Final Report for RAE Baseline Assessment Project

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I. Introduction

The EPA develops an annual Inventory of U.S. Greenhouse Gas Emissions and Sinks that tracks total U.S. emissions and removals by sector, source-sink category, and greenhouse gas. The inventory process follows IPCC Guidance and UNFCCC reporting requirements. In an effort to incorporate the IPCC Wetlands Guidance into the U.S. GHG Inventory, NOAA funded a baseline assessment of U. S. coastal carbon resources, that was incorporated into the 2016 submission of the U.S. National GHG inventory (NGGI). The goal this project was to anticipate the need for improved data management for future revisions of the NGGI, and specifically to convert the spreadsheet data used for the 2016 NGGI to a format that is more sustainable for data entry, flexible for data analysis, and less error prone.

In an earlier project, we converted the original spreadsheet data used for the 2016 NGGI into flat files, and wrote computer code that reproduced the original calculations. In the process, we uncovered a variety of errors and identified opportunities to improve data quality. This led to the present project, and the following specific tasks:

* Examine the individual publications that were used for the 2016 NGGI to verify the accuracy of the data that were extracted, and document assumptions that were made in extracting data.

* Correct known and newly identified errors in the data, and implement a list of changes to the procedures for aggregating data and calculating pools and fluxes. These changes were made to the flat files (i.e. Excel spreadsheets) and QA/QC computer codes.

* Post the data, codes and summary tables online. This included: (i) PDFs of published papers, extracted data, and notes on data extraction and assumptions, (ii) statistical summaries of the data by categories (e.g. means and standard deviations of *temperate marsh biomass*), and (iii) highly aggregated summaries as reported to the IPCC.

II. Accomplishments

Here we list the steps taken to review and update the data used for the 2016 NGGI.

Criteria for Extracting Data From Literature

The first step was develop criteria that to consistently applied to our review of the literature. We began with 135 individual datasets and, after applying the six criteria listed below, ended with 105 datasets. The criteria and procedures we used were:

<u>Criterion 1</u>: The library will only include data that is in a citable public repository, which includes both publications and public data libraries. Only primary literature is used, not review papers unless they contain original data. This criterion excluded a small number of data points that were used in the 2016 NGGI. However, a number of new papers were added to the dataset as well.

Criterion 2: The data library captured data at a resolution appropriate for NGGI goals, and is not meant to be a repository of all data points reported in a publication. Authors typically sample in a design that includes strata such as plant community composition or elevation, and replication within strata. As such, publications report both averages within strata, and averages across strata. We used the means of the strata identified by the authors as reported in the publication. In some cases we extracted data from a publication (i.e. the authors did not report averages for a stratum), we calculated the average only if there were clear criteria in the metadata for linking each data point to the appropriate stratum.

Criterion 3: Perhaps the biggest risk of using large spreadsheets for the NGGI is the likelihood of introducing errors when converting from one unit to another. As such, data were translated from the publication to the flat file in their native units to minimize transcription errors, and unit conversions were then calculated by code.

Criterion 4: Soil and biomass stock data are rarely reported in a form appropriate for the NGGI, and converting the data for our purposes requires complex code and data structures. In order to minimize the amount of information stored in the flat file for each publication, calculations of stocks were performed in a separate spreadsheet and document in the "read me" file. Any further extrapolations or manipulations of these data (e.g. to estimate soil carbon from organic matter) will be done separately by code.

Criterion 5. Scrub-shrub communities were classified using dimension data when such data are available. We used the forest service definition for the division between trees and lower stature woody plants used in the US carbon accounting system. For now we are assuming that trees are >4.6 m in height and 7.6 cm for DBH.

Criterion 6. All sites were in the United States.

Steps to Assure Data Quality

1. Data Traced to Original Sources. Dr. Meng Lu revisited each publication that met our criteria and attempted to locate the data that had been used for the original 2016 NGGI spreadsheet. He documented the source of the data in a document (stored in a separate folder for each publication) that included an image of the table, figure, or text. The images were annotated to indicate precisely where the data was taken. This step allows future researchers to quickly verify the figures used in the NGGI.

2. Re-Extraction of Graphical Data. In cases where the data appeared in a figures, Meng Lu used an objective and accurate program to extract data from the figure. This improved on the visual method used previously.

3. Consultation with Dr. Bernal. Dr. Bernal produced the version of the spreadsheet used in the 2016 NGGI. Dr. Lu communicated with Dr. Bernal to resolve errors or inconsistences discovered in the review process. Their exchanges and the outcome are documented in the '4-Data Analysis' folder. This folder contains a word file "Notes on Errors, Deliberations, and Solutions"

with all the questions posed by Meng, responses from Blanca, and the decision we made based on the communications. (Note that the publication ID in this file does not match the publication IDs used in the previous contract because we renumbered the publications when the total was reduced from 135 to 105 in the first step.

