem space out.

Use value: value derived from actual use of a good or service. Uses may include indirect uses. For example, enjoying a television show about whales provides an indirect use value for the whales.

Utilitarian framework: Utilitarians maintain that the ultimate aim of any policy, law or action should be to promote the greatest happiness for the greatest number of people.

Willingness to pay: the amount—measured in goods, services, or dollars—that a person is willing to give up to get a particular good or service.

AVAILABLE ESV DECISION SUPPORT TOOLKITS/METHODS AND SOFTWARE

Software and/or Web Based Tools

(descriptions are taken directly from the developers' websites)

- Ecopath http://www.ecopath.org/
    - Ecopath with Ecosim (EwE) is a free ecological/ecosystem modeling software suite. EwE has three main components: Ecopath - a static, mass-balanced snapshot of the system; Ecosim - a time dynamic simulation module for policy exploration; and Ecospace - a spatial and temporal dynamic module primarily designed for exploring impact and placement of protected areas. The Ecopath software package can be used to
        - Address ecological questions;
        - Evaluate ecosystem effects of fishing;
        - Explore management policy options;
        - Analyze impact and placement of marine protected areas;
        - Predict movement and accumulation of contaminants and tracers (Ecotracer);
        - Model effect of environmental changes.

    The latest release of Ecopath with Ecosim is version 6.3, released on November 25, 2012.

- Integration Value of Ecosystem Services and Tradeoffs (InVEST) – Natural Capital Project http://www.naturalcapitalproject.org/InVEST.html

    - InVEST is a suite of software models used to map and value the goods and services from nature that sustain and fulfill human life.

- ARIES - developed with funding from the National Science Foundation at the University of Vermont's Gund Institute for Ecological Economics http://www.ariesonline.org/

    - ARIES is a suite of applications, all delivered to end users through the Web. All applications have been designed with the help of professional usability engineers, and are accessible through a standard web browser. Along with the main toolkit (Ecosystem Services Explorer, Valuation Database, and Biodiversity Explorer), custom ARIES interfaces can be built to simplify use by specific groups of end users.

- Land Server - Pinchot Institute for Conservation http://www.landserver.org/

    - LandServer is a web-based tool that provides farmers and woodland owners with a quick and easy natural resource assessment, an evaluation of their property's

potential to receive payments for implementing conservation actions, and information on how to get started.

- Simple, Effective Resource for Valuing Ecosystem Services (SERVES) – Earth Economics http://www.esvaluation.org/serves.php

    - SERVES ("Simple and Effective Resource for Valuing Ecosystem Services") is a component of Earth Economics' Ecosystem Valuation Toolkit, that is currently used by Earth Economics staff only. EVT and SERVES will soon be made more widely available as a subscription-based self-service natural capital appraisal tool for anyone to estimate the economic value of ecosystem services for anywhere in the world. SERVES outputs are already being used for developing natural capital financing mechanisms, informing policy at all scales or simply summarizing available research data for a given location. This paves the way for improving public and private investment and helping correct economic incentives and shift/create markets to solve some of humanity's most pressing problems. Those who are interested in access to SERVES or its outputs should contact the Earth Economics team at evt@eartheconomics.org.

- Wildlife Habitat Benefits Estimation Toolkit – Defenders of Wildlife

    - The Wildlife Habitat Benefits Estimation Toolkit is a set of user-friendly Excel models that allows users to generate quantitative estimates of the economic values generated by specific natural areas of interest to them. The Toolkit includes detailed user manuals, presentations, technical documentation of the estimation models and literature reviews. Download the toolkit(.zip) and user manual here.

- InFOREST – Virginia Department of Forestry http://inforest.frec.vt.edu/

    - InForest is a tool designed to provide landowners, natural resource managers, and land-use planners state-of-the-art access to information about the natural resources they manage. The tool enhances the user's ability to make better informed decisions about their forest management and land conservation activites. InForest utilizes a Geographical Information System (GIS) platform to integrate natural resource data with the functionality necessary to generate custom maps, reports and information about ecosystem services for a specific tract of land.

- SolVES – USGS http://solves.cr.usgs.gov/http://solves.cr.usgs.gov/

    - SolVES is a geographic information system (GIS) application designed to use data from public attitude and preference surveys to assess, map, and quantify social values for ecosystem services. SolVES calculates and maps a 10-point Value Index representing the relative perceived social values of ecosystem services such as recreation and biodiversity for various groups of ecosystem stakeholders. SolVES

output can also be used to identify and model relationships between social values and physical characteristics of the underlying landscape. These relationships can then be used to generate predicted Value Index maps for areas where survey data are not available.

- Wetland Restoration Tool Planning Tool (Oregon Wetlands Explorer) – Oregon University Institute for Natural Resources, The Wetlands Conservancy, and the Oregon State University Libraries http://oe.oregonexplorer.info/wetlands/restoration/
    - The Wetland Restoration Tool Planning Tool locates the most appropriate sites to implement restoration within a given watershed (watersheds are typically 4th level, 8-digit HUCs). It strives to identify which wetland complexes are the best to restore, based on current wetland condition, land management status, suitable soils, hydrology, and proximity to existing restoration projects, and also what plant materials to use for the job. The Oregon Wetlands Explorer supports the conservation and restoration of Oregon's wetlands through a variety of multimedia stories, data collections, mapping tools and other wetland resources. The intent is to create a single web-based source for information on wetlands in Oregon that will improve decision-making for wetlands restoration and protection programs and projects. This portal provides analytical and mapping tools and information to the public, decision makers, environmental professionals and land managers. Use the Explorer to: map wetlands, find priority areas for wetland mitigation, and learn about Oregon's Greatest Wetlands, wetland restoration, history, ecology and classification.

