Final Report: Working and Natural Lands Working Group

Wetlands Subgroup

November 2020

Table of Contents

Acknowledgements 4

Executive Summary 6

Background and Context 8

Connecticut Wetland Habitat Types 9

Importance of Wetlands 10

Wetlands, Carbon Sequestration, Transportation and Ecosystem Benefits 12

Impact Assessment and Vulnerability 15

Progress since the 2011 Report 17

Recommendations 18

2020.W.1: Protect and enhance the ecosystem services value of wetlands using sound science and adaptive management strategies 18

1.Encourage land and ocean management behaviors that support ecosystem services 18

2. Identify and conserve ecosystem services vulnerable to climate change 20

3. Continue monitoring and assessment of impacts of climate change on wetlands and near coastal waters and update management tools and strategies. 22

4. Encourage research to understand the effects of potential adaptation approaches and develop new, innovative approaches to support adaptive management 24

5. Advance regional research and modeling to guide conservation efforts 25

Recommendation 2020.W.2: Communicate the value of wetlands to Connecticut home and business owners through engagement on climate resilience efforts. 27

1. Continue to develop and update all municipal emergency preparedness plans for extreme weather events 27

2. Educate and assist private landowners and developers in the management of their lands to minimize impacts to wetlands and reduce risk from climate change. 29

3. Encourage adaptation strategies, including natural habitat conservation, Low Impact Development (LID) Best Management Practices (BMPs), agriculture water BMPs and drinking water treatment standards that will ameliorate the effects of water inundation 30

4.Implement new or modified policies that would encourage appropriate land use and reduce repetitive losses 32

Recommendation 2020.W.3: Further develop policies that encourage protections for wetlands. 34

1. Update and develop wetland protection policies, including regulatory programs, to ensure that they include protection for climate change mitigation, adaptation, and resiliency benefits of wetlands and near coastal waters. 35

2. Reevaluate Connecticut's Green Plan and open space grant programs to prioritize acquisition of land and conservation easements for ecosystem services most at risk from climate change 36

3. Acquire land and conservation easements to provide upslope — advancement zones adjacent to tidal marshes 38
Appendix 41
References 43

Acknowledgements

The Working and Natural Lands Wetlands Sub-Working Group (WNLSWG-Wetlands) would like to thank Governor Ned Lamont for his commitment to and efforts surrounding climate change in Connecticut. The work produced by this and other groups will help Connecticut achieve its goals toward climate change mitigation and adaptation through the lens of Equity and Environmental Justice.

During 2020 and the challenges that COVID-19 has presented, the WNLSWG-Wetlands worked diligently to gather the information needed to understand the important roles that inland, tidal, and coastal wetlands and the near shore open Long Island Sound play in carbon sequestration and mitigation of climate impacts. Wetlands play an important role on their own and in partnership with the other areas included in the Working and Natural Lands studies. The work in this report would not have been possible without the participation of a broad membership committed to the work at hand.

Co-Chairs **Leslie Kane, Audubon Connecticut** and **Jenny Dickson, CTDEEP** would like to sincerely thank the following members of the WNLSWG-Wetlands:

- **Peter Auster,** Mystic Aquarium and UCONN Marine Sciences
- **Juliana Barrett,** UCONN Sea Grant & CLEAR
- **Rick Bennett,** Science Director, USFWS
- **Alex Croft**, Save the Sound
- **Chris Elphick,** UCONN Ecology and Evolutionary Biology
- **Anne Hartjen**, City of New Haven, Planning
- **Kimberly Lesay,** CONN DOT
- **Gwen MacDonald,** Save the Sound
- **Denise Savageau,** Chair, CT Council on Soil and Water Conservation
- **Michelle Staudinger,** USGS, NE Climate Adaptation Center
- **Rudy Sturk,** CT Green Bank Steve Lecco, AICP, GZA
- **Jamie Vaudrey,** Dept. of Marine Science, UCONN Avery Pt.
- **Aicha Woods,** City of New Haven Planning

In addition, our work would not have been possible had it not been for the experts who aided the WNLSWG-Wetlands in their research. The entire Working Group would like to thank the following experts who added to our work:

- **Roger Wolfe, CT DEEP Wildlife**
- **David Kozak, CT DEEP Water Protection and Land Use**
- **Debbie Surabian, NRCS, USDA**
- **Dr. Beth Lawrence, UCONN Department of Natural Resources and the Environment**
- **Penny Vlahos, UCONN Marine Sciences**
- **Kristen Floberg, WestCOG**
- **Charles Vidich, WestCOG**
- **Amy Paterson, CT Land Conservation Council**

- **Brad Gentry, Yale School of Forestry and Environmental Sciences**
- **Robert La France, Audubon CT**

We would like to extend a special thank you to the DEEP Interns who devoted their time to helping us prepare this report:

- **Brian Basso, Graduate Student, Environmental Management, Yale University**
- **Alec Shub, Graduate Student, Oceanography, UCONN Marine Sciences**

The information presented by the above experts to the Sub Working Group is available on the GC3 website**.**

Executive Summary

There are approximately 220,000 acres of wetlands in Connecticut. This represents 7% of the land within the State. Wetlands play important roles in climate mitigation and adaptation and provide numerous ecosystem services including: .

