A CONCEPTUAL FRAMEWORK AND BENEFIT TRANSFER FOR VALUATION OF SELECT ECOSYSTEM GOODS AND SERVICES PROVIDED BY THE WETLANDS OF THE OKEFENOKEE NATIOINAL WILDLIFE REFUGE

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Abstract. The USFWS manages the National Wildlife Refuge System, which is the world's premier example of public lands designated for their wildlife habitat value. We examine the feasibility of estimating the economic value of ecosystem services supported by wetlands in the Okefenokee National Wildlife Refuge (NWR) in Southeast Georgia, using existing economic and ecological information. Estimates of economic values from flows of ecosystem services are intended to augment the NWR economic impact data analysis currently used and implemented by the USFWS. We specifically examine wetlands in the Okefenokee NWR and estimate gross economic values for the following subset of ecosystem services which have received a relatively strong treatment in the valuation literature: flood control, nutrient cycling, recreational fishing and hunting, wildlife observation, and commercial fishing. We use benefit transfer techniques with multiple-regression coefficients taken from two published meta-analysis studies (Brander, et al., 2006, Woodward and Wui, 2001) to predict valuation results. Due to a rejection of the hypothesis of convergent validity across primary valuation estimators in the original meta-analysis studies, we present a series of value estimates, each conditional on regression predictions for a particular primary valuation technique. Additionally, we separately predict the net present value of wetland carbon pools for the supporting ecosystem service, carbon dioxide storage. Using benefit transfer values or prices for a unit mass of stored carbon dioxide derived from carbon market prices and Nordhaus 1991, we estimate the gross welfare effects of stored carbon in wetlands of the Okefenokee NWR. Our results are presented as partial, gross economic values attributable to NWR designation. We discuss the applicability of partial as well as gross economic values.

INTRODUCTION

Our study is motivated by questions relating to the total social welfare impact of designating certain lands as public lands. For example, in order to pass a strict cost-benefit oriented policy analysis, one must show both that the gross economic value of designated lands exceeds all other feasible uses for the land, and also that the marginal value of designating an additional piece of land is not exceeded by the marginal value of converting that same piece toward a competing land use. An estimate of gross economic values for wetlands can be undertaken with resource intensive methodologies such as the Hedonic Price Method (HPM), Contingent Valuation Method (CVM), or the Travel Cost Method (TCM). Alternatively, and as employed here, a statistical study of studies referred to as a meta-analysis can provide regression coefficients which allow for economic value estimation via a multi-regression prediction.

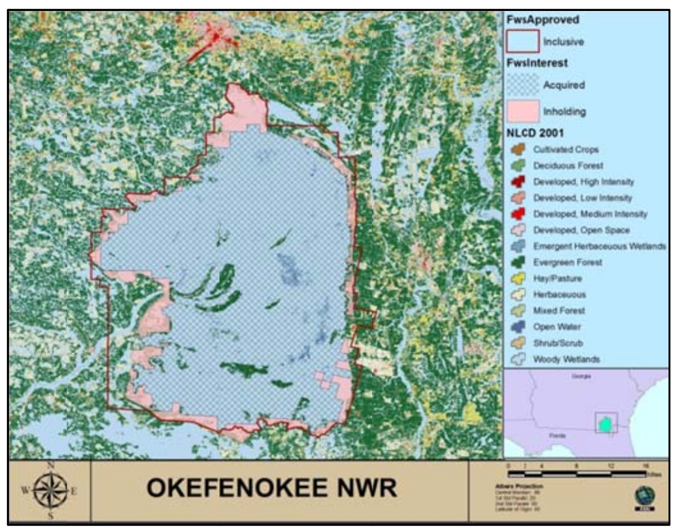

Figure 1. Okefenokee NWR by Ownership and NLCD 2001

The Okefenokee National Wildlife Refuge (NWR) occupies approximately four hundred thousand acres, mostly in Southeast Georgia. The landscape is fed by limited uplands resulting in an ombrotrophic or rainfed ecosystem, characterized by scarce nutrients, moderately high salt concentrations, and acidic water (Flebbe, 1982). Nearly 94% of the four hundred thousand acres managed by the US Fish and Wildlife Service (USFWS) are wetlands, and these wetlands are characterized by closed nutrient systems(Hopkinson, 1992) with selective pressure favoring nutrient efficient species. The town of Waycross Georgia is visible in Figure 1 to the north of the Okefenokee NWR and Jacksonville, Florida is approximately thirty-five miles southeast of the refuge.