- Conceptual Ecological Model Construction Assistance Toolbox (CEMCAT) – US Army Corps of Engineers (USACE) http://cw-environment.usace.army.mil/eba/cemcat.cfm
    - The USACE Engineer Research and Development Center (ERDC) has developed a software program to assist in the design and implementation of conceptual ecological models. The software streamlines the process of constructing conceptual models for project developers who already incorporate them into the planning process, and offers a standard structure in which to design and build them. The software allows those less familiar with conceptual ecological models to improve their projects by quickly and efficiently incorporating this recommended element into the planning and implementation process.

- Ecosystem Crediting Platform (ECP) – Willamette Partnership http://willamettepartnership.ecosystemcredits.org/
    - The Ecosystem Crediting Platform (ECP) is designed for use by land managers and project developers generating credits under Willamette Partnership's Counting on the Environment protocol and standards. This tool translates environmental restoration and conservation actions into ecosystem service credits using the Willamette Partnership's Counting on the Environment standards. Users of this

software can map their projects, create multiple project designs, and manage their projects through the required approval process.

- Comet 2.0
  http://www.comet2.colostate.edu/
  COMET-VR 2.0 is a user-friendly, web-based tool that provides estimates of carbon sequestration and net greenhouse gas emissions from soils and biomass for US farms and ranches. It links a large set of databases containing information on soils, climate and management practices to dynamically run the Century ecosystem simulation model as well as empirical models for soil N_2O emissions and CO_2 from fuel usage for field operations.
  The system uses your farm-specific information to provide mean estimates and uncertainty for CO_2 emissions and sequestration from soils and woody biomass and soil N_2O emissions for annual crops, hay, pasture and range, perennial woody crops (orchards, vineyards), agroforestry practices, and fossil fuel usage.

- Envision - USDA Forest Service & Pacific Northwest Research Station
  http://forsys.cfr.washington.edu/envision.html
  - EnVision is designed to be a full featured rendering system for stand- and landscape-scale images. Applicable projects range from a few to several thousand acres. The system is built upon many of the original concepts used to develop the Vantage Point visualization system. However, EnVision does not attempt to model changes to the landscape over time. Basic components of an EnVision project include a digital terrain model to define the ground surface, color and texture maps to define ground surface characteristics, and groups of objects or "actors". Scene definitions include background imagery used to add clouds and distant landscape features, model components (e.g. terrain model(s) and polygon overlays), viewpoint and camera characteristics, and foreground imagery used to provide high detail in the image foreground. EnVision models individual light sources including a simulated sun position and atmospheric effects such as fog and haze. EnVision renders images using a geometrically correct camera model making it possible to match real photographs taken from known viewpoints to simulated scenes.

- Restorable Wetland Prioritization Tool – University of Minnesota
  https://beaver.nrri.umn.edu/MPCAWLPri/
  - The tool was developed using 30 meter resolution Geographic Information System (GIS) data. At this scale the tool will prioritize areas across the user's area of interest (county, watershed, etc) that are most likely to meet their restoration goals. From the high priority areas the user can use aerial imagery and available environmental data housed in the tool along with site visits to pinpoint their

restoration site. At this scale the tool will not allow the user to identify individual restoration sites.

- This tool enables one to prioritize areas for maximizing water quality improvements, in the form of nitrogen or phosphorus removal, and/or habitat and for restoring or protecting high functioning sustainable wetlands. The tool consists of five primary layers. The base layer is a restorable wetlands inventory that predicts restorable wetland locations across the landscape. There are also three decision layers including a stress, viability, and benefits layer. The stress and viability decision layers can be weighted differently depending on the users interest in nitrogen and phosphorus reductions and habitat improvement. Lastly, there is a modifying layer with aerial imagery and other supplemental environmental data.

- Ecosystem Portfolio Model (USGS)
  http://www.usgs.gov/climate_landuse/lcs/projects/ecosys_model.asp
  - The Puget Sound Ecosystem Portfolio Model (PSEPM) is a decision support tool that uses land-use change scenarios and a suite of spatially-explicit models to explore the implications of future regional growth and development, including shoreline modifications, to Puget Sound nearshore ecosystems through 2060. The tool currently focuses on threats to barrier and bluff-backed beaches, which represent 50 percent of Puget Sound shorelines by length. A suite of sub-models identify multiple connections between land use and the nearshore's capacity to support valued ecosystem components (VECs) and ecosystem services. VECs are key elements of the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) conceptual framework for nearshore restoration, and were selected to communicate the value of Puget Sound nearshore restoration to managers and the public.
  - The South Florida Ecosystem Portfolio Model (SFL EPM) is a Geographic Information System-based multi-criteria decision support web tool that evaluates land use plans and proposed land use/land cover (LU/LC) changes in terms of performance criteria related to three dimensions of value: 1) modeled ecological criteria related to ecosystem services, expressed as "ecological value" 2) predicted land market prices and the associated probability of LU/LC conversion, and 3) community quality-of-life indicators. Each of these dimensions is implemented as a sub-model of the EPM that generates "value maps" for a given land use pattern and set of user-elicited preferences, where the value map reflects changes in parcel and landscape attributes. The modeled parcel/landscape attribute changes are related to land use/cover change, including changes in habitat potential and landscape fragmentation, distances to human perceived amenities, community "character", flooding and hurricane evacuation risks, water quality buffer potential, ecological restoration potential, and other relevant performance criteria. Users can examine the resulting value maps for one or more land use/cover patterns under

different weighting schemes, allowing the user to explore how different prioritizations of objectives affects the evaluation process. More broadly, users can also compare ecological value maps, predicted land price maps, maps of community quality-of-life indicators for sets of land use/cover patterns to characterize regional-scale trade-offs between ecological, economic, and social values. By using maps as the means of comparison, local details are retained, while regional patterns emerge.

