Valuing the Wetlands Ecosystem Services Using Meta-Regression: Applications to BIL Grant -Funded Projects

George Gardner, PhD
Economist
NOAA-OCFO-PRSSO
george.gardner@noaa.gov

Project Summary

- The Bipartisan Infrastructure Law (BIL) provided historic investments–about $3 billion–for NOAA to take action in the areas of coastal resilience and conservation, improved climate service delivery, and fisheries management.
- PRSSO assessed the value of potential ecosystem service benefits from 93 BIL-grant funded projects ($417 million in federal funding).
  - From habitats including wetlands, lakes/ponds, forests, and floodplains, among others.
- This project focused on assessing the value of BIL-grant funded wetland restoration, preservation, and creation projects.

Example BIL-Grant Funded Wetland Projects

Program:	National Estuarine Research Reserves Habitat Protection and Restoration
Award Title:	Jug Bay Wetlands Sanctuary Stream and Shoreline Restoration, Phase I
Recipient:	Maryland Department of Natural Resources
Federal Funding:	$1.0 million
Description:	This award will result in the creation of a freshwater tidal marsh living shoreline through the restoration of three headwater streams and implementation of upland stormwater best management practices in the Jug Bay Wetlands Sanctuary. These efforts will enhance the tidal marsh's resilience to sea level rise, significantly reduce sediment and nutrient pollution flow to the Chesapeake Bay, and increase resilience to increased rainfall events.

Program:	Coastal Habitat Restoration and Resilience Grants for Underserved Communities
Award Title:	Restoring Resilience Through Central Wetlands Reforestation Collective
Recipient:	Coalition to Restore Coastal Louisiana
Federal Funding:	$720,000
Description:	The Coalition to Restore Coastal Louisiana will restore habitat in the Central Wetlands Unit, a nearly 30,000-acre marsh bordering communities in the Ninth Ward of Orleans Parish and St. Bernard Parish. The awardee will engage local community members in the project to provide the next generation with skills and hands-on experience related to coastal restoration.

Methodology: Overview

- Given the significant resources and time required to collect data at multiple worksite locations for primary valuation methods, this project utilized a meta-regression model (MRM) and benefit transfer approach (BT).
- MRM: in this context, a 52-observation regression model whose specification is informed from 24 wetland valuation stated preference studies is used. Willingness-to-pay for wetlands are a function of wetland acres, wetland type (forested or non-forested, saltwater or freshwater), and (provisioning, regulating, and cultural) ecosystem services.
- BT: WTP values from studies found in one location are transferred to another (i.e., policy site). The MRM is used to further adjust WTP values based on characteristics of the policy site.

Methodology: the Meta -regression Model

- The MRM was originally developed in Moeltner et al (2019) and was later enhanced (with the addition of new wetland metadata) in EPA's Economic Analysis for the Final "Revised Definition of 'Waters of the United States'" Rule (2022).
  - The EPA had used the MRM to estimate potential wetland ecosystem service benefits from freshwater wetlands–benefits from reduced wetland losses that would result from a redefining of WOTUS (using waters defined by the 1986 regulations relative to waters defined under the 2020 Navigable Waters Protection Rule) and a change in mitigation requirements for discharges of dredged or fill material.
- In contrast, for this project, the model is applied to both freshwater and saltwater wetlands.

Methodology: the Meta -regression Model

Bayesian estimation techniques are used to generate the model:

$$\ln(y_{js}) - \ln(q_{1,js} - q_{0,js}) = x'\beta + \gamma \frac{(q_{1,js} + q_{0,js})}{2} + \epsilon_s$$

- Uses Bayesian updating to estimate model coefficients and the error term.
  - Updating occurs following a Gibbs Sampling MCMC procedure with vague priors.
  - Initial estimates are taken from an OLS model which are then updated to generate 100,000 samples.
- In short, the approach generates 100,000 models and an entire distribution of coefficients and error terms.