- Carbon storage and sequestration
- Salt Marsh ecosystems can remove over 10X the amount of CO_2 from the atmosphere per hectare than forests
- Coastal Blue Carbon stored in soils can remain for centuriesAlthough salt water marsh soils store more carbon than inland wetland soils, the larger acreage of inland wetlands on the landscape make them important carbon sinks. In Connecticut, our largest inland wetlands area are red maple swamps where more carbon is stored in the organic soils than in the woody vegetation above ground.

The WNLSWG-Wetlands focused primarily on three areas: Tidal Wetlands, Inland Wetlands, and, given the absence of a working group dedicated specifically to Long Island Sound, near shore open waters to a depth of

TIDAL WETLANDS:

Tidal Wetlands are the single most vulnerable natural resource in the face of a changing climate and rising sea levels. They are also ubiquitous with many of our urban communities along coastal Connecticut. Coastal wetlands are a dominant reservoir for carbon and provide protection of coastal resources in coastal storms. Keeping coastal wetlands healthy and resilient is vital to vulnerable communities and vital to achieving our climate mitigation objectives.

Tidal Wetlands:

- Are among the most biologically productive resources in the world
- Provide habitat, nesting, feeding, and refuge areas for shorebirds
- Are nursery and feeding grounds for many organisms in Long Island Sound, including fish and shellfish that are recreationally and commercially harvested
- Improve water quality by trapping sediments and filtering contaminants
- Attenuate wave action and provide natural protection of shorelines
- Are Coastal Blue Carbon sinks

INLAND WETLANDS:

Inland Wetlands are a key resource in stormwater retention while wetlands associated with rivers and streams provide water retention to mitigate flooding. Trap sediments from runoff protect watercourses, and their soils are critical sinks for carbon.

Inland Wetlands:

- Are essential to an adequate supply of surface and underground fresh water
- Are integral to hydrological stability in the State
- Provide control of flooding and erosion by retaining water in storm events
- Improve water quality by trapping sediments and filtering contaminants
- Are critical to habitat needs of many forms of plant and animal life

- Are Teal Carbon sinks

- **Reduce health inequities**
    - Healthy wetlands reduce vector insect species
    - Improving regulations for development (including roads) near wetlands and in poor drainage areas will reduce housing in areas that flood and/or have higher risk for mold
- **Support community interests**
    - Fishing, food source, and public access to water resources - wetlands are the nurseries of fish and marine species
    - Water purity – inland wetlands purify water for drinking, swimming, and healthier fish populations
    - Water purity – coastal wetlands clean freshwater entering Long Island Sound for safer swimming and fish consumption
- **Engage community**
    - The 3 largest urban centers in CT are located “downstream” of inland wetlands and 2 of these are located on Long Island Sound
    - Low- and Middle-Income households will benefit from healthy wetlands that result in clean and abundant water supply, provide protection for severe storm events, reduce mosquitos, and provide recreational opportunities

Background and Context

Wetlands span 173,000 acres over Connecticut's 3,548,000 acre land surface ("State Summary Highlights" 2020) ("Inventoried Roadless Area" 2020). Wetlands are commonly identified using familiar terms such as marsh, swamp, bog, bank, or meadow. They occur within or near different types of watercourses, but can be broken down into two main categories — salt, brackish and tidal and freshwater wetlands. Connecticut has been on the forefront of wetland protection and has adopted specific legal definitions for both types of wetlands. These differ from the federal definitions and may differ from the definitions used in other states ("Connecticut Wetlands" 2020).

Connecticut defines tidal wetlands as those areas which border on or lie beneath tidal waters, such as, but not limited to banks, bogs, salt marshes, swamps, meadows, flats, or other low lands subject to tidal action, including those areas now or formerly connected to tidal waters, *and whose surface is at or below an elevation of one foot above local extreme high water*; and upon which may grow or be capable of growing some, but not necessarily all, of 62 different plant species ("Connecticut 440" 2011). More broadly, tidal wetlands are systems containing plants that are adapted to wet conditions with tidal flow and have poorly to very poorly drained mineral-rich organic soil. They occur in intertidal areas of marine, estuarine, and tidal riverine systems where the land meets the water and daily tidal action moves water in and out of the systems. In Connecticut, low marsh areas are flooded by tidal waters twice a day, while high marsh areas are flooded a few times a month ("Tidal Wetlands" n.d.).

