Unit Title: Wetlands, Carbon and Climate Change

Subject/target grade: High School Biology or Science Elective

Unit Summary: *The purpose of this unit is to raise awareness of the important role wetlands play in maintaining air and water quality and providing critical habitat to aquatic and terrestrial species. In addition to learning about wetlands and their carbon impact, students will learn how wetland restoration can be one tool for mitigating climate change, and other everyday tools they can use to minimize their own impact on the climate.*

This unit can be inserted into biology curriculums from several vantage points:

- *Nutrient cycles (Water, nitrogen, phosphorus, and carbon cycles)*
- *Food webs*
- *Photosynthesis and respiration*
- *Weather and climate*
- *Biological adaptations (specifically focusing on hydrophytic plant adaptations)*

Students should begin this unit with prior knowledge of the water cycle, photosynthesis and respiration. Students will have learned the scientific method in previous years, but this unit provides the opportunity, through the PeatCosm study, to work with real research data and see how scientists are working with natural systems to solve human-induced problems. This unit can be the stepping stone to other topics, as listed above, either as the entire unit, or broken into individual lessons interspersed within the broader topic of life science. The computer activity can be used to introduce Microsoft Excel to students lacking computer skills, or provide a better understanding of the uses of spreadsheets and graphing to the higher level student. Interpreting the graph that they create and using it to predict outcomes stimulates critical thinking skills and may require additional class time if students are not versed in graphical interpretation.

There are extensive notes contained within each Powerpoint to assist with using the slides.

Next Generation Science Standards:

LS2: Ecosystems: Interactions, Energy, and Dynamics

HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.

HS-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

LS2.A: Interdependent Relationships in Ecosystems

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

ESS2: Earth's Systems

ESS3: Earth and Human Activity

ESS2.C: The Roles of Water in Earth's Surface Processes

ESS2.D: Weather and Climate

ESS3.D: Global Climate Change

HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.

HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Learning Objectives: Students will be able to:

Lesson 1:

- Identify the three criteria that must be met for an ecosystem to be classified as a wetland.
- Identify at least two examples for each of the three wetland criteria.
- Describe how wetlands promote and maintain high air, water, and habitat quality.
- Explain that wetlands are a critical habitat for most terrestrial and aquatic species.

Lesson 2:

- Identify fast and slow components of the carbon cycle.
- Describe how wetlands transfer carbon from the fast to slow carbon cycle.
- Identify wetlands' contribution to each of the Earth's systems.
- Explain, given above- and below-ground diagrams of a wetland ecosystem, how carbon will cycle within the ecosystem.

Lesson 3:

- Describe the role carbon plays in regulating the environment and climate.
- Articulate the difference between weather and climate.
- Understand how human activities impact climate.
- Identify what human activities have the highest impact on climate.
- Recognize the influence wetland ecosystems can have on climate.
- Identify at least 5 ways they can reduce their impact on climate.

Lesson 4:

- Connect class material with what they experience on a field trip to a wetland.

Lesson 5:

- Create a model to predict how wetlands will sequester or emit carbon given anticipated regional climate change trends.
- Use their model to determine if an impacted wetland is mitigating or contributing to climate change.

Table of Lessons:

Lesson Title- Brief Description	**Learning Objectives** Students will be able to:	**NGSS Addressed**	**Materials**
What is a Wetland? *Students learn what defines a wetland and their impact on other ecosystems*	• Identify the three criteria that must be met for an ecosystem to be classified as a wetland. • Identify at least two examples for each of the three wetland criteria. • Describe how wetlands promote and maintain high air, water, and habitat quality. • Explain that wetlands are a critical habitat for most terrestrial and aquatic species.	• LS2.A: Interdependent Relationships in Ecosystems • ESS2.C: The Roles of Water in Earth's Surface Processes	• Overhead projector • Note taking materials • Lesson Plan *01 Inquiry Lesson 1 What is a wetland* • Powerpoint *02 Slides Lesson 1 What is a wetland*
The Carbon Cycle *Students are introduced to the fast and slow carbon cycles in the context of wetland ecosystems*	• Identify fast and slow components of the carbon cycle. • Describe how wetlands transfer carbon from the fast to slow carbon cycle. • Identify wetlands' contribution to each of the Earth's systems. • Explain, given above- and below-ground diagrams of a wetland ecosystem, how carbon will cycle within the ecosystem.	• LS2.B: Cycles of Matter and Energy Transfer in Ecosystems • LS2: Ecosystems: Interactions, Energy, and Dynamics • HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. • HS-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.	• Overhead projector • Note taking materials • Lesson Plan *03 Inquiry Lesson 2 the carbon cycle* • Powerpoint *04 Handouts Lesson 2 C cycle for class notes* • Powerpoint *05 Slides Lesson 2 Carbon cycling and wetlands* • Example activity *05b Example GK12 Crossword Puzzle*