MRM Variable Definitions

Variable Name	Description
ln(year)	natural log of year of data collection
ln(inc)	natural log of income, 2024$
sagulf	1 = South-Atlantic/Gulf (AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA)
nema	1 = Northeast/mid-Atlantic (CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT)
nmw	1 = North/Mid-West (AK, IA, IL, IN, KS, MI, MN, MO, MT, NE, ND, OH, SD, WI)
can	1 = Canadian study, 0 = otherwise
local	1 = wetland is within 30 miles, on average, of counties in the State, 0 = otherwise
prov	1 = provisioning function affected, 0 = otherwise
reg	1 = regulating function affected, 0 = otherwise
cult	1 = cultural function affected, 0 = otherwise
forest	1 = forested wetland, 0 = non-forested
q_0	baseline wetland acreage
q_1	policy wetland acreage
$(q_0 + q_1)/2$	the midpoint between baseline and policy acres
volunt	1 = payment is a voluntary contribution, 0 = otherwise
lumpsum	1 = single payment, 0 = annual payment
salt	1 = saltwater wetland, 0 = freshwater wetland

MRM Results

- Ecosystem services matter: (freshwater) wetlands that provide regulating and cultural services are valued more.
- Wetland type matters: wetlands that are forested are valued more; ecosystem services provided by saltwater wetlands are valued more.
- Baseline wetlands matter: wetlands preserved in areas with larger amounts of baseline wetlands are worth less.
- Local vs. non-local wetlands matter: wetlands that are local are worth more.
- Location matters: (freshwater) wetlands in the South-Atlantic/Gulf are worth more.

Meta-regression Model Results

variables	post. mean	post. std	p(>0)
Constant	-0.441	3.040	0.444
ln(year)	-1.261	0.398	0.002
ln(inc)	0.216	0.289	0.771
sagulf	1.998	1.378	0.925
nema	-1.617	1.157	0.079
nmw	1.177	1.078	0.861
CAN	3.078	1.638	0.966
local	3.184	0.576	1.000
prov	-3.458	0.694	0.000
reg	0.346	0.596	0.716
cult	1.211	0.733	0.947
forest	2.052	0.577	0.999
(q0+q1)/2	-0.001	0.001	0.090
volunt	-2.095	0.828	0.009
lumpsum	2.234	0.563	1.000
const*salt	-0.430	2.056	0.433
ln(year)*salt	-0.095	0.767	0.425
ln(inc)*salt	-0.120	0.302	0.340
sagulf*salt	-2.122	1.762	0.141
local*salt	0.342	0.699	0.657
prov*salt	4.954	0.926	1.000
reg*salt	6.412	1.154	1.000
cult*salt	2.459	2.356	0.837
(q0+q1)/2*salt	-0.001	0.001	0.145
σ^2	0.767	0.232	1

Primary Data Sources

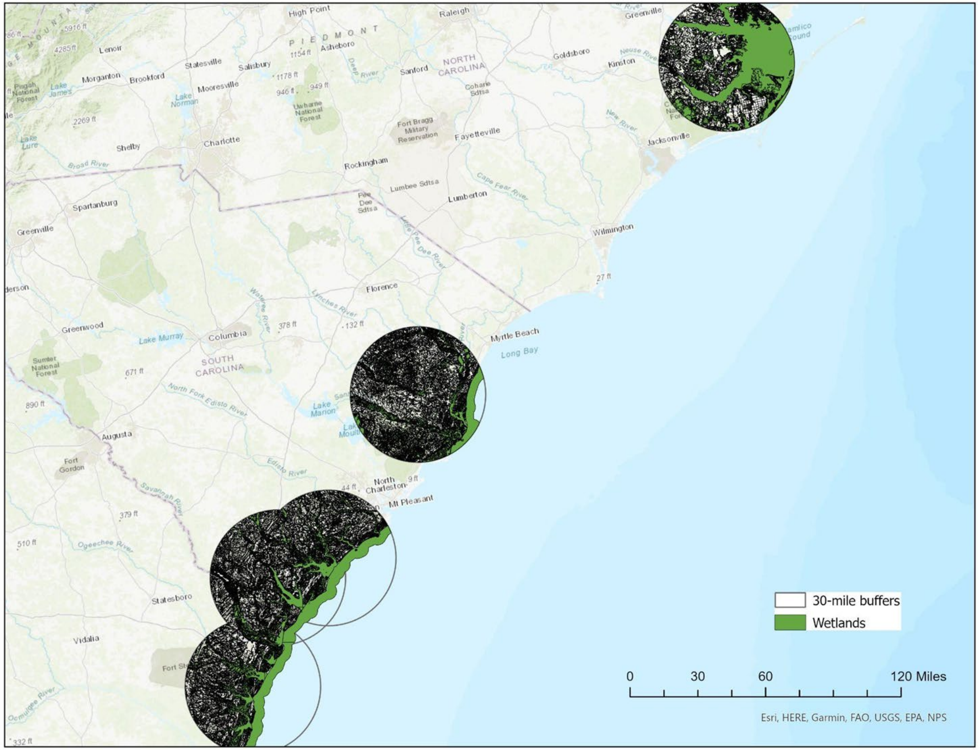
- GrantsOnline [replaced by GEMS]: contains applications, project narrative documentation, budget information, and supplementary materials (maps, resumes, letters of approval, etc.) from grant applicants.
- US Census' American Community Survey 2022 (5-year): used to obtain data on income and the persons per household at the county level.
- USFWS National Wetland Inventory: used to obtain baseline data on the number of wetland acres in the vicinity of the project worksite(s).
- NASA SEDAC: County level population projections until the year 2100. Combined with Census data on persons per household to obtain county level household projections.