Tidal wetlands are defined in the Tidal Wetlands Act by their current or former tidal connection and their capacity to support certain salt-tolerant wetland vegetation. Tidal wetlands are regulated exclusively by the CT DEEP. In contrast, freshwater wetlands are defined in Connecticut by both soil type and watercourse types; and are typically regulated by the municipalities of CT. ("How are Inland Wetlands" 2020).
The CT Inland Wetlands and Watercourse Act (CGA 22a-38) (IWWA) defines inland wetlands and watercourses separately. Together, the definitions protect all freshwater wetlands and riverine floodplains in the state. Specifically, inland wetlands are defined as "land, including submerged land…, which consists of any soil types designated as poorly drained, very poorly drained, alluvial, and flood plain" by the National Cooperative Soil Survey but does not include tidal wetlands. Identifying inland wetlands by soils allows us to recognize those areas during times of drought when there is no surface water present, or during winter when characteristic wetland indicator plants may not be obvious ("How are Inland Wetlands" 2020). Watercourses are defined as "rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs, and all other bodies, natural or artificial, vernal or intermittent ("How are Inland" 2020)". All resources within the definitions are regulated under the IWWA.
Defining the scope of the various habitats classified as wetlands is important to consider when recognizing the impacts of climate change, as well as the scope of human use of these habitats.

Connecticut Wetland Habitat Types

1. Palustrine System
   A. Non-forested
      i. Palustrine Aquatic Beds (floating or submerged aquatic beds; often rooted in shallow water)
      ii. Pond and Lake Shores (seasonally exposed sandy, gravelly, or muddy sediments)
      iii. Riverbank Communities (flood-scoured rocky or gravelly riverbanks with annual or perennial vegetation)
      iv. Alluvial Marshes (open wetlands periodically inundated by adjacent rivers or streams, influenced by runoff from adjacent upland; peat accumulation minimal)
      v. Basin Marshes (open wetlands found in glacial kettles or other topographically defined basins)
      vi. Spring Fens (naturally open wetlands occupying groundwater discharge sites; peat accumulation minimal)
      v. Topogenic Peatlands (natural peatlands occupying topographically defined basins; influenced by groundwater; on deep, poorly decomposed peats)
         a. Rich Fens (peatlands influenced by base-rich waters)
         b. Medium Fens (peatlands dominated by ericaceous shrubs and sedges, flooded by surface water)
         c. Bogs (poor fens) (peatlands dominated by ericaceous shrubs, influenced by ground water.

   B. Forested
      i. Basin Swamps (forested and/or shrub swamps with stagnant or slow-moving water; in geographically defined basins; on decomposed peats and muck. These swamps include many types of red maple swamps, Atlantic White Cedar Swamps and Black Spruce Basin Swamps and others.
      ii. Seepage Swamps (swamps with flowing surface and/or telluric water, on gently sloping to sloping sites; peat accumulation minimal)
      iii. Alluvial Swamps (swamps influenced by periodic flooding from adjacent rivers or streams, often influenced by runoff from the adjoining upland) This includes floodplain forests.

2. Estuarine
      i. Estuarine aquatic beds (floating or submerged beds; often rooted in shallow water) This would include salt, brackish and freshwater tidal SAV beds
      ii. Intertidal flats (irregularly and regularly exposed mud or sand with sparse or dense vegetation

iii. Intertidal beaches and shores (rock, gravel, and/or sandy shorelines where erosion and deposition are controlled by wave action and the diurnal rise and fall of the tides)
    a. Saltwater Intertidal Beaches and Shores
    b. Brackish Intertidal Beaches and Shores
    c. Freshwater Intertidal Beaches and Shores
iv. Intertidal Marshes (regularly and irregularly flooded marshes)
    a. Salt Marshes
    b. Brackish Marshes
    c. Freshwater Tidal Marshes
v. Intertidal Swamps (regularly flooded swamps dominated by woody shrub and scattered trees)
    a. Freshwater Intertidal Swamps

Importance of Wetlands

Tidal wetlands deliver numerous "ecosystem services" that benefit Connecticut's communities and its economy. Tidal wetlands are among the most biologically productive resources in the world. Tidal wetlands provide habitat, nesting, feeding, and refuge areas for shorebirds; they serve as a nursery ground for larval and juvenile forms of many organisms that occur in Long Island Sound, as well as many estuarine-dependent marine species; species that are the target of recreational and commercial fisheries have important ecological linkages to tidal wetlands. Tidal wetlands improve water quality by trapping sediments, reducing turbidity, restricting the passage of chemical pollutants and heavy metals, trapping nutrients, decreasing biological oxygen demand (BOD), and buffering storm and wave energy. Tidal wetland vegetation stabilizes shorelines, buffers erosion, and additionally, the plants and soil provide carbon sequestration. Tidal wetlands provide recreational opportunities for fishing, wildlife observation and hunting; they are important to commercial and recreational shell- and fin-fisheries; and they are areas of scientific and educational value. Tidal wetlands are also a major source of coastal open space and offer exceptional scenic views ("Tidal Wetlands" n.d.). Tidal wetlands have a disproportionately high economic value per area due to these many ecosystem services, greater than many of the other critical habitats found in Connecticut (Basso et al. 2018).

The freshwater wetlands in Connecticut are a fragile natural resource with which the citizens of the state have been endowed. They are an interrelated web of natural resources, essential to an adequate supply of surface and underground water; to hydrological stability and control of flooding and erosion; to the recharging and purification of groundwater; and to the existence of many forms of animal, aquatic, and plant life. Many freshwater wetlands have been destroyed or are in danger of destruction because of unregulated use through the deposition, filling or removal of material; the diversion or obstruction of water flow; and the erection of structures and other uses. These actions have despoiled and polluted the state's wetlands and watercourses. Such unregulated activity has had a significant and adverse impact on the

environment and ecology of the state and will continue to imperil the quality of the environment, thus adversely affecting the ecological, scenic, historical, and recreational values and benefits of the state ("Chapter 440" 2011).