Changes in Calculations Since 2016 NGGI

In addition to correcting errors in the data assurance step (above), we implemented changes in some of the calculations used to summarize the data in individual publications, and also the full master dataset. These are listed below.

1. Soil stocks are now calculated to the depth sampled and reported, and not extrapolated to a greater depth (i.e. 1 meter in the 2016 NGGI).

2. All sites that fall into a reporting category (e.g. temperate marsh) were averaged. This is a change from the 2016 NGGI in which sites falling within 0.1 degree latitude/longitude were averaged.

3. We will calculated means and confidence intervals from Log10-transformed data (i.e. we used geometric means). This transformation was done because the data distributions were often skewed. The 2016 NGGI also used geomeans, but by a different method. In the 2016 NGGI, the individual data points were Log_{10} transformed; the transformed data averaged; and geomean was then calculated from the exponentials of averaged Log_{10}.

Example of Calculations of Soil C Stock Geomeans:

logSOC=log_{10}(SOC), where SOC was the original soil C stock in the unit of Mg C ha^{-1}

MeanlogSOC=mean($logSOC_1$, $logSOC_2$, $logSOC_3$…), to calculate the mean value of Log_{10} transformed data

GeomeanSOC=10^(MeanlogSOC), to calculate the geomean of SOC

Example of Calculations of Soil C Stock Geomean Confidence Intervals:

95%CIMeanlogSOC=SeMeanlogSOC ×1.96; where SeMeanlogSOC is the standard error of MeanlogSOC

Lower 95%CI GeomeanSOC =10^(MeanlogSOC – 95%CIMeanlogSOC)

Upper 95%CI GeomeanSOC =10^(MeanlogSOC + 95%CIMeanlogSOC)

4. We used an equation developed by James Holmquist (in review) from his large soil profile database for converting from organic matter (OM) to carbon (C). It is similar to the commonly used equation from Chris Craft and is quite defensible based on sample size, but differs from the 2016 NGGI approach of assuming that organic matter is 50% carbon. The conversion equation was:

$$SoilCC=0.074*(OM/100)*(OM/100) + 0.421*(OM/100) - 0.0080$$, where

SoilCC = C concentration in units of grams C per grams soil

OM = organic matter concentration in units of grams OM per grams soil

Public Posting of Data

The results of this exercise were posted on a Smithsonian Institution Github site set to public access. The Github site has the following folders:

1-Publication Library: All the included and exclude PDFs during our 3rd data compilation
2-NGGI Data Sets: PDF, data extraction and entry sheet for each publication
3-Assembled Dataset: Merged data set from 105 individual data set
4-Data Analysis: SAS code and output of Geomean calculation
5-Final Report: This report

Summary

The credibility of the NGGI process depends on our ability to transparently document the data sources, quality control processes, and decisions made to include or exclude data. This project successfully advance the NGGI process for coastal wetlands by revisiting all of the literature in the 2016 NGGi, verifying the data extracted, documenting the data sources in detail, and using relatively error-free code to analyze the data. We provide documentation of errors uncovered in the process, and decisions we made about data analysis that collectively increased the rigor of the updated coastal wetlands NGGI.

The consequences of the changes made to the database are summarized in Table 8. In general, the changes in the mean stocks and fluxes (and the confidence intervals) were small. In most cases the 2017 update values decreased the estimates by <25% of the 2016 NGGI value. The only exceptions were in warm temperate palustrine emergent wetlands where the 2017 value increased by 11%, and the subtropical palustrine emergent wetlands where the value increased by 56%.

Our recommendations are: (1) encourage research on carbon stocks and fluxes in palustrine and scrub/shrub wetlands, (2) adopt a standard for classifying sites are forest or scrub/shrub, and (3) perform an uncertainty analysis to determine whether the current classification of coastal wetlands into ecosystem types and climate zones is warranted by the data.

Table 1. Summary of revised coastal wetlands NGGI calculations for **aboveground biomass**. The 95% confidence intervals (CI) are of the geomeans. Units are Mg ha^{-1} biomass. nd: no data. The grey shaded area is a new category that was included here to illustrate data gaps.