Wetlands and Climate Change *Students will learn about climate change and how wetlands can mitigate, or contribute to, climate change.*	• Describe the role carbon plays in regulating the environment and climate. • Articulate the difference between weather and climate. • Understand how human activities impact climate. • Identify what human activities have the highest impact on climate. • Recognize the influence wetland ecosystems can have on climate. • Identify at least 5 ways they can reduce their impact on climate.	• ESS3: Earth and Human Activity • ESS2.C: The Roles of Water in Earth's Surface Processes • ESS2.D: Weather and Climate • ESS3.D: Global Climate Change	• Overhead projector • Note taking materials • Lesson Plan *06 Inquiry Lesson 3 wetlands and climate change* • Powerpoint *07 Slides Lesson 3 Wetlands and climate change* • Handout *08 Handout Lesson 3 How can you combat climate change* • Handout *09 Handout Lesson 3 peatcosm_information* • Handout *10 Homework Lesson 3 Wetlands C Climate change*
Wetlands Field Trip *Students will tour the U.S. Forest Service Northern Research Station facilities' Rhizotron and PeatCosm studies (or a local wetland)*	• Connect class material with what they experience on a field trip to a wetland.	• HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. • HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.	• Transportation to the site • Note taking materials • Sturdy/waterproof footwear • Lesson Plan *11 Inquiry Lesson 4 wetlands field trip* • Handout *12 Handout PEATcosm Field Trip Guided Notes*

Climate Change Impact on Wetlands *Students will use data from the USFS PeatCosm study to determine if the impacted wetland is sequestering or losing carbon*	• Create a model to predict how wetlands will sequester or emit carbon given anticipated regional climate change trends. • Use their model to determine if an impacted wetland is mitigating or contributing to climate change.	• ESS3.D: Global Climate Change • HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems. • HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.	• Computers with a spreadsheet program • Printer • Lesson Plan *13 Inquiry Lesson 5 climate change impacts on wetlands* • Handout *14 Handout Lesson 5 Wetlands C climate change computer activity* • Quiz *15 Lesson end Wetlands C Climate Change Quiz*

Safety Considerations:
The only safety concern in this unit involves the field trip to see the research project (or local wetland). Students will be traipsing through underground facilities or along the edge of a wetland. All standard safety procedures for field trips will be followed, including parental consent to participate. A list of participating students and staff, and destination will be provided to school administrators prior to departure. Students will need to dress for the weather, with sturdy footwear. Underground facilities are much cooler than outdoor ambient temperature. Visiting a local wetland may entail muddying footwear. A first aid kit should be accessible and a means of mobile communication.

Evaluation Plan:
Formative assessment tools include:

- Student participation through note-taking, question and answer, and homework assignments using simple graphic interpretation that are covered the following class period.
- Work in pairs or teams to develop a model to predict the wetlands' response to climate change.

Summative assessment tools include:

- A guided note sheet with questions the students must answer during the field trip. This also provides questions they may ask the researchers, if they are not courageous enough to ask their own independent questions.
- A homework assignment completed before the field trip consisting of reading the PeatCosm informational pamphlet and answering questions on the material, and looking up some key definitions.
- Creation of a graph illustrating carbon uptake or emissions during the previous growing season.
- Interpretation of graphical depictions of relationships between photosynthesis, respiration, and sequestration.
- A quiz at the end of the unit requiring description of a terrestrial plus aquatic carbon cycle.

Resources (websites, articles and textbooks):

Environmental Protection Agency, 2013. Summary of the Clean Water Act. URL: http://www2.epa.gov/laws-regulations/summary-clean-water-act, accessed 9 November 2012.

Environmental Protection Agency (EPA) (2014). Climate Change: what are the impacts where I live? URL: http://www.epa.gov/climatechange/, accessed 12 December 2012.

FAO (Food and Agricultural Organization of the United Nations) (1997). Drylands development and combating desertification: Bibliographic study of experiences in China. Environment and Energy Paper 15. URL: http://www.fao.org/docrep/W7539E/W7539E00.htm, accessed 18 February 2014.

Great Lakes Integrated Sciences and Assessments Center (2014). Great Lakes Climate. URL: http://glisa.msu.edu/great_lakes_climate/background.php, accessed 8 November 2012.

Kane, Evan (2012). Scientists and Staff profile. URL: http://www.nrs.fs.fed.us/people/ekane

Kane, Evan (2014). Faculty profile. URL: http://www.mtu.edu/forest/about/faculty/kane/

Kirschbaum, M.U.F. and Mueller, R. (2001) Net Ecosystem Exchange. Cooperative Research Centre for Greenhouse Accounting. URL: ftp://ftp.biosfera.dea.ufv.br/users/francisca/Net%20Ecosystem%20Exchange.pdf, accessed 12 January 2013.

Lilleskov, Erik (2012). Scientists and Staff profile. URL: http://www.nrs.fs.fed.us/people/Lilleskov

Lilleskov, Erik (2014). Faculty profile. URL: http://www.mtu.edu/forest/about/faculty/lilleskov/

Mitsch, W. J., & Gosselink, J. G. (2007). Wetlands (J. G. Gosselink, Trans. 4th ed.). Hoboken, N.J.: Wiley.