Role of Wetlands in Climate Change Mitigation

Tidal and freshwater wetlands as well as subaqueous soils provide numerous ecosystem services because of their location in the landscape and high organic carbon content. One ecosystem service, critical to the carbon emission goals of the state, is their unique ability to store and sequester carbon. Salt marsh ecosystems remove over 10x the amount of CO_2 from the atmosphere per hectare than forests. This carbon is removed from the atmosphere and stored primarily in soils, where it can remain sequestered for centuries. Additionally, subaqueous soils, as defined by the National Cooperative Soil Survey, are also near shore carbon sinks and should be protected as an important resource for by the State of Connecticut. (COASTAL BLUE CARBON)SEPSEPThe predominant freshwater wetland type in Connecticut is the red maple swamp, which is usually associated with poorly or very poorly drained soils. These soils are rich in organic carbon and decompose slowly. Most carbon studies of forested wetlands have focused on above ground storage and sequestration, ignoring the role of these highly organic soils and the understanding that in all forest ecosystems, more carbon is stored in soils than above ground. These wetland soils serve as important carbon sinks and continue to sequester carbon as they continually trap organic matter within the forested system. Although coastal wetlands are generally better carbon sinks than freshwater wetlands, the substantial extent of forested wetlands, and associated hydric soils, across the landscape of Connecticut needs to be recognized as important to GHG mitigation and incorporated into inland wetland protection efforts in Connecticut. (TEAL CARBON)

Ecosystem Services provided by Wetlands:

Ecosystem Services		Inland Wetlands	Tidal Wetlands	Near Coastal Waters
Provision services	Food	X	X	X
	Raw materials	X	X	X
	Fresh water	X		
	Medicines	X	X	X
Regulating services	Local climate modification	X	X	X
	Biomass - ecosystem productivity	X	X	X
	Carbon sequestration & storage	X	X	X
	Water purification and filtration	X	X	
	Erosion and sediment control	X	X	
	Water flow control	X	X	
	Moderation of extreme storms	X	X	
Support services	Species Habitat	X	X	X
	Biodiversity	X	X	X
Cultural services	Recreation	X	X	X
	Sense of Place	X	X	X
	Aesthetic	X	X	X
	Tourism	X	X	X
	Physical and mental health	X	X	X

Wetlands, Carbon Sequestration, Transportation and Ecosystem Benefits

Coastal ecosystems are at risk from increased development and populations along the coast and climate change impacts including flooding in response to an increase in the frequency and duration of storms, precipitation, and sea level rise (Dupigny-Giroux et al., 2018). Predicting the effects of urbanization and climate change on tidal wetland persistence, functioning and benefits they provide is critical to both inform spatial management decisions and properly quantify the risks to coastal infrastructure and communities. Not only is private property and associated infrastructure at risk but transportation infrastructure that supports communities, such as roads, bridges, and rail systems are at increased risk as well. Infrastructure in the United

States, including roads, bridges, rail systems, dams, levees, sewer and stormwater systems, and other built structures are vital to the nation's security, economy, health, and safety (ASCE, 2016).

Transportation is an essential component of the economy, providing connections for businesses, consumers and tourism while also connecting people with their workplaces, homes and communities. Changing environmental conditions threaten the performance and functionality of transportation infrastructure. For example, damage to infrastructure from flooding, washouts, scouring and heaving from freeze-thaw cycles, can result in increased congestion and delays, that can have cascading economic costs, particularly for vulnerable communities and urban infrastructure (DeFries et al., 2019, Jacobs et al., 2018). While transportation systems are vulnerable to the impacts of climate change from increased storms, precipitation and sea level rise they also serve as one of the top contributors to U.S. greenhouse gas emissions. Since 2016, the transportations sector has become the top contributor to greenhouse gas emissions in the United States (EPA, 2020). Sea level rise and marsh migration should be incorporated into future transportation planning efforts. This would help to minimize the negative impacts to tidal wetlands resulting from transportation adaptation strategies and may offer an opportunity to improve marsh resilience and migration capabilities.