The Okefenokee NWR currently comprises acquired lands in addition to in-holdings on the physical margin; acquired lands include the majority of wetlands in the ecosystem. Figure 1 is a National Land Cover Dataset (NLCD) 2001 map overlain with refuge boundaries from the USFWS Cadastral Geodatabase. The central area is mostly light-blue which designates woody wetlands, the overlain cross-hatch pattern indicates the land has been acquired by the USFWS. Pink overlain lands are private in-holdings for which the USFWS does not currently have an official interest.

Ecosystem service flows contribute to the welfare or well-being of everyone on earth. However, significant economic and technological barriers prevent the efficient functioning of markets for ecosystem services, and consequently too little valuable ecosystem services are provided by the market. Market failure or inefficiency leads to inadequate price and quantity data, metrics which would otherwise provide an accurate basis for estimating the welfare impact of ecosystem services. Two fundamental reasons for market failure with respect to ecosystem services are the inability of providers of ecosystem services to exclude non-payers and also, the inability of providers to extract maximum willingness to pay from those enjoying non-rival ecosystem services; both non-excludability and non-rival services are expected to lead to under-provision of ecosystem services relative to the economically efficient quantities (see Bergstrom and Randall, 2010, chapter 10).

Benefit Transfer Theory and Methods. Non-market valuation methodologies rely on information about the preferences of relevant user populations obtained from stated (e.g. CVM) or revealed preference (e.g. TCM and HPM) techniques. Significantly, both groups of methods require extensive data collection, requiring much time and money. Even well thought-out studies tend to rely on numerous assumptions, which when relaxed may lead to substantially different conclusions. In meta-analysis studies, variations in value estimates across studies are assumed to be due to variations in relevant variables such as the following: the user population, the quality and quantity of ecosystem service flows, and also the methods of estimation. Accordingly, researchers have attempted to systematically define the manner in which ecosystem service value estimates vary. The study of the systematic variation in ecosystem service value estimates across existing studies is a type of meta-analysis. When the results of the meta-analysis are used to predict the economic benefits a population derives from non-market goods and services at a new policy site, the practice is referred to as meta-analysis benefit transfer (Bergstrom and Taylor, 2006). Typical meta-analysis models use linear, multiple regression techniques, which allow a practitioner to specify parameters for each variable thought to influence the value estimates obtained from a sample of non-market valuation studies. The inclusion of variables in the model is limited by the full column rank requirements of classical linear regression models such as ordinary least squares. Careful selection of studies and thoughtful inclusions and omissions of variables can lead to convincing regression models. However unobserved heterogeneity across studies and the small samples available for meta-analysis tend to lead to results sensitive to the assumptions of the meta-analysis practitioner.

In this study, we utilize regression results from two separate meta-analysis studies (Brander, et al., 2006, Woodward and Wui, 2001) to explore the feasibility of estimating economic welfare benefits attributable to the ecosystem services arising from the natural capital and ecological processes of Okefenokee NWR wetland ecosystems according to the following equation,

$$\varepsilon_{ij} = f_i(E_j),$$
$$\text{where } E_j = r_j\,(N).$$

In the above model we assume that over a set of ecosystem services, j=1,2,…,J for consumers i=1,…,I, each consumer chooses her consumption, ε_{ij} , of ecosystem service j, from available potential ecosystem goods and services, E_j. Potential ecosystem goods and services arise from the ecosystem processes, or ecological/economic transformation function, $r_j(.)$ that has as its argument the ecosystem's natural capital. The provisioning of potential ecosystem goods and services, E_j is distinguished from actual ecosystem services, ε_{ij} , due to the defining feature of goods and services as they relate directly to human welfare or well-being.

Microeconomic theory suggests the use of a Hicksian welfare measure, such as compensating surplus, aggregated over the population of beneficiaries. Hicksian compensating surplus, in the context of ecosystem services, is a measure of an individual's willingness to pay to obtain a change in the consumption of ecosystem services such that the individual has utility equivalent to the case without payment and without enjoyment of the new quantity of ecosystem services, according to the following function,

$$U_i(\,P_q, Q^0, \ldots, \boldsymbol{\varepsilon_{ij}}^{\boldsymbol{0}}, B_i\,)$$
$$= U_i(\,P_q, Q^1, \ldots, \boldsymbol{\varepsilon_{ij}}^{\boldsymbol{1}}, B_i - WTP_{ij}\,)$$
$$= U_i^0.$$