- Marxan (The University of Queensland, Australia)
  http://www.uq.edu.au/marxan/
  Marxan is freely available conservation planning software. It provides decision support to a range of conservation planning problems, including: the design of new reserve systems; reporting on the performance of existing reserve systems; and developing multiple-use zoning plans for natural resource management. Marxan is flexible- it can be applied to a wide range of problems such as reserve design and natural resource management in terrestrial, freshwater, and marine systems. Marxan is efficient and repeatable- it provides many good solutions to complex problems, providing a number of options and encouraging stakeholder participation. These features provide users with decision support to achieve an efficient allocation of resources across a range of different uses.

Toolkits/Methods

- Conservation Action Planning
  http://www.conservationgateway.org/ConservationPlanning/ActionPlanning/Pages/conservation-action-plann.aspx
  - What is Conservation Action Planning?
    Conservation Action Planning (CAP) is a powerful ten-step tool to guide conservation teams to develop focused strategies and measures of success. When regional priorities have been set, Conservation Action Planning is used to determine the plan of action for these priorities. As actions are taken and outcomes are measured, conservation action plans are revised to incorporate new knowledge. - See more at:
    http://www.conservationgateway.org/ConservationPlanning/ActionPlanning/Pages/conservation-action-plann.aspx#sthash.U6Z56919.dpuf

- Multiscale Integrated Model of Ecosystem Services (MIMES)
  http://www.afordablefutures.com/services/mimes
  - MIMES is a multi-scale, integrated set of models that assess the value of ecosystem services. These sophisticated models allow government decision-makers, NGOs, and any other natural resource managers to quickly understand:
    - Dynamics of ecosystem services
    - How ecosystem services are linked to human welfare?
    - How the value might change under various management scenarios?

MIMES has been developed in collaboration with a large international group of scientists and is being applied at a broad range of sites and scales, both in the US and abroad. MIMES provides economic arguments for land use managers to approach conservation of ecosystems as a form of economic development. The model facilitates quantitative measures of ecosystem service effects on human well-being.

- Corporate Ecosystem Services Review – World Resources Institute
  http://www.wri.org/project/ecosystem-services-review
  - The Corporate Ecosystem Services Review (ESR) is a structured methodology for corporate managers to proactively develop strategies for managing business risks and opportunities arising from their company's dependence and impact on ecosystems.

- Comparative Valuation of Ecosystem Services (CVES)
  http://yosemite.epa.gov/SAB/sabcvpess.nsf/e1853c0b6014d36585256dbf005c5b71/7d3938054039aeee85256ed70050b52f/$FILE/Lents%20Project%20Final%20Submittal%20June.pdf
  - In a project supported by the City of Portland, an interdisciplinary team developed a method for quantifying the economic values associated with riparian restoration projects. The team included ecologists, environmental planners and scientists, natural-resource policy advisors, and natural-resource economists from David Evans and Associates, ECONorthwest, and the City. The team's approach, termed Comparative Valuation of Ecosystem Services (CVES), combines a systems-dynamic model of changing ecosystem services with ecosystem-economics data and information on the value of ecosystem services.

- The Toolkit for Ecosystem Service Site-based Assessment (TESSA)
  http://www.birdlife.org/datazone/info/estoolkit
  - This toolkit was compiled by Anglia Ruskin University, BirdLife International, Cambridge University (Geography and Zoology Departments), Royal Society for the Protection of Birds, Tropical Biology Association and UNEP World Conservation Monitoring Centre.
  - The toolkit was developed for use by local non-specialists, enabling the identification of which ecosystem services may be important at a site, and for evaluating the magnitude of benefits that people obtain from them currently, compared with those expected under alternative land-uses. - See more at: http://www.conservation.cam.ac.uk/resource/journal-articles/tessa-toolkit-rapid-assessment-ecosystem-services-sites-biodiversity#sthash.eu4BMQav.dpuf

- The Wetlands-At-Risk Protection Tool
  http://www.wetlandprotection.org/

The Wetlands-At-Risk Protection Tool, or WARPT, is a process for local governments and watershed groups that acknowledges the role of wetlands as an important part of their community infrastructure, and is used to develop a plan for protecting at-risk wetlands and their functions. The basic steps of the process include quantifying the extent of at-risk wetlands, documenting the benefits they provide at various scales, and using the results to select the most effective protection mechanisms.

The next two are more international in focus but provide useful suggestions and methods which may be integrated into U.S. wetland restoration planning procedures.

- Integrated Wetland Assessment Toolkit
  http://data.iucn.org/dbtw-wpd/edocs/2009-015.pdf
  This toolkit sets out a process for integrated assessment and provides a set of methods that can be used to investigate the links between biodiversity, economics and livelihoods in wetlands, and to identify and address potential conflicts of interest between conservation and development objectives. The integrated approach presented in the toolkit also enables practitioners to assess a wetland in terms of its combined biodiversity, economic and livelihood values. Funded by the UK governments' Darwin Initiative, the Strengthening pro-poor wetland conservation using integrated biodiversity and livelihood assessment project developed the Toolkit through case study assessments at Mtanza-Msona Village in Tanzania and in the Stung Treng Ramsar Site in Cambodia.

- Wetland Resources Action Planning Toolkit
  http://www.wraptoolkit.org/
  The Wetland Resources Action Planning (WRAP) toolkit is a toolkit of research methods and better management practices used in HighARCS (Highland Aquatic Resources Conservation and Sustainable Development), an EU-funded project with field experiences in China, Vietnam and India. It aims to communicate best practices in conserving biodiversity and sustaining ecosystem services to potential users and to promote the wise-use of aquatic resources, improve livelihoods and enhance policy information. Potential users of the WRAP toolkit would be HighARCS' primary stakeholders: the fishing communities; government and non-government institutions; scientists and researchers; and policy makers in the project sites. It will also cater to the needs of those agencies and institutions that are planning to develop and implement a similar project involving highland aquatic resources conservation and sustainable development.