An important function of wetlands and other terrestrial and aquatic ecosystems is that they serve as natural sinks for atmospheric carbon dioxide (Fleming et al., 2018). Coastal wetland ecosystems have a large capacity to store carbon making them carbon sinks, often referred to as blue carbon. McLeod et al. (2011) found that vegetated coastal ecosystems are disproportionately important in sequestering carbon dioxide when compared with terrestrial ecosystems, sequestering atmospheric carbon dioxide at rates 10–100s times higher than terrestrial forests. Carbon sequestration rates have been shown to range from 0.3 to 5.9 tons of CO2e/acre/year with a mean value of 1.78 CO2e/acre/year (Bridges et al., 2015). Wang et. al. (2019) estimated that under a business as usual Representative Concentration Pathway (RCP 8.5 scenario) U.S. tidal wetlands could double their carbon sequestration to 9.40 Tg C yr-1 by 2100 if the wetland ecosystems are not restricted by human activities. Bridges et al. (2015) reported that the dollar value for carbon sequestered by wetlands ranged from $27-97/metric ton of carbon. These values are consistent with those reported for by the Interagency Working Group on Social Cost of Greenhouse Gases (2016). The resilience of tidal wetlands to sea level rise depends on its vertical accretion rate and/or potential horizontal migration to upland. With ongoing climate change, the amount of carbon sequestered by tidal wetlands can be maintained or increased as long as sediment accumulation rates keep pace with relative sea level rise (Kirwan et al., 2016). Management actions to restore wetlands and other terrestrial and aquatic ecosystems, along with improvements in land management practices could maintain or increase ecosystem carbon sinks (i.e., carbon storage or removal) while decreasing the sources or emissions of carbon to the atmosphere (Fargione et al., 2018, Shrestha et al. 2018). Determining the value of carbon sequestered by wetlands and combining them with the other socio-economic benefits provided by coastal ecosystems can provide the rationale to pursue conservation and restoration of coastal ecosystems. Should these ecosystems be

degraded or lost, their carbon uptake potential will be diminished, and their stored carbon could be potentially released into the atmosphere.

Wetlands are a first line of natural defense against erosion, waves, flooding, and storm surge (Fleming et al., 2018). Wetlands deliver a wide range of ecosystem services that contribute to human well-being, such as fish and fiber, water supply, water purification, climate regulation, flood regulation, coastal protection, recreational opportunities, and tourism (Millennium Ecosystem Assessment, 2005; Lipton et al., 2018). Natural coastal infrastructure, including beaches, dunes, seagrass beds, and marshes, can reduce wave energy, coastal erosion, and flood hazards (Arkema et el., 2013, Sutton-Grier et al., 2015). Narayan et al., (2017) reported that where coastal wetlands where present over $625 million in avoided flooding damages were estimated and communities behind marshes experienced 20% less property loss during Hurricane Sandy.

The potential of wetlands as a carbon sink to help offset greenhouse gas emissions along with the multiple benefits they provide, e.g. habitat for fish and wildlife resources, reduced shoreline erosion from waves, reduced flooding, infrastructure protection, nutrient reduction, improved water quality, and enhanced recreational opportunities, it is essential that society conserves and restores these valuable and vital natural ecosystems. Understanding and addressing the threats associated with the maintenance and continued functioning of wetlands in conjunction with reestablishing habitat connectivity across terrestrial, freshwater, and marine systems are fundamental elements for ecosystems to adapt to changing environmental conditions (Lipton et al. 2018).

Over the past two decades, engineers and scientists have learned how to build new infrastructure with natural landscape features to provide protection, e.g., flood protection, while also providing other ecological and community benefits. These nature-based solutions combine built and natural infrastructure in hybrid Natural and Nature Based Infrastructure (NNBI) designs to provide storm erosion and flood risk reduction, while providing other ecological and community benefits that built infrastructure typically fails to deliver. These benefits include the creation of habitats for commercially and recreationally valuable fishes, maintenance and enhancement of biodiversity, improved aesthetics and access to “nature” that can increase tourism and recreation, and improved water quality, with estimated benefits valued at over $100 billion annually (Sutton-Grier et al., 2018). There will always be a need for built infrastructure as development and populations level increase along the coast, however, coastal communities that incorporate NNBI into their planning, planned upgrades and future investments will benefit the most (Bridges et al., 2015, Bridges et al., 2018, Sutton-Grier et al, 2015, Sutton-Grier et al., 2018, Webb et al., 2019).

Impact Assessment and Vulnerability

Rapid sea level rise (characterized by 20 inches or more by 2050) will likely result in loss of coastal marsh habitat, decreasing connectivity between marsh patches and lowering edge habitat which are both vital to many fish species and to the ability of the coastline to resist storm surge and flooding events (Torio and Chmura 2013).

Some of the natural resources most at risk from climate change are tidal marshes, freshwater wetlands, and forested swamps. These habitat types are broadly distributed across Connecticut from the coast to upland watersheds and forests. While the degree of impact will vary changes likely include conversion of rare habitat types (e.g. tidal marsh and offshore islands to submerged lands), loss and/or replacement of ecologically critical and rare species dependent on select habitats, and the increased susceptibility of habitats to other on-going threats (e.g., fragmentation due to development, establishment of invasive species) (Governor's Steering Committee 2011).

Human actions, both direct and indirect, can adversely impact tidal wetlands and their functions. Direct actions include activities such as filling, dredging, and trampling; indirect actions include upland uses that result in sedimentation, increased runoff and stormwater discharge, proximate septic system failures, nutrient discharges from well-functioning septic systems, or the installation of culverts in a manner that decreases salt water flushing; and seaward actions such as degradation of seagrass meadows, shellfish reefs and other barriers to wave energy that result in erosion of marsh boundaries/channels. In these cases, the delicate balance between soil surface, water level, water quality and/or salinity is disturbed. This results in a stressed habitat which is usually less productive than a healthy marsh and frequently promotes infiltration of undesirable or invasive species, most typically Common Reed (*Phragmites australis subsp.australis*). Many of these activities have historically occurred in Connecticut, resulting in the loss or degradation of the majority of tidal wetlands. As a result it is even more important to protect the wetlands that remain. ("Tidal Wetlands" n.d)"

Climate change is expected to impact freshwater wetlands for Connecticut in two major ways. First, through changes in storm events, both in terms of precipitation rates and their distribution over time; and second, through increases in temperature.