Here the utility function contains P_q, a vector of prices in the economy, and Q_i, the utility optimizing set of market goods purchased at prices, P_q. The consumer, i, will have a positive willingness to pay for ecosystem service, j, $WTP_{ij}>0$, when the consumption of that service is such that $\boldsymbol{\varepsilon_{ij}}^{\boldsymbol{1}} > \boldsymbol{\varepsilon_{ij}}^{\boldsymbol{0}}$. The Hicksian welfare measure allows for optimizing adjustments by the consumer to market good purchases, Q, due to a change in the availability of ecosystem services. An example of an optimizing adjustment to a (substitute) market purchase due to a change in consumption of ecosystem services is as follows: a consumer may purchase fewer water filters when water quality provisioning services provide a relatively greater quantity of quality water. In addition, the Hicksian measure of compensating surplus implies that the consumer does not have a legal right to the higher level of ecosystem services, ε_{ij}^{1}. The gross economic value for the set of consumers, {1,…,I}, over the set of services, {1,…,J}, is then the aggregate or sum,

$$\Sigma_i \Sigma_j WTP_{ij} .$$

The meta-analysis benefit transfer we perform produces estimates of per acre willingness to pay (WTP) economic welfare measures aggregated across the entire user population for each particular service. While the theoretically desirable meta-analysis would produce welfare measures for individual consumers conditional on relevant characteristics of the consumer and ecosystem, the data requirements to estimate (Σ_i =I)x(Σ_j =J) non-aggregate welfare measures for each individual from the entire user population for each service creates a formidable data-gather and modeling challenge. Alternatively, with a user population's per acre willingness to pay as the dependent variable, a researcher can use meta-analysis benefit transfer techniques to estimate an out of sample user population's per acre willingness to pay for the provisioning of an ecosystem service. The meta-analysis of per acre welfare measures aggregated over a user population from existing primary valuation studies, allows for a parsimonious model, albeit with more numerous, less plausible assumptions.

We employ the results of two published wetland ecosystem service meta-analysis studies, Woodward and Wui from 2001 and Brander, Florax, and Vermaat 2006. Woodward and Wui (2001) provide clear prose and one of the earlier meta-analysis studies of wetland ecosystem service valuation studies. Brander, et al. (2006) provide a meta-analysis spanning a much larger sample of studies, while also controlling for variations in population density and local GDP; these or similar socio-economic variables are not included in Woodward and Wui (2001).

Considerable latitude in predicting value estimates is available to the meta-analysis benefit transfer practitioner due to imprecise specification of regression models in the existing meta-analysis studies. This imprecise specification is particularly difficult to avoid due to the extensive heterogeneity amongst the few available observations in the sample. In order to estimate the aggregate, partial economic value of ecosystem services supported by Okefenokee NWR wetlands, separate non-market valuation studies are simulated to estimate the economic welfare benefits of flood control, nutrient cycling, recreational fishing and hunting, wildlife observation, and commercial fishing.

The summation of predicted valuation results across J ecosystem services can produce biased results due to the possibility of path dependence in demand specification; accordingly, our results are based on the assumption of path independence(see Just, et al., 2005, pages 157-182 for more details). The estimation of partial, gross economic welfare benefits from NWR lands can lead to a downward bias if the results are interpreted as total, gross economic value estimates; however, if partial, gross economic values can be shown to exceed total, gross economic values for alternative uses of a landscape, then NWR designation is supported by the cost/benefit criterion.

Benefit Transfer Results and Discussion. In addition to estimating the aggregate, gross economic values of select ecosystem service flows supported by Okefenokee NWR wetlands, we predict the gross welfare effect from J=5 ecosystem services of acquiring additional lands and incorporating them into the refuge. Our results indicate substantial benefits might be estimated if measured by a primary non-market valuation study using the method as designated by the coding of the independent variables representing primary study technique. We refer to our regression predictions with respect to the coding of the primary valuation methodology, and we further qualify our results as being from hypothetical primary valuation studies due to the non-equivalence of valuation methodology parameters (e.g HPM, TCM, CVM) in the original meta-analysis studies. The hypothesis of convergent validity essentially supposes that valuation methodologies will return convergent results when estimated with correct procedures and with sufficiently rich data (Champ, et al., 2003, Ch. 14). The inequality of parameter estimates in both meta-analysis studies used herein can be interpreted as a rejection of the convergent validity hypothesis. Thus we advise caution in using our benefit transfer results as economic value estimates, and we recommend using the lower values as "conservative estimates" of the economic value of Okefenokee NWR ecosystem services.