Generating Baseline Wetlands

- NWI wetlands classified by Cowardin category were placed into simplified forested/non-forested, saltwater/freshwater categories required for the MRM.
- Acreage was estimated using a 30-mile buffer from project worksite locations.

NWI Wetland Classification to Simplified Wetland Classification for MRM			
Type		**Classification**	**Codes**
Freshwater	Forested	-Palustrine, forested	PFO
Freshwater	Non-forested	-Palustrine (class = all except forested) -Lacustrine (class = all) -Riverine (class = all)	PUB, PAB, PSS, PEM, PRB, PUS, PML L R
Saltwater	Forested	-Estuarine, forested	E2FO
Saltwater	Non-forested	-Estuarine (class = all except forested) -Marine (class = all)	E1, E2 M1, M2

Generating Baseline Wetlands



A visual illustration of the approach using a sample of project work sites.

BIL Wetland Project Locations

Figure 1: Map of Wetland Project Work Sites

Benefit Transfer Steps

1. Apply parameter settings to each of the 100,000 MRMs estimated by the Gibbs Sampler to generate HH WTP estimates.
2. Take an "ecosystem service combination" weighted average of HH WTP using the ecosystem service probabilities generated from the metadata.
3. Truncate WTP results at the 95th percentile.
4. Compile summary statistics of HH WTP (mean, median, min, max, 5%, 95%).
5. Aggregate HH WTP across households at the county-level.
6. Estimate TPV and annualized benefits.
   a. Period of analysis = 2024 to 2043 (20-year period).
   b. Discount rate = 3.1% (following Circular A-94).
   c. Benefits begin after a 1-year delay from project end date.

Benefit Transfer Settings

- A ‘mixing’ procedure is used whereby benefits are generated over 8 possible combinations of ecosystem services. A weighted average of benefits is then estimated based on the proportions of ecosystem services that appear in the metadata.

Variables	Setting for Benefit Transfer	Source (if applicable)
constant	1	
ln(year)	ln(2021-1988) = 3.4965	
ln(inc)	ln(median income)	U.S. Census 5-year ACS 2022
sagulf	1 = South-Atlantic/Gulf (AL, AR, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA)	BIL Application Review Reports
nema	1 = NE/mid-Atlantic (CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT)	BIL Application Review Reports
nmw	1 = North/Mid-West (AK, IA, IL, IN, KS, MI, MN, MO, MT, NE, ND, OH, SD, WI)	BIL Application Review Reports
CAN	0	
local	1	
prov	various (used in mixing procedure)	
reg	various (used in mixing procedure)	
cult	various (used in mixing procedure)	
forest	project-specific	BIL Application Review Reports
(q0+q1)/2	project-specific	BIL Application Review Reports; USFWS National Wetland Inventory
volunt	0	
lumpsum	0	
const*salt	project-specific	BIL Application Review Reports
ln(year)*salt	project-specific	
ln(inc)*salt	project-specific	
sagulf*salt	project-specific	
local*salt	project-specific	
prov*salt	various (used in mixing procedure)	
reg*salt	various (used in mixing procedure)	
cult*salt	various (used in mixing procedure)	
(q0+q1)/2*salt	project-specific	

Benefit Transfer Mixing Procedure

- A Bayesian mixing procedure allows WTP to be averaged over all potential combinations of ecosystem services.