Since the retreat of the last regional glaciers, freshwater wetlands developed in low lying areas, containing a combination of gentle slopes, sediment and organic material deposition, and shallow water tables, highlighting their vulnerability to extreme climate events. Changes in the distribution and intensity of rainfall, coupled with continued development, will impact many wetland functions. Predictions indicate that rainfall events will be less frequent but more intense, and there is evidence that these changes are already taking place. These new rainfall patterns can result in flash flood events where the increased quantity of water falling onto the landscape is high enough to create short periods of flooding followed by longer periods of drought. While wetlands naturally regulate water quantity and quality, the loss of acreage to development, increased runoff from impervious surfaces, and increased extreme weather events are expected to overwhelm remaining wetland ecosystems. Intense rainfall events will not only disrupt seasonal water regimes but intense rainfall events will also increase erosion and nonpoint source pollutants that are carried from the upper reaches of watersheds,

resulting in increased sedimentation and pollutant loading in lower watershed sections which include wetlands. Protecting freshwater wetlands from severe stormwater impacts through low impact development, best management and buffer management, will allow wetlands to continue to provide ecosystem services that are critical to climate change adaptation and resilience, including providing clean and abundant drinking water and flood protection.
Increasing temperatures impact water resources, including freshwater wetlands in several ways. Climate change is increasing the growing season with "leaf out" occurring earlier in the spring and "leaf drop" happening later in the fall. This may result in additional evapotranspiration and lowering water tables, especially during periods of drought. Increased heat will also put additional stresses on wetland vegetation during periods of drought.
Warming temperatures are also predicted to increase exposure to vector diseases with host species over-wintering in larger numbers. Mosquitos breed in still water in wetlands, however, larvae are often washed downstream during periodic rainfall events. With the expectation of longer dry periods between storm events and increased temperatures, mosquito larvae will have maximum conditions to develop into adults and increase in population earlier in the season. Additionally, with lower water conditions, natural predators of mosquito larvae will no longer be able to access isolated pools.
Maintaining core forest areas and buffer vegetation in and surrounding freshwater wetlands is likely to moderate temperatures and the impacts of heat islands on wetlands and will help to preserve the hydrologic functions of freshwater wetlands.

Progress since the 2011 Report

There has been some progress in the understanding of the roles wetlands play in climate mitigation, carbon storage, water recharge and storm surge protection. Much still needs to be researched and understood. This report recommends more research to better understand the importance of wetlands of all types in Connecticut. Nearby States are doing research and we recommend Connecticut participate in regional information gathering both in Long Island Sound and in our freshwater wetlands resources.

As storm severity increases and the severity of short duration storms with heavy rainfall increase their impacts on communities across the state, progress must continue on protecting and expanding wetlands in Connecticut. Adding to these stressors for our State are increases in diseases and understanding the role healthy wetlands can play in mitigating disease. Lastly progress needs to continue on making the resources of wetlands available to urban communities for food and recreation.

Recommendations

The following recommendations are proposed for consideration by the GC3 in the upcoming 2021 GC3 report to Governor Lamont. They were assessed by the Wetlands subgroup members as being of both high importance and areas where the Wetlands subgroup will take a leading role in developing implementation strategies. Each recommendation includes the specific implementation actions that need to be taken in order to achieve the broader goal of each recommendation, as well as an assessment of each action's impact on vulnerable communities as defined by the GC3 Equity and Environmental Justice Working Group.

2020.W.1: Protect and enhance the ecosystem services value of wetlands using sound science and adaptive management strategies

1.Encourage land and ocean management behaviors that support ecosystem services	
Recommended Implementation Action Description	Land and ocean management behaviors that support ecosystem services of wetlands should be encouraged. It is important to prioritize and incorporate new and emerging science and technologies to best implement those actions, recent examples include: sediment additions on tidal marshes, regenerative farming and gardening, natural pest control methods, crop rotation and no-till agriculture will reduce the negative impact on ecosystem services by conserving soil properties and moisture, increasing the organic content of soil, and supporting biodiversity. Using alternative LID (low impact development) construction and landscaping practices can help support ecosystems by building resilience. These LID practices start with minimizing the footprint of any construction project, especially minimizing the disturbance of native vegetation and soils. Conservation subdivision approaches afford the opportunities to position footprints to minimize impacts to natural hydrology and existing habitats. Appropriate soil structure, stability, permeability and oxygen levels for urban soils should be identified to support appropriate urban tree species. Additionally, restoration and recovery of oyster (and other shellfish) reefs and seagrass meadows, and assessing the feasibility of artificially constructed oyster reefs should be explored in appropriate locations to reduce wave energy impacts to wetland edges. Management of erosion by wakes of vessels and prop scarring of seagrass meadows can be mediated by vessel traffic controls in harbors and along coasts. Management and mitigation of impacts of invasive species (e.g., mitten crab) that burrow and destabilize marsh edge habitats is also