Table 1. Acquired Acreage Predicted Average Values (2010 $/acre/year), Coefficients from Brander, et al. 2006.

Valuation Method	Flood Control	Nutrient Cycling	Recreational Fishing and Hunting	Wildlife Observation	Commercial Fishing
CVM	$7,342	$11,985	$2,256	$6,778	$6,194
TCM	$1,671	$2,728	$514	$1,543	$1,410
HPM	$814	$1,328	$250	$751	$686
Market Prices	$1,590	$2,595	$489	$1,468	$1,341

Table 1 contains predictions of average gross economic values in 2010 dollars per acre per year from our meta-analysis regression predictions. Table 1 is organized so that one sees, when moving up and down, the method coded for the primary valuation technique, and when moving left to right the ecosystem service in question.

The classical linear meta-analysis regression model does not allow for direct incorporation of information about prior expectations regarding ecosystem service values into the process of estimation. Accordingly, we have reported the results of our meta-analysis regression prediction for commercial fishing in the Okefenokee NWR, but we expect the economic value of the refuge towards the commercial fishing industry to be quite low. The refuge, however, may contribute indirectly towards the health of downstream ecosystems through services such as nutrient cycling.

In Figure 2, below, one can see the variation in value estimates from Table 1 compared by the valuation methodology selected in our regression prediction. The choice of valuation methodology clearly has a large impact on the magnitude of the estimated economic welfare effect.

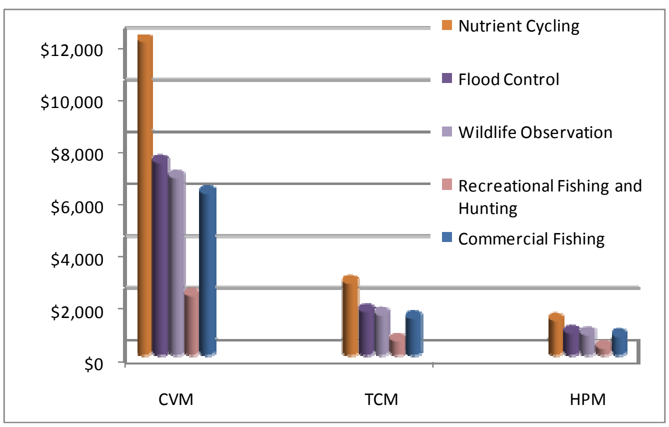

Figure 2. Variation in Values from Table 1 by Primary Valuation Method and Ecosystem Service.

The predictions obtained from the published meta-analysis studies used in this study are prone to numerous sources of bias, and gross, partial economic values are less useful for many policy questions than net, total economic values, consequently the applicability of our results to social welfare comparisons and decisions is limited. The general nature of the regression results obtained from the meta-analysis studies employed here allow for little information about the particulars (i.e. natural capital and ecosystem processes) of the ecosystem to inform the results. The Okefenokee NWR and relevant user population have many qualities distinguishing the value of ecosystem service flows from other freshwater, temperate wetlands. Accordingly, and echoing Woodward and Wui (2001), our confidence in the results obtained in this paper suggest that the predicted values are appropriate replacements for qualitative (e.g. ordinal) descriptions of value, but the cardinal use of our predictions in benefit analyses should proceed with caution and a conservative approach.

Below, in Table 2, we present economic value estimates from each study for each ecosystem service for acquired refuge lands. These values are partial, gross economic values for the average acre of land in 2010 US dollars. We choose a single primary valuation technique from each meta-analysis in a rather ad-hoc manner, such that predicted values conform to our vague prior expectations for the results. Below, (MP) denotes market prices and (NFI) denotes net factor income. Table 3 contains the results from Table 2, but aggregated across the approximately four hundred thousand acres of acquired NWR wetlands. In both tables we also provide averages from the two meta-analysis studies used for prediction.

Table 2. Select Predicted and Averaged Ecosystem Service Values, per Acre per Year.

Predicted Gross, Partial Economic Values for Wetlands in the Okefenokee NWR						
Ecosystem Service	Flood Control and Storm Buffering	Nutrient Cycling	Recreational Fishing and Hunting	Wildlife Observation	Commercial Fishing	
	Brander et al. 2006					
Primay Valuation Methodology	(HPM)	(HPM)	(TCM)	(TCM)	(MP)	sum
Predicted Service Value	$1,171	$1,912	$740	$2,222	$1,931	$7,976
	Woodward and Wui 2001					
Primay Valuation Methodology	(CVM)	(CVM)	(TCM)	(TCM)	(NFI)	sum
Predicted Service Value	$489	$519	$155	$1,509	$968	$3,639
Average Service Value	$830	$1,216	$447	$1,865	$1,450	$5,808
						2010 US Dollars per acre per year

Table 3. Selected Predicted Ecosystem Service Values Aggregated Across Okefenokee NWR USFWS Acquired Wetlands.