Other Resources

- Ecosystem-Based Management Tools Network http://www.ebmtools.org/
- EcoMetrix http://www.ecometrixsolutions.com/ecometrix.html
- Eco Marketplace
  http://www.ecosystemmarketplace.com/pages/dynamic/library.landing_page.php
- Ecosystem-Based Management Tools Network http://www.ebmtools.org/

- National Land Cover Data Set (USGS) http://landcover.usgs.gov/
- USDA Office of Environmental Markets http://www.fs.fed.us/ecosystemservices/OEM/index.shtml/index.shtml
- Final Ecosystem Goods and Services Classification System (FEGS-CS) – EPA http://ecosystemcommons.org/sites/default/files/fegs-cs_final_v_2_8a.pdf
- EnviroAtlas – EPA http://www.epa.gov/research/enviroatlas/
- National Ecosystem Services Partnership http://nicholasinstitute.duke.edu/initiatives/national-ecosystem-services-partnership#.UnPpjvmTgXs
  - Ecosystem Commons http://ecosystemcommons.org/home
- The Millennium Ecosystem Service Assessment http://www.unep.org/maweb/en/index.aspx
- TEEB for Business Coalition http://www.teebforbusiness.org/what.html
- Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) http://www.ipbes.net/
- University of California Cooperative Extension Rangeland Ecosystem Services http://ucanr.edu/sites/RangelandES/
- The Environmental Valuation Reference Inventory™ https://www.evri.ca/Global/HomeAnonymous.aspx

OTHER CASE STUDIES

Websites with multiple case studies available:

1. **GecoServ:**
   Additional wetland valuation studies can be found in the GecoServ Gulf of Mexico Ecosystem Services Valuation Database developed by the Harte Research Institute for Gulf of Mexico Studies at the Texas A&M University.
2. **Duke Nicholas School and Marine Ecosystem Services Partnership**
   This website contains a Valuation Library containing 870 case studies and counting…
   http://mesp2.env.duke.edu/home
   www.marineecosystemservices.org
3. **The Economics of Ecosystems and Biodiversity (TEEB):**
   The TEEB report titled "The Economics of Ecosystem and Biodiversity for Water and Wetlands" (2013) provides several case studies, including an informative table which provides examples of wetland valuation studies based on the type of ecosystem service being studied. A copy of the wetland valuation studies table is provided below.

Taken from TEEB Report: Wetland Valuation Studies

Ecosystem services	Ecosystem structure and function	Examples of Valuation Studies
Coastal protection	Attenuates and/or dissipates waves, buffers winds	Badola and Hussein (2005), Barbier (2007), Costanza et al. (2008), Das and Vincent (2009), Bayas et al. (2011)
Erosion control	Provides sediment stabilisation and soil retention	Sathirathai and Barbier (2001)
Flood protection	Water flow regulation and control	Brouwer and van Elk (2004)
Water supply	Groundwater recharge/discharge	Acharya and Barbier (2000, 2002), Smith and Crowder (2011)
Water purification	Provides nutrient and pollution uptake, as well as retention, particle deposition	Byström (2000), Yang et al. (2008), Jenkins et al. (2010)
Carbon sequestration	Generates biogeochemical activity sedimentation, biological productivity	Jenkins et al. (2010), Sikamäki et al. (2012)
Maintenance of temperature, precipitation	Climate regulation and stabilisation	
Raw materials and food	Generates biological productivity and diversity	Sathirathai and Barbier (2001), Islam and Braden (2006)
Maintains fishing, hunting and foraging activities	Provides suitable reproductive habitat and nursery grounds, sheltered living space	Johnston et al. (2002), Barbier (2007), Smith (2007), Aburto-Oropeza et al. (2008), Sanchirico and Mumby (2009)
Tourism, recreation, education and research	Provides unique and aesthetic landscape, suitable habitat for diverse fauna and flora	Hammitt et al. (2001), Johnston et al. (2002), Carlsson et al. (2003), Othman et al. (2004), Brouwer and Bateman (2005), Birol et al. (2006), Birol and Cox (2007), Do and Bennet (2008), Jenkins et al. (2010).
Culture, spiritual and religious benefits, bequest values	Provides unique and aesthetic landscape of cultural, historic or spiritual meaning	Kwak et al. (2007)

Source: building on Barbier 2011

4. **National Oceanic and Atmospheric Administration (NOAA)**
   Ecosystem Services Valuation Inventory
   http://www.ppi.noaa.gov/economics/
   This inventory downloads as a spreadsheet with 90 case studies.
5. **Earth Economics Ecosystem Valuation Toolkit**
   This website hosted by Earth Economics has a researcher's library with published and gray literature on primary ecosystem service valuation studies as well as an exchange platform. It also contains resources – some free, some for a fee – which contains materials for education, best practices, communication and policy.
   http://esvaluation.org/

Other ecosystem valuation case studies:

- New Zealand Department of Conservation (2006). The Value of Conservation: What Does Conservation Contribute to the Economy? NZDC, New Zealand.
- Emerton L. and Kekulandala L.D.C.B. (2003). Assessment of the Economic Value of Muthurajawela Wetland. Occasional Papers of IUCN Sri Lanka, No. 4.
- Emerton L. and Bos E. (2004). Value: Counting Ecosystems as an Economic Part of Water Infrastructure, IUCN, Gland, Switzerland and Cambridge, http://data.iucn.org/dbtw-wpd/edocs/2004-046.pdf.
- Smith M.D. and Crowder L.B. (2011). Valuing Ecosystem Services with Fishery Rents: A Lumped-Parameter Approach to Hypoxia in the Neuse River Estuary. Sustainability 3: 2229-2267.
- Molnar M., Kocian M. and Batker D. (2012). Valuing the Aquatic Benefits of British Columbia's Lower Mainland: Near shore Natural Capital Valuation. David Suzuki Foundation and Earth Economics.
- Prato, Tony and Donald Hey (2006). Economic Analysis of Wetland Restoration Along the Illinois River. Journal of the American Water Resources Association 42: 125-131.
- Jenkins, W. Aaron, Murray, Brian C., Kramer, Randall A., Faulkner, Stephen P. (2010). Valuing Ecosystem Services from Wetlands Restoration in the Mississippi Alluvial Valley. Ecological Economics 69:1051-1061.
- Carver, Erin and James Caudill (2013). Banking on Nature: The Economic Benefits to Local Communities of National Wildlife Refuge Visitation. U.S. Fish & Wildlife Service, Division of Economics, Washington, D.C.
- Conservation International. 2008. Economic Values of Coral Reefs, Mangroves, and Seagrasses: A Global Compilation. Center for Applied Biodiversity Science, Conservation International, Arlington, VA, USA.
- Grossman, Malte (2012). Economic Valuation of Wetland Ecosystem Services: Case Studies from the Elbe River Basin. Technische Universitat Berlin.
- Batker, David, de la Torre, Isabel, Costanza, Robert, Swedeen, Paula, Day, John, Boumans, Roelof, and Bagstad, Kenneth (2010). Gaining Ground: Wetlands, Hurricanes and the

Economy: The Value of Restoring the Mississippi River Delta. Earth Economics, Tacoma, Washington.
- Kaza, Nikhil and Todd K. BenDor (2013). The Land Value Impacts of Wetland Restoration. Journal of Environmental Management, 127:289-299.
- Brander, L.M., Bräuer, I., Gerdes, H., Ghermandi, A., Kuik, O., Markandya, A., Navrud, S., Nunes, P.A.L.D., Schaafsma, M., Vos, H., Wagtendonk, A., 2012. Using Meta-Analysis and GIS for Value Transfer and Scaling Up: Valuing Climate Change Induced Losses of European Wetlands. Environmental and Resource Economics 52, 395-413.
- Brander, L., Brouwer, R., Wagtendonk, A., 2013. Economic valuation of regulating services provided by wetlands in agricultural landscapes: A meta-analysis. Ecological Engineering 56, 89-96.

Wetland ecosystem services for natural infrastructure (case studies and links):

- Broekx S., Smets S., Liekens I., Bulckaen D. and De Nocker L. (2011). Designing a long-term flood risk management plan for the Scheldt estuary using a risk-based approach, Natural Hazards, 57 (2): 245-266.
- Turpie (2010) J., Wastewater treatment by wetland, South Africa, http://www.eea.europa.eu/atlas/teeb/water-quality-amelioration-value-of/view.
- A Green Sponge for a Water-Resilient City: Qunli Stormwater Park http://www.asla.org/2012awards/026.html
- The Landscape Architecture Foundation has several interesting case studies that you can sort by performance benefit, project type and location: http://www.lafoundation.org/research/landscape-performance-series/case-studies/?benefit=select_all&project_type=21&location=select_all
- Nine Acre L.A. Parking Lot Transformed into Pollution-Reducing Wetlands http://inhabitat.com/nine-acre-l-a-parking-lot-transformed-into-a-pollution-reducing-wetland/
- Staten Island Bluebelt Project: http://www.nyc.gov/html/dep/html/dep_projects/bluebelt.shtml
- Philadelphia's Green Stormwater Infrastructure projects: http://www.phillywatersheds.org/what_were_doing/green_infrastructure
- The Green Infrastructure Center has a useful website: http://www.gicinc.org/index.htm

Benefits related to wetland restoration:

- Loth P. (ed) (2004). The Return of the Water: Restoring the Waza Logone Floodplain in Cameroon, IUCN, Gland, Switzerland and Cambridge.
- Pollard S. R., Kotze D. C. and Ferrari G. (2008). Valuation of the livelihood benefits of structural rehabilitation interventions in the Manalana Wetland, in D. C. Kotze and W. N. Ellery (eds) WETOutcome Evaluate: An Evaluation of the Rehabilitation Outcomes at Six Wetland Sites in South Africa, WRC Report No TT 343/08, Water Research Commission, Pretoria.

- Thompson P. and Balasinorwala T. (2010). Wetland protection and restoration increases yields, Bangladesh, http://www.eea.europa.eu/atlas/teeb/wetland-protectionand-restorationincreases-1.
- Slootweg, R. (2010a). Wetland restoration incorporates ecosystem service values, Aral Sea, Central Asia.

REFERENCES

Alexander, S. & McInnes, R. (2012). The benefits of wetland restoration. *Ramsar Scientific and Technical Briefing Note no.4*. Gland, Switzerland: Ramsar Convention Secretariat.

Alpizar, F., Blackman, A., & Pfaff, A. (2007). Payments for Ecosystem Services: Why Precision and Targeting Matter. *Resources*, 20-22. Retrieved from Resources for the Future: http://www.rff.org/News/Features/Pages/Payments-for-Ecosystem-Services-Why-Precision-and-Targeting-Matter.aspx

Appleton, A. F. (2012). *The Staten Island Bluebelt: A Study in Sustainable Water Management.* Retrieved September 9, 2013, from The Cooper Union: http://cooper.edu/isd/news/waterwatch/statenisland

Bagstad, K. J., Semmens, D.J., & Winthrop, R. (2013). Comparing approaches to spatially explicit ecosystem service modeling: A case study from the San Pedro River, Arizona. *Ecosystem Services*, e40-e50.

Bagstad, K.J., Semmens, D., Winthrop, R., Jaworski, D., Larson, J. (2012). *Ecosystem Services Valuation to Support Decisionmaking on Public Lands - A Case Study of the San Pedro River Watershed, Arizona.* Reston, VA: Bureau of Land Management and the US Geological Survey.