Mitsch, W. J., B. Bernal, A. M. Nahlik, Ü. Mander, L. Zhang, C. J. Anderson, S. E. Jørgensen and H. Brix (2013). "Wetlands, carbon, and climate change." Landscape Ecology 28(4): 583-597.

NASA Earth Observatory (2013). Climate and the Earths Energy Budget. URL: http://earthobservatory.nasa.gov/Features/EnergyBalance/page6.php, accessed 20 January 2014.

National Oceanographic and Atmospheric Administration (NOAA) (2014). NOAA Climate.gov: Science and Information for a Climate-Smart Nation. URL: http://www.climate.gov/, accessed 12 December 2012.

National Park Service (2013). What is climate change? URL: http://www.nps.gov/goga/naturescience/climate-change-causes.htm, accessed 14 November 2012.

Peel, M. C.,B. L. Finlayson and T. A. McMahon (2007). Updated world map of the Köppen-Geiger climate classification, Hydrol. Earth Syst. Sci., 11, 1633-1644, 2007. From Wikimedia Commons, URL: http://commons.wikimedia.org/wiki/File:Americas_Koppen_Map.png, accessed 19 February 2014.

Rydin, H. and J. Jeglum (2006). The Biology of Peatlands. Oxford; New York, Oxford University Press.

Scripps CO2 Program (2014). Welcome to the Home of the Keeling Curve. URL: http://scrippsco2.ucsd.edu/home/index.php, accessed 12 November 2012.

The Teachers Corner (2014). The Teachers Corner Crossword Puzzle Maker (free online website). URL: http://worksheets.theteacherscorner.net/make-your-own/crossword/, accessed 26 February 2014.

United States Department of Agriculture Forest Service (2012). Clean Air and Water: Mesocosm Research. URL: http://www.nrs.fs.fed.us/clean_air_water/carbon_sequestration/mesocosm/, accessed 8 December 2012.

United States Department of Agriculture Forest Service. (2012). Mesocosm. URL: http://www.nrs.fs.fed.us/clean_air_water/carbon_sequestration/mesocosm/, accessed 7 November 2012.

United States Department of Agriculture, 2013. Wetlands. URL: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/wetlands/, accessed 12 November, 2012.

United States Department of Energy (DOE) (2008). Carbon Cycling and Biosequestration: Report from the March 2008 Workshop, DOE/SC-108, U.S. Department of Energy Office of Science. (p. 2-3) URL: http://genomicscience.energy.gov/carboncycle/report/

United States Global Change Research Program (2009). Global Climate Change Impacts in the United States. Karl, T. R., J. M. Melillo, and T. C. Peterson (eds.). Cambridge University Press, NY. 196pp. URL: http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf

Watershed Center Grand Traverse Bay (2011). Adopt-a-Stream. URL: http://www.gtbay.org/our-programs/adopt-a-stream/, accessed 11 November 2012.

WGBU (German Advisory Council on Global Change) (1998) The Accounting of Biological Sinks and Sources Under the Kyoto Protocol – A Step Forwards or Backwards for Global Environmental Protection? Special Report 1998. 85p Available at: http://www.wbgu.de/fileadmin/templates/dateien/veroeffentlichungen/sondergutachten/sn1998/wbgu_sn1998_engl.pdf

Brief description of how this unit relates to your graduate research. (1 page):

My dissertation research specifically addresses wetland restoration impacts on hydrology and carbon cycling. My sites are located in impacted peatland and fens (sedge-dominated wetlands) located within the Seney National Wildlife Refuge.

Seney National Wildlife Refuge (SNWR) comprises 38,541 ha (95,238 acres) in the eastern Upper Peninsula of Michigan. The refuge is dominated by wetlands interspersed with forests and other cover types. Prior to being designated a National Wildlife Refuge, ditches were dug in a failed attempt to drain the land for conversion to agriculture. After incorporation into the National Wildlife Refuge system in 1935, a series of dikes were constructed to create pools for waterfowl habitat. The ditches and dikes have intercepted normal ground and surface water flow and have changed the hydrology and carbon dynamics of the system. Carbon dynamics differ between peatland, streams and lakes, with peatland sequestering more carbon than open water systems. Conversion of SNWR peatland to open water could potentially convert the area from a net carbon sink to carbon source, contributing to climate change.

Wetlands are the unsung heroes of the world, providing us with clean water, clean air, and forming the basis of many food chains we rely upon for our food (e.g., commercial fisheries). The ability of wetlands to act like a sponge during rain events provides base flow into our streams and rivers, preventing them from going dry, and minimizing flood events. Ignorance of the critical role wetland ecosystems play in our environment has led to the view that wetlands are waste land, best drained or filled in to provide a more direct benefit to society. Only recently have scientists come to realize the hidden – and critical – value of wetlands. The next step is to increase public awareness of the importance of wetlands. Hurricane Katrina's impact on New Orleans was the first indicator of how wetlands benefit us, since the storm buffering capacity of the wetlands surrounding the city was decimated due to commercial development. The catastrophic results brought wetland restoration science into public awareness. Yet most citizens are ignorant of what a wetland is, and why they are important.