Predicted Gross, Partial Economic Values for Wetlands in the Okefenokee NWR						
Ecosystem Service	Flood Control and Storm Buffering	Nutrient Cycling	Recreational Fishing and Hunting	Wildlife Observation	Commercial Fishing	
	Brander, et al. 2006					
Primay Valuation Methodology	(HPM)	(HPM)	(TCM)	(TCM)	(MP)	sum
Predicted Service Value	$438,070,904	$715,070,242	$276,546,997	$830,793,094	$722,256,818	$2,982,738,055
	Woodward and Wui 2001					
Primay Valuation Methodology	(CVM)	(CVM)	(TCM)	(TCM)	(NFI)	sum
Predicted Service Value	$182,961,269	$194,080,784	$57,874,362	$564,124,224	$361,866,183	$1,360,906,821
Average Service Value	$310,516,086	$454,575,513	$167,210,680	$697,458,659	$542,061,500	$2,171,822,438
						2010 US Dollars per year

The ad-hoc selection method used to determine the primary valuation technique results from meta-analysis models which do not offer clear guidance for estimating a single number for each ecosystem service (although as mentioned above, to be conservative we recommend using lower estimates in benefit-cost analysis). The inclusion of information regarding our prior expectations can be formally included in the model using Bayesian econometric techniques, such as can be seen in Moeltner and Woodward's (2008) recent meta-analysis.

Okefenokee Carbon Sequestration Method. We estimate the gross economic value of carbon dioxide sequestration attributable to the wetlands of the Okefenokee NWR through a price times quantity approach. Although carbon dioxide sequestration is a supporting service(see Brown, et al., 2007, for a taxonomy of services) to the more relevant measure of the contribution to the endpoint service, averted climate change, we quantify the value of carbon dioxide sequestration due to the presence of markets and the extensive literature on carbon dioxide related welfare effects. The aggregate quantity of stored elemental carbon can be converted into its carbon dioxide equivalent, and then multiplied by the average price of a unit of carbon dioxide to obtain an economic value of the aggregate carbon store.

Carbon Sequestration Results and Discussion. The first step in our valuation methodology is to quantify the existing stores (stock) of organic carbon within the boundaries of the Okefenokee NWR. We follow accounting guidelines derived from those of the IPCC 2006 to estimate the quantity of carbon stored within wetlands of the Okefenokee NWR. We obtain above ground living and dead biomass data from Schlesinger(1978) and Greening and Gerritson(1987). Below ground living biomass calculations are assumed to be a quarter of above ground living biomass, loosely following methods advised in the Georgia Carbon Sequestration Registry (Siry, et al., 2006). Below ground biomass data and carbon content data as well as invaluable background information are obtained from Cohen et al. (1984). Table 4 contains our estimates of elemental carbon storage in the wetlands of the Okefenokee NWR.

Table 4. Elemental Carbon Storage in the Okefenokee National Wildlife Refuge.

	above ground		below ground	
	living	dead	living	dead
inholding	20,024	2,253	5,006	16,581
acquired	204,635	23,031	51,159	171,733
approved	235,193	26,470	58,798	197,165
	x100 MT Carbon			

Our estimates, derived from rather dated data, avoid the temporal variability of carbon storage in the wetland ecosystem. We expect that the dramatic role of fire in the landscape has changed the mosaic of land covers since these early studies; however, the assumption of a relatively constant distribution of land cover and vegetation maturity is sufficient to justify reporting constant values. Alternatively, the numbers below might be conceived as a multi-decadal average. Future research is needed to understand the relationship between the fire dynamic of the Okefenokee NWR and the temporal variation in ecosystem service flows (see Hamilton, 1984, for more information on the role of distrubance in the Okefenokee NWR).