Barnes, G. (2014, March 13). *Encouraging Investments in Wetland and Water Quality Improvements on Private Property through Low-Interest Loans.* Retrieved from University of North Carolina Environmental Finance Center: http://efc.web.unc.edu/2014/03/13/encouraging-investments-in-wetland-and-water-quality-improvements/

Brown, T. C., Bergstrop, J. C., & Loomis, J. B. (2007). Defining, Valuing, and Providing Ecosystem Goods and Services. *Natural Resources Journal*, 329-376.

Carson, R., Flores, N. E., Meade, N. F. (2001). Contingent Valuation: Controvies and Evidence. *Environmental and Resource Economic*, 19(173-210).

Chan, K. M.A., Satterfield, T., Goldstein, J.(2012). Rethinking Ecosystem Services to Better Address and Navigate Cultural Values. *Ecological Economics*, 8-18.

Christie, J. & Bostwick, P. (2012). *Climate Change Adaptation Plan for Coastal and Inland Wetlands in the State of Michigan.* North Windham, ME: The Association of State Wetland Managers.

Colgan, C., Yakovleff, D., Merrill, S. (2013). *An Assessment of the Economics of Natural adn Built Infrastructure for Water Resources in Maine.* Portland, Maine: University of Southern Maine.

Costanza, R., Kubiszewski, I., Ervin, D., Bluffstone, R., Boyd, J., Brown, D., Chang, H., Dujon, V., Granek, E., Polasky, S., Shandas, V., & Yeakley, A. (2011). Valuing Ecological Systems and Services. *F1000 Biology Reports*, 3:14.

Costanza, R., Wilson, M., Troy, A., Voinov, A., Liu, S., D'Agostino, J. (2006). *The Value of New Jersey's Ecosystem Services and Natural Capital.* Burlington, VT: Gund Institute for Ecological Economics, University of Vermont.

Cox, L. M., Almeter, A. L., & Saterson, K. A. (2013). Protecting Our Life Support Systems: An inventory of U.S. federal research on ecosystem services. *Ecosystem Services*, 5: 163-169.

Dahl, T. E. (1990). *Wetlands Losses in the United States 1780s to 1980s.* Washington, D.C.: U.S. Department of the Interior, Fish & Wildlife Service. Retrieved September 9, 2013, from U.S. Department of the Interior, Fish and Wildlife Service.

Dahl, T. E. (2011). *Status and Trends of Wetlands in the Conterminous United States 2004 to 2009.* Washington, D.C.: Department of the Interior, Fish and Wildlife Service.

Dahl, T.E. and Stedman, S.M. (2013). *Status and Trends of Wetlands in the Coastal Watersheds of the Conterminous United States 2004-2009.* Washington, D.C.: U.S. Dept. of the Interior, Fish and Wildlife Service and National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

de Groot, R.S., Stuip, M.A.M., Finlayson, C.M. & Davidson, N. (2006). *Valuing Wetlands: Guidance for Valuing the Benefits Derived from Wetland Ecosystem Services.* Gland, Switzerland: Ramsar.

Declerck, F. (2013, September 20). Land sharing or sparing? Considering ecosystem services in the debate. http://wle.cgiar.org/blogs/2013/09/20/land-sharing-or-sparing-considering-ecosystem-services-in-the-debate/.

Eigenbrod, F., Armsworth, P. R., Anderson, B. J., Heinemeyer, A., Gililngs, S., Roy, D. B., Thomas, C. D., and Gaston, K. J. (2010). The Impact of Proxy-based Methods on Mapping the Distribution of Ecosystem Services. *Journal of Applied Ecology*, 47(377:385).

Erwin, K. L. (2009). Wetlands and global climate change: the role of wetland restoration in a changing world. *Wetlands Ecological Management*, 17:71-84.

Fisher, B., Bateman, I., Turner, R.K. (2011). *Valuing Ecosystem Services: Benefits, Values, Space and Time.* Nairobi, Kenya: United Nations Environment Program.

Frey, E.F., Palin, M.B., Walsh, P.J., Whitcraft, C.R. (2013). Spatial Hedonic Valuation of a Multiuse Urban Wetland in Southern California. *Agricultural and Resource Economics Review*, v(42):2, 387-402.

Glick, P., Hoffman, J., Koslow, M., Kane, A.,& Inkley, D. (2011). *Restoring the Great Lakes' Coastal Future: Technical Guidance to the Design and Implementation of Climate-Smart Restoration Projects.* Ann Arbor, Michigan: National Wildlife Federation.

Gomez-Baggethun, E., de Groot, R., Loomas, P. L., & Montes, C. (2009). The History of Ecosystem Services in Economic Theory and Practice: From Early Notions to Markets and Payment Schemes. *Ecological Economics*, 1209–1218.

Hausman, J. (2012). Contingent Valuation: From Dubious to Hopeless. *Journal of Economic Perspectives*, 26(43-56).

Hermann, A., Schleifer, S., Wrbka, T. (2011). *The Concept of Ecosystem Services Regarding Landscape Research: A Review.* Retrieved September 9, 2013, from Living Reviews in Landscape Research: http://landscaperesearch.livingreviews.org/Articles/lrlr-2011-1

IPCC Working Group II. (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability.* Geneva, Switzerland: Intergovernmental Panel on Climate Change.