	needed. In addition to LID and best management practices, land conservation is an important tool for protecting both tidal and freshwater wetlands. Effective use of land conservation and restoration tools in wetlands and adjacent areas.
Indicators and Targets	**Target 1.** Zero) loss of seaward marsh edge habitat. ● Indicator: area of marsh loss (and/or linear measure of edge) ● Indicator: marsh channel and edge area burrowed (or linear measure of edge length). **Target 2.** Maintain areas of high-elevation marsh (e.g. Spartina patens dominated marsh). **Target 3.** Adoption of Conservation Subdivision approaches statewide that focus on conservation of tidal and inland wetland preservation. **Target 4.** Regulatory wetland buffers (in addition to wetland review areas) - size will depend on wetland type. Currently CT DEEP recommends a 100 ft buffer around inland wetlands (but non-regulatory). **Target 5.** Fund research and tool development to support tidal wetland conservation **Target 6**. Inventory and prioritize tidal and freshwater wetlands, including marsh migration areas, for land conservation through acquisition and/or easement.
Completion Timeframe	**Less than 2 years** ● Assessment and implementation of additional vessel speed and area restrictions. ● Develop and implement invasive species plan using the least toxic and most controlled methods available. ● Adoption of wetland buffer regulations for coastal and inland wetlands at all government levels. ● Fund research and tool development **3 - 5 years** ● Develop and implement reef and seagrass meadow plan. ● Adoption of conservation subdivisions statewide. ● Coastal wetland buffer vegetation targets.
Implementation Entities	CT DEEP, DA Aquaculture Division, CZM, Harbor Management Comm, Planning and Zoning Commissions, Inland Wetlands Commissions, Land Trusts, Academic Institutions, Connecticut Sea Grant, UConn CLEAR
Climate challenges addressed	Organic agriculture and gardening can have the co-mitigation benefit of sequestering carbon. Restored and constructed oyster (and other shellfish) reefs, as well as seagrass meadows, buffers shoreline development and wetlands against waves produced by extreme weather events, while also providing important habitat for ecologically and economically important species. Urban tree plantings provide localized cooling for buildings, a benefit during extreme heat events,

	at the same time, offering water capture and storage areas that could mitigate flooding. Conservation Subdivisions can save critical tidal and inland wetland areas and buffers zones by providing incentives for clustered land development. Vegetated buffers will help protect sensitive wetlands in the face of increased stormwater runoff and increased storm events.
Protection of vulnerable communities	Ecosystem services such as water quality, storm/flooding mitigation, mitigation of wave energy, and cooling from natural tree cover are all areas that disproportionately impact vulnerable communities in Connecticut. These ecosystem services provide equal economic benefit to all communities that rely on them but when they are overwhelmed, communities and individuals without the means to quickly adapt to the loss of those services are affected to a much greater extent. Encouraging land and ocean management practices that promote these ecosystem services will therefore be most beneficial to those vulnerable communities who rely on those services and do not have a means to augment them if they fail.
References for action	● CIRCA: Dredge Material ● Sacred Heart Univ/CIRCA: Stratford Point Living Shoreline ● Control and Management of Chinese Mitten Crab ● Gadwa et al. 2011. "The Scientific Basis for Wetland and Watercourse Buffer Zones." ● Janowiak et al. 2018. "New York and Northern New England Forest Ecosystem Vulnerability Assessment and Synthesis." ● Richard Hauer et al. 2020. "Street Trees, Construction and Longevity: Tree Growth and Response over Four Decades (1979-2018)." ● STAC: Boat Wave Impacts蜉

2. Identify and conserve ecosystem services vulnerable to climate change	
Recommended Implementation Action Description	Ecosystem services that provide protection for adjoining habitats and human-built structures are particularly important in building natural resiliency to the effects of sea level rises and extreme weather events. Currently, coastal wetlands provide an important buffer against coastal storms, but sea level increases would convert some of these areas to open water. Critical wetlands often have the ability to naturally advance inland if they are unimpeded by barriers, such as development or coastal infrastructure. Therefore, identifying and preserving future inland advancement zones would help create future protective storm buffers for coastal communities while providing the co-benefit of