Probabilities for Provisioning, Regulating, and Cultural Ecosystem Services		
	Freshwater	Saltwater
p(prov=1)	0.40	0.25
p(reg=1)	0.73	0.31
p(cult=1)	0.67	0.29
Probabilities shown above are based on sample proportions in the metadata. Ecosystem services are not mutually exclusive so do not sum to 1.		
Probabilities for Combinations of Provisioning, Regulating, and Cultural Ecosystem Services		
	Freshwater	Saltwater
p(prov=0, reg=0, cult=0)	0.05	0.37
p(prov=1, reg=1, cult=0)	0.11	0.15
p(prov=0, reg=1, cult=0)	0.14	0.16
p(prov=0, reg=1, cult=1)	0.29	0.07
p(prov=1, reg=0, cult=0)	0.04	0.12
p(prov=1, reg=0, cult=1)	0.07	0.05
p(prov=1, reg=1, cult=0)	0.10	0.05
p(prov=1, reg=1, cult=1)	0.20	0.02
Total	**1.00**	**1.00**

Benefit Transfer HH WTP per Acre Estimates

Ecosystem Service-Weighted WTP per Acre (2024$) Summarized at the Project Work Site Level										
County FIPS	County	Mean WTP/Acre	Median WTP/Acre	Std WTP/Acre	Saltwater	Forested	q1-q0	q0 (1,000s)	Income (1,000s)	Region
01003	Baldwin	$3.53	$1.17	$5.53	1	0	3.0	443.5	$76.3	sagulf
01003	Baldwin	$3.55	$1.17	$5.58	1	0	1.0	439.8	$76.3	sagulf
01003	Baldwin	$3.89	$1.33	$5.99	1	0	9.7	376.9	$76.3	sagulf
01003	Baldwin	$0.38	$0.29	$0.30	0	1	40.0	166.8	$76.3	sagulf
01097	Mobile	$2.35	$0.63	$4.03	1	0	22.8	744.1	$59.4	sagulf
01097	Mobile	$2.36	$0.63	$4.05	1	0	100.0	740.0	$59.4	sagulf
02122	Kenai Peninsula	$8.43	$6.06	$7.28	1	0	20.0	301.9	$81.9	nmw
06023	Humboldt	$0.08	$0.05	$0.09	0	1	15.7	2.3	$62.1	

Aggregate Benefit Estimates by Census Region

Total Present Value (TPV) and Annualized Benefits by Region using a 3.1% Discount Rate (in million 2024$)								
Region	Projects	Worksites	Acres	Households[a]	TPV (Low)	TPV (High)	Annualized Benefits (Low)	Annualized Benefits (High)
Alaska	1	1	20	25,453	$35.10	$48.81	$2.31	$3.21
Midwest	5	10	973	977,989	$20.12	$25.87	$1.32	$1.70
Northeast	6	8	1,008	991,174	$208.46	$249.06	$13.72	$16.39
South	18	28	1,957	3,331,811	$2,002.24	$5,740.90	$131.75	$377.88
West[b]	16	33	2,120	1,425,245	$2,517.11	$3,646.84	$165.62	$240.47
Total	**46**	**80**	**6,078**	**6,751,672**	**$4,783.04**	**$9,711.48**	**$314.72**	**$639.66**

[a]The total number of households across all counties within a region where project activities take place.

[b]The U.S. Census region 'West' was adjusted to exclude Alaska and Hawaii which are treated as their own distinct regions for the purposes of this analysis.

Limitations and Uncertainties

- Largely excludes benefits from carbon sequestration and climate change mitigation.
- Quality of data on predicted ecosystem services from application review reports varies significantly (i.e., from qualitative descriptions to site-specific pre-restoration monitoring).
- Predictions of WTP for saltwater wetlands are based on only 8 studies in the metadata leading to a great deal of uncertainty in benefit transfer results.
- Excludes aggregate benefits for projects in PR, AS due to a lack of information on income, household size, and population projections.

Future Work

- Include additional stated preference wetland valuation studies (especially for saltwater wetlands)
- Use a locally-weighted MRM approach to generate tighter WTP estimates, following Moeltner et al (2023).

Thank You!

The full report is now publicly available and can be found in the link below:
Investing in America: The Estimated Socioeconomic Impacts and Ecosystem Services Benefits of NOAA Coastal Management and Habitat Restoration Investments