King, D., and Mazzotta, M.J. (2000). *Applying Ecosystem Value Estimates - Benefit-Cost Analysis.* Retrieved September 9, 2013, from Ecosystem Valuation: http://www.ecosystemvaluation.org/1-04.htm

King, D., and Mazzotta, M.J. (2000). *Productivity Methods*. Retrieved September 9, 2013, from Ecosystem Service Valuation: http://www.ecosystemvaluation.org/productivity.htm

King, D., and Mazzotta, M.J. (2000). *Damage Cost Avoided, Replacement Cost, and Substitute Cost Methods*. Retrieved September 9, 2013 from Ecosystem Valuation: http://www.ecosystemvaluation.org/contingent_valuation.htm

King, D., and Mazzotta, M.J. (2000). *Contingent Valuation Method*. Retrieved September 9, 2013 from Ecosystem Valuation: http://www.ecosystemvaluation.org/contingent_valuation.htm

King, D., and Mazzotta, M.J. (2000). The *Contingent Choice Method*. Retrieved September 9, 2013 from Ecosystem Valuation: http://www.ecosystemvaluation.org/contingent_choice.htm

Kocian, M., Traughber, B., Batker, D. (2012). *Valuing Nature's Benefits: An Ecological Economic Assessment of Iowa's Middle Cedar Watershed.* Tacoma: Earth Economics.

Kusler, J. (2006). *Common Questions: Wetland, Climate Change, and Carbon Sequestering.* http://www.aswm.org/pdf_lib/11_carbon_6_26_06.pdf: Association of State Wetland Managers.

Landers, DH., & Nahlik, A.M. (2013). *Final Ecosystem Goods and Services Classification System (FEGS-CS).* Washington, D.C.: U.S. Environmental Protection Agency.

Lange, G.M., Belle, A., & Kishore, S. (2010). *Valuation of Ecosystem Services in Work Bank Group Work.* Washington, D.C.: The World Bank Group.

Liu, S., Costanza, R., Farber, S., & Troy, A. (2010). Valuing Ecosystem Services: Theory, Practice, and the Need for a Transdiciplinary Synthesis. *Annals of the New York Academy of Sciences*, 54-78.

Martínez-Salinas, A., DeClerck, F., Garbach, K., & Estrada-Carmona, N. (2013, September 13). Managing Farmscapes for Biodiversity Conservation and Ecosystem Services (Birds return the favor: providing ecosystem services in Costa Rica). http://wle.cgiar.org/blogs/2013/09/13/birds-return-the-favor-providing-ecosystem-services-in-costa-rica/?utm_source=Agriculture+and+Ecosystems+Blog+Subscribers&utm_campaign=145ef428cf-_WLE_AgEco_Friday_Links_Women_s_Day3_8_2013&utm_medium=email&utm_term=0.

Meacham, M. (2013, August 28). A Bundle of Ecosystem Services: Principles for Resilience in Agricultural Landscapes. Stockholm.

Millennium Ecosystem Assessment. (2005). *Ecosystems And Human Well-Being: Wetlands And Water Synthesis.* Washington, D.C.: World Resources Institute.

Morse-Jones, S., Luisetti, T., Turner, R. K., & Fisher, B. (2011). Ecosystem Valuation: some principles and a partial application. *Environmetrics (Special Issue: Quantitative Approaches to Ecosystem Service Evaluation)*, 22:5, 675-685.

National Research Council. (2004). *Valuing Ecosystem Services: Toward Better Environmental Decision-Making.* Washington, D.C.: The National Academies Press.

Natural England. (2012). *Valuing Ecosystem Services: Case Studies from Lowland England.* Retrieved September 9, 2013, from Natural England: http://publications.naturalengland.org.uk/publication/2319433

Natural Resources Conservation Service. (2012). *Restoring America's Wetlands: A Private Lands Conservation Success Story.* USDA. Retrieved from http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1045079.pdf

New York City Department of Environmental Protection. (2009). *Wetlands in the Watersheds of the New York City Water Supply System.* Kingston, NY: New York City Department of Environmental Protection.

O'Connor, F.M., Boucher, O., Gedney, N., Jones, C.D., Folberth, G.A., Coppell, R., Friedlingstein, P., Collins, W.J., Chappellaz, J., Ridley, J., & Johnson, C.E. (2010). Possible Role of Wetlands, Permafrost, and Methane Hydrates in the Methane Cycle Under Future Climate Change: A Review. *Review of Geophysics*, 48: RG4005.

Pagiola, S. (2008). How Useful Is Ecosystem Valuation? *Economics and Conservation in the Tropics: A Strategic Dialogue.* Washington, D.C.: Resources for the Future.

Parks, S., and Gowdy, J. (2013). What Have Economists Learned About Valuing Nature? A Review Essay. *Ecosystem Services*, e1-e10.

Perrings, C. (2010). *Biodiversity, Ecosystem Services, and Climate Change: The Economic Problem.* Washington, D.C. : The World Bank.

Pew Center on Global Climate Change. (2006). *Climate Change 101.* Philadelphia: The Pew Charitable Trusts.

Pritchard, L. Jr., Folke, C., & Gunderson, L. (2000). Valuation of Ecosystem Services in Institutional Context. *Ecosystems*, 36-40.

Radford, K.G.,and James, P. (2013). Changes in the Value of Ecosystem Services Along a Rural-Urban Gradient: A case study of Greater Manchester, UK. *Landscape and Urban Planning*, 117-127.

Reed, D., Martin, L., & Cushing, J. A. (2013). *Using Information on Ecosystem Goods and Services in Corps Planning: An Examination of Authorities, Policies, Guidance, and Practices.* Alexandria, VA: Institute for Water Resources.

Ruckelshaus, M., McKenzie, E., Tallis, H., Guerry, A., Daily, G., Kareiva, P., Polasky, S., Ricketts, T., Bhagabati, N., Wood, S.A., & Bernhardt, J. (2013). Notes from the field: Lessons learned from using ecosystem service approaches to inform real-world decisions. *Ecological Economics*, http://dx.doi.org/10.1016/j.ecolecon.2013.07.009.