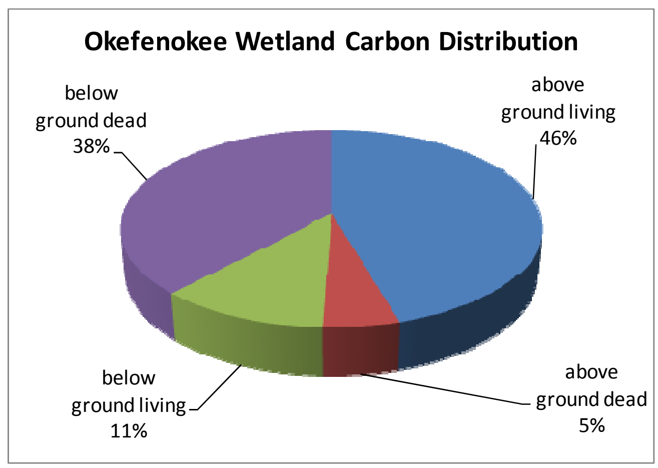

Figure 3. Okefenokee Wetland Carbon Distribution, Approved Acquisition

As can be seen in Figure 3, belowground dead biomass (i.e. peat) and above ground living biomass constitute the bulk of carbon stored in the ecosystem. Our estimate of below ground dead biomass in wetlands of the Okefenokee NWR is prone to under-estimation, as the distribution of peat was assumed uniform across all acres of Okefenokee wetlands. We expect that uplands have little to no peat deposits. On the other hand, we expect that our estimate of aboveground living biomass is biased upwards. Biomass data in Schlesinger (1978) for bog ecosystems are based on a dense cypress stand, while

NLCD 2001 identification of woody wetlands likely includes many stands of lower densities.

For the price component of the welfare estimate, we consider maximum, minimum, and average Chicago Climate Exchange (CCX) Carbon Financial Instrument (CFI) prices. We also examine the price of $20 per metric ton of carbon dioxide, in order to provide a comparison with some of the larger numbers in the literature such as can be found in Nordhaus (1991, Table 3).

Table 5. Gross Economic Value of Carbon Dioxide Storage, Net Present Value

	low ccx	high ccx	average ccx	$20/MT
100 Mt CO2	0.05	7.40	2.04	2000
inholding (marginal)	$ 8,036	$ 1,189,321	$ 328,535	$ 321,438,122
acquired	$ 82,542	$12,216,222	$3,374,581	$ 3,301,681,752
approved	$ 94,829	$14,034,693	$3,876,911	$ 3,793,160,152
	U.S. Dollars, no inflation adjustment			

Above, Table 5 contains our estimates of the economic value of carbon stored in the wetlands of the Okefenokee NWR, evaluated at a range of possible prices to reflect the uncertainty of the magnitude and distribution with respect to time and across populations of damages and costs of avoiding climate change. We report marginal values for the gross economic value of adding all current designated in-holdings to the acquired NWR lands. The values for the row, ‘acquired’, represent lands currently owned, while values in the row, ‘approved’, are for all lands in the most inclusive boundary for private and public lands in the Okefenokee NWR ecosystem.

The use of a price in estimation of a welfare effect requires numerous assumptions regarding the efficiency and mechanism of the market generating the price, and the CCX does not meet the strict requirements for a well-performing market. Currently the CCX has halted trading of the CFI due to poor market performance, generally attributed to uncertainties about the future value of carbon and the unwillingness of politicians to create binding policies for carbon emissions. Thus, perhaps seemingly contradictory to the “conservative approach” mentioned above, we recommend the high CCX price as a “lower bound” estimate of the value of Okefenokee NWR carbon sequestration since the low CCX price of $0.05 represents a collapsed (i.e. non-functioning) market price.

Our estimates of the economic value of carbon storage in the wetlands of the Okefenokee NWR are gross economic values. To answer questions of the marginal value of ecosystem services due to NWR designation, the gross economic value of the highest feasible non-NWR land use must be netted out. The expected fate of the Okefenokee NWR if it were auctioned off in a private market, and the economic value of ecosystem services resulting from subsequent private management (most likely for commercial timber production and commercial recreation and tourism) would serve as a useful point of comparison to evaluate the net, partial economic welfare contribution of NWR designation.

Conclusions. Our estimates of Okefenokee NWR ecosystem service values can be best viewed as a likely range for the “true values” of ecosystem services supported by refuge wetlands. We have avoided selecting a single number for any of the services we have considered in part, because of uncertainty with respect to primary valuation method or the price of carbon. However, numerous other sources of variation in ecosystem service values are expected, including seasonal variation and variation due to climate change. Future research is needed to address the limitations of a classical regression model when using small samples. Future research is also needed to model time dependent changes in ecosystem service values.

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