Ecosystem	**Climate Zone**	**Geomean**	**Lower 95% CI**	**Upper 95% CI**	**N**
Palustrine Scrub/Shrub Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Palustrine Emergent Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	7.49	4.60	12.18	11
	Subtropical	13.00	12.61	13.40	2
	Mediterranean	nd	nd	nd	0
Estuarine Forested Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	40.44	24.75	66.07	25
	Mediterranean	nd	nd	nd	0
Estuarine Scrub/Shrub Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Estuarine Emergent Wetland	Cold Temperate	4.29	3.02	6.11	4
	Warm Temperate	8.70	5.69	13.31	19
	Subtropical	24.40	15.10	39.43	10
	Mediterranean	6.20	nd	nd	1
Palustrine Forested Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0

Table 2. Summary of revised coastal wetlands NGGI calculations for **aboveground biomass sequestration rate**. The 95% confidence intervals (CI) are of the geomeans. Units are Mg $ha^{-1}yr^{-1}$ biomass. nd: no data. The grey shaded area is a new category that was included here to illustrate data gaps.

Ecosystem	Climate Zone	Geomean	Lower 95% CI	Upper 95% CI	N
Palustrine Scrub/Shrub Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Palustrine Emergent Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	12.88	10.27	16.14	9
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Estuarine Forested Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	7.56	5.55	10.31	15
	Mediterranean	nd	nd	nd	0
Estuarine Scrub/Shrub Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Estuarine Emergent Wetland	Cold Temperate	5.79	4.46	7.52	5
	Warm Temperate	12.86	8.73	18.96	12
	Subtropical	8.10	4.42	14.84	6
	Mediterranean	nd	nd	nd	0
Palustrine Forested Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	2.40	nd	nd	1
	Mediterranean	nd	nd	nd	0

Table 3. Summary of revised coastal wetlands NGGI calculations for **belowground biomass**. The 95% confidence intervals (CI) are of the geomeans. Units are Mg ha^{-1} biomass. nd: no data. The grey shaded area is a new category that was included here to illustrate data gaps.

Ecosystem	Climate Zone	Geomean	Lower 95% CI	Upper 95% CI	N
Palustrine Scrub/Shrub Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Palustrine Emergent Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	8.22	2.99	22.64	8
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Estuarine Forested Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	32.51	26.66	39.64	8
	Mediterranean	nd	nd	nd	0
Estuarine Scrub/Shrub Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Estuarine Emergent Wetland	Cold Temperate	29.06	2.06	408.98	2
	Warm Temperate	18.91	8.52	41.96	16
	Subtropical	18.11	11.17	29.35	9
	Mediterranean	17.19	nd	nd	1
Palustrine Forested Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0

Table 4. Summary of revised coastal wetlands NGGI calculations for **belowground biomass sequestration rate**. The 95% confidence intervals (CI) are of the geomeans. Units are Mg $ha^{-1}yr^{-1}$ biomass. nd: no data. The grey shaded area is a new category that was included here to illustrate data gaps.

Ecosystem	Climate Zone	Geomean	Lower 95% CI	Upper 95% CI	N
Palustrine Scrub/Shrub Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Palustrine Emergent Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	5.18	nd	nd	1
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Estuarine Forested Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	4.65	3.96	5.46	7
	Mediterranean	nd	nd	nd	0
Estuarine Scrub/Shrub Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Estuarine Emergent Wetland	Cold Temperate	29.69	21.53	40.94	2
	Warm Temperate	47.33	39.15	57.22	10
	Subtropical	3.27	2.45	4.36	8
	Mediterranean	nd	nd	nd	0
Palustrine Forested Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0

Table 5. Summary of revised coastal wetlands NGGI calculations for **soil carbon stocks**. The 95% confidence intervals (CI) are of the geomeans. Units are Mg C ha^{-1}. nd: no data. The grey shaded area is a new category that was included here to illustrate data gaps.

Ecosystem	**Climate Zone**	**Geomean**	**Lower 95% CI**	**Upper 95% CI**	**N**
Palustrine Scrub/Shrub Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Palustrine Emergent Wetland	Cold Temperate	309.38	240.92	397.29	4
	Warm Temperate	264.34	232.44	300.62	60
	Subtropical	208.35	146.29	296.75	17
	Mediterranean	nd	nd	nd	0
Estuarine Forested Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	270.82	197.41	371.52	44
	Mediterranean	nd	nd	nd	0
Estuarine Scrub/Shrub Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Estuarine Emergent Wetland	Cold Temperate	324.98	271.72	388.68	37
	Warm Temperate	146.71	128.65	167.30	183
	Subtropical	166.81	136.32	204.12	92
	Mediterranean	223.08	196.34	253.46	47
Palustrine Forested Wetland	Cold Temperate	292.92	231.89	370.01	2
	Warm Temperate	nd	nd	nd	0
	Subtropical	390.46	321.67	473.97	13
	Mediterranean	nd	nd	nd	0

Table 6. Summary of revised coastal wetlands NGGI calculations for **soil carbon sequestration rate measured by ^{210}Pb**. The 95% confidence intervals (CI) are of the geomeans. Units are Mg C ha^{-1} yr^{-1}. nd: no data. The grey shaded area is a new category that was included here to illustrate data gaps.