Russi D., ten Brink P., Farmer A., Badura T., Coates D., Förster J., Kumar R. & Davidson N. (2013). *The Economics of Ecosystems and Biodiversity For Water and Wetlands.* London and Brussels: The Institute for European Environmental Policy.

Searle, B., and Cox, S. (2009). *The State of Ecosystem Services.* Boston: The Bridgespan Group, Inc.

Springate-Baginski, O., Allen, D. & Darwall, W.R.T. (eds.) (2009). *An Integrated Wetland Assessment Toolkit: A guide to good practice.* Gland,: IUCN Species Programme.

Stein, B.A., Glick, P., Edelson, N., & Staudt, A. (2014). *Climate-Smart Conservation: Putting Adaptation Principles into Practice*. National Wildlife Federation, Washington, D.C.

Talberth, J., Gray, E., Yonavjak, L., & Gartner, T. (2013). Green vs Gray: Nature's Solutions to Infrastructure Demands. *Solutions*, Vol 4, No. 1. pp.

TEEB. (2010). *The Economics of Ecosystems and Biodiversity Ecological and Economic Foundation.* London and Washington, D.C.: Earthscan.

The White House Office of Management and Budget. (1992, October 29). Circular A-94 Revised. Washington, D.C., U.S.

Tianyu, Y. (2009, November 9). Restoring China's Disappearing Wetlands. *China Daily*, pp. http://www.chinadaily.com.cn/business/2009-11/09/content_8933093.htm.

Tiner, R. W. (2001). *Delaware's Wetlands: Status and Recent Trends.* Hadley, MA: U.S. Fish & Wildlife Service. Retrieved September 9, 2013, from Delaware Wetlands: Department of Natural Resources and Environmental Control: http://www.dnrec.delaware.gov/Admin/DelawareWetlands/Pages/DelawareWetlandsStatusandTrends.aspx

Tiner, R. W. (2012, August 1). *LLWW*. Retrieved September 9, 2013, from Association of State Wetland Managers: http://www.aswm.org/wetland-science/wetlands-one-stop-mapping/2810-llww-

Tiner, R.W., Biddle, M.A., Jacobs, A.D., Rogerson, A.B., & McGuckin, K.G. (2011). *Delaware Wetlands: Status and Changes from 1992 to 2007.* Hadley, MA: U.S. Fish and Wildlife Service.

Troy, A., and Wilson, M. (2006). Mapping Ecosystem Services: Practical Challenges and Opportunities in Linking GIS and Value Transfer. *Ecological Economics*, 60(435:449).

Turner, R.K., Morse-Jones, S., & Fisher, B. (2010). Ecosystem Valuation: A Sequential Decision Support System and Quality Assessment Issues. *Annals of the New York Academy of Sciences*, 79-101.

U.S. Department of Agriculture. (2011, July 11). *USDA Office of Environmental Markets*. Retrieved from USDA Forest Service: http://www.fs.fed.us/ecosystemservices/OEM/index.shtml/index.shtml

U.S. Environmental Protection Agency (2013, September 12). A *Watershed Approach*. Retrieved June 14, 2014, from: http://water.epa.gov/type/watersheds/approach.cfm

U.S. Environmental Protection Agency. (2012, December 12). *Checking the Health of Wetlands: Easy as 1-2-3*. Retrieved November 11, 2013, from: http://www.epa.gov/research/gems/scinews_123-scienceapproach.htm

U.S. Environmental Protection Agency. (2012, March 6). *Federal Guidance for the Establishment, Use and Operation of Mitigation Banks*. Retrieved September 9, 2013, from: http://water.epa.gov/lawsregs/guidance/wetlands/mitbankn.cfm

U.S. Environmental Protection Agency. (2014, March 20). *Mitigation Banking Factsheet: Compensating for Impacts to Wetlands and Streams.* Retrieved June 16, 2014, from http://water.epa.gov/lawsregs/guidance/wetlands/mitbanking.cfm.

U.S. Environmental Protection Agency (2010). *Part 230 - Section 404(b)(1) Guidelines for Specification of Disposal Sites for Dredged or Fill Material*. Retrieved on June 16, 2014 from: http://water.epa.gov/lawsregs/rulesregs/cwa/upload/CWA_Section404b1_Guidelines_40CFR230_July2010.pdf

U.S. Environmental Protection Agency (2014, March 16). *Summary of the Clean Water Act*. Retrieved September 9, 2013, from: http://www2.epa.gov/laws-regulations/summary-clean-water-act

U.S. Environmental Protection Agency (2012, October 9). *Wetlands Protection*. Retrieved October 9, 2012, from: http://water.epa.gov/type/wetlands/protection.cfm

U.S. Environmental Protection Agency Scientific Advisory Board. (2009). *Valuing the Protection of Ecological Systems and Services.* Washington, D.C.

U.S. Fish & Wildlife Service. (2014, March 26). Division of Bird Habitat: North American Wetlands Conservation Act. Retrieved June 18, 2014, from: http://www.fws.gov/birdhabitat/Grants/NAWCA/index.shtm

Vermont Natural Resources Board. (2010). *Vermont Wetland Rules: Vt. Code R. 12 004 056* . Montpelier, VT: Vermont Natural Resources Board.

Water Land Ecosystems. (2013, August 30). A Bundling of Services is Key to Resilience. http://wle.cgiar.org/blogs/2013/08/30/a-bundle-of-services-is-key-to-resilience/.

Windham, L., Laska, M.S., & Wollenberg, J. (2004). Evaluating Urban Wetland Restorations: Case Studies for Assessing Connectivity and Function. *Urban Habitats*, http://www.urbanhabitats.org/v02n01/evaluating_full.html.

Weitzman, M.L. (2001). Gamma Discounting. The American Economic Review, 91(1), 260-271. http://are.berkeley.edu/courses/ARE263/fall2008/paper/Discounting/Weitzman_Gamma%20Discounting_AER01.pdf