Ecosystem	Climate Zone	Geomean	Lower 95% CI	Upper 95% CI	N
Palustrine Scrub/Shrub Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Palustrine Emergent Wetland	Cold Temperate	1.01	0.85	1.20	2
	Warm Temperate	1.54	1.16	2.06	41
	Subtropical	0.45	0.10	2.05	2
	Mediterranean	nd	nd	nd	0
Estuarine Forested Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	0.87	0.55	1.39	9
	Mediterranean	nd	nd	nd	0
Estuarine Scrub/Shrub Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Estuarine Emergent Wetland	Cold Temperate	2.17	1.42	3.32	5
	Warm Temperate	0.82	0.37	1.83	5
	Subtropical	1.09	0.71	1.65	7
	Mediterranean	0.85	0.72	0.99	22
Palustrine Forested Wetland	Cold Temperate	1.00	0.34	2.93	2
	Warm Temperate	nd	nd	nd	0
	Subtropical	0.67	0.56	0.82	5
	Mediterranean	nd	nd	nd	0

Table 7. Summary of revised coastal wetlands NGGI calculations for **soil carbon sequestration rate measured by ^{137}Cs**. The 95% confidence intervals (CI) are of the geomeans. Units are Mg C ha^{-1} yr^{-1}. nd: no data. The grey shaded area is a new category that was included here to illustrate data gaps.

Ecosystem	Climate Zone	Geomean	Lower 95% CI	Upper 95% CI	N
Palustrine Scrub/Shrub Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Palustrine Emergent Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	1.43	1.23	1.67	14
	Subtropical	1.84	1.32	2.57	8
	Mediterranean	nd	nd	nd	0
Estuarine Forested Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	2.03	1.16	3.55	2
	Mediterranean	nd	nd	nd	0
Estuarine Scrub/Shrub Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0
Estuarine Emergent Wetland	Cold Temperate	2.38	2.05	2.76	2
	Warm Temperate	0.39	0.25	0.60	24
	Subtropical	1.76	1.30	2.37	35
	Mediterranean	1.05	0.92	1.19	25
Palustrine Forested Wetland	Cold Temperate	nd	nd	nd	0
	Warm Temperate	nd	nd	nd	0
	Subtropical	nd	nd	nd	0
	Mediterranean	nd	nd	nd	0

Table 8. A comparison of the literature data used in the 2016 NGGI and the updated calculations produced in the present update project. The 95% confidence intervals (CI) are of the geomeans. Units are Mg C ha^{-1}. nd: no data. The grey shaded area is a new category that was included here to illustrate data gaps. Notice that many of the categories missing data in the 2017 update are not missing in the 2016 NGGI. This is because missing data in the 2016 NGGI where filled with data from similar categories as a best estimate.

2016 NGGI				2017 Update to NGGI		
		Geomean	**95% CI**	**Geomean**	**Lower 95% CI**	**Upper 95% CI**
Ecosystem	**Climate Zone**	(Mg C ha^{-1})				
Palustrine Scrub/Shrub Wetland	Cold Temperate	329.15	53.45	nd	nd	nd
	Warm Temperate	236.18	216.55	nd	nd	nd
	Subtropical	135	189	nd	nd	nd
	Mediterranean	274.91	37.36	nd	nd	nd
Palustrine Emergent Wetland	Cold Temperate	329.15	53.45	309.38	240.92	397.29
	Warm Temperate	236.18	216.55	264.34	232.44	300.62
	Subtropical	133.67	93	208.35	146.29	296.75
	Mediterranean	274.91	37.36	nd	nd	nd
Estuarine Forested Wetland	Cold Temperate	329.15	53.45	nd	nd	nd
	Warm Temperate	346	76	nd	nd	nd
	Subtropical	346	76	270.82	197.41	371.52
	Mediterranean	274.91	37.36	nd	nd	nd
Estuarine Scrub/Shrub Wetland	Cold Temperate	329.15	53.45	nd	nd	nd
	Warm Temperate	346	76	nd	nd	nd
	Subtropical	346	76	nd	nd	nd
	Mediterranean	274.91	37.36	nd	nd	nd
Estuarine Emergent Wetland	Cold Temperate	329.15	53.45	324.98	271.72	388.68
	Warm Temperate	196.34	27	146.71	128.65	167.30
	Subtropical	218.16	80.45	166.81	136.32	204.12
	Mediterranean	274.91	37.36	223.08	196.34	253.46
Palustrine Forested Wetland	Cold Temperate	nd	nd	292.92	231.89	370.01
	Warm Temperate	nd	nd	nd	nd	nd
	Subtropical	nd	nd	390.46	321.67	473.97
	Mediterranean	nd	nd	nd	nd	nd