	preserving an ecologically important habitat helping protect Long Island Sound from pollutants.
Indicators and Targets	**Target 1:** Identify salt tolerant grasses and trees suitable for planting in areas of sea level rise encroachment. **Target 2:** Develop quantitative metrics of the ecosystem services provided. For example, how much carbon storage/sequestration, denitrification does a wetland habitat support. **Target 3:** Identify and prioritize potential areas to allow habitat transgression. **Target 4:** Develop best management practices to allow and speed up movement of habitats so that they don't succumb to "coastal squeeze". **Target 5**: Identify freshwater wetlands needed for resiliency, included but not limited to, drinking water supply and flood protection.
Completion Timeframe	Ongoing
Implementation Entities	CT DEEP, Non-governmental Organizations (e.g. Audubon, TNC, etc.), land trusts, Municipal commissions, Academic Institutions, UConn CIRCA
Climate challenges addressed	Ecosystem services in wetlands with a direct link to climate change adaptation, mitigation, and/or resilience ● soil carbon sequestration ● tidal wetland storm/flood water buffering ● inland wetland water filtration
Protection of vulnerable communities	Ecosystem services such as water quality, storm/flooding mitigation, and cooling from natural tree cover are all areas that disproportionately impact vulnerable communities in Connecticut. These economic services provide equal economic benefit to all communities that rely on them but when they are overwhelmed, communities and individuals without the means to quickly adapt to the loss of those services are affected to a much greater extent. Identifying and conserving ecosystem services vulnerable to climate change will therefore be most beneficial to those vulnerable communities who rely on those services and do not have a means to augment them if they fail.
References for action	● Basso et al. 2015. "Status and Trends of Wetlands in the Long Island Sound Area." ● CIRCA: Dredge Material ● CIRCA: Restored v. Natural Living Shorelines ● Coastal Planting Guide ● UConn Coastal Landscaping Guide蛑

3. Continue monitoring and assessment of impacts of climate change on wetlands and near coastal waters and update management tools and strategies.	
Recommended Implementation Action Description	State and local resource managers will review and update local mapping of wetland, floodplains, and near coastal waters, evaluate impacts of climate change on these resources and also the flood protection benefits provided, and develop strategies for maintaining and enhancing the flood and erosion control benefits these wetlands and green infrastructure provide to communities. State and local resource managers will identify additional sites where wetlands restoration, including removal of structures/housing in flood hazard areas, will provide flood and erosion control to make communities more resilient to sea level rise and storm events. Connecticut's Water Planning Council will evaluate the impact of climate change on wetlands as they relate to drinking water supplies to inform implementation of the State Water Plan. CT DEEP and DPH will also provide technical and financial support to municipalities in wetland management/restoration to control vector disease transmission.
Indicators and Targets	**Target 1.** Adoption of the most recent Flood Insurance Rate Maps (FIRM) for all of Connecticut's municipalities to be used in combination with the latest information from CIRCA to inform state and local land use decisions in determining base flood elevations for predicted changes in sea level rise and flooding. **Target 2.** Revised state and municipal floodplain regulations consistent with science driven adaptive management practices including preservation and enhancement of wetlands and use of green infrastructure. **Target 3**. Water Planning Council will evaluate freshwater wetlands in drinking water supply watersheds and incorporate recommendations into the State Water Plan. **Target 4.** DEEP will expand its wetlands program to work with municipalities on wetland management/restoration for mosquito management. Restoration should use the least toxic methods possible to control invasive plant species. **Target 5:** Develop climate change sentinels monitoring program to ensure that key indices, such as salt marsh bird and plant measures, are measured every 3-5 years. **Target 6**: Allocate funding to support a central clearing house for relevant data. **Target 7:** Transportation and infrastructure upgrades - wetland mitigation and modification and monitoring of projects - continue to make sure transportation infrastructure upgrades include …. develop

	mechanisms to proactively assess the needs for future infrastructure improvements. Pro actively think about changes in infrastructure - EEJ community link
Completion Timeframe	**Less than 2 years** ● Expand mosquito control program ● Funding for support of a central clearing house for information….. **3-5 Years** ● Adoption of updated Flood Insurance Rate Maps completed for coastal municipalities ● Revised municipal floodplain regulations ● Assessment of wetland and floodplain for flood control ● Assessment of wetlands in drinking water supply watersheds
Implementation Entities	Lead: State Agencies, UConn CIRCA and Center for Biological Risk, COGs, Municipalities, Supporting: NGOs. Academic Institutions, Federal Agencies, LISS
Climate challenges addressed	This recommendation addresses adapting to sea level rise, severe storm events, and increases in vector diseases by ensuring that Connecticut has the latest science needed to protect, enhance, and restore flood and erosion control protection benefits of wetlands and flood plains.
Protection of vulnerable communities	Vulnerable communities often rely on ecosystem services that are threatened by climate change. Adaptive management procedures ensure that the best available science and methods will be used to preserve ecosystem functioning. Additionally, because wetland and flood hazard zones land values are cheaper, these lands are often identified for development of affordable housing. Environmental justice usually looks at bringing a nuisance/hazard to a community (e.g. landfills). In this case, using lands that are marginal for development is bringing communities to the nuisance/hazard and should be avoided. Converting land back to wetlands and restoring ecosystem services can serve to protect vulnerable communities from unsustainable development practices which often result in direct harms to community health, economic prosperity, and stability.
References for action	● Emergency Watershed Protection Program ● FEMA Flood Service Map Center ● Field and Elphick. 2014. "Sentinels of Climate Change: Coastal Indicators of Wildlife and Ecosystem Change in Long Island Sound." ● Johnston et al. 2018. "Using Ecosystem Service Values to Evaluate Tradeoffs in Coastal Hazard Adaptation." ● Kocia et al. 2015 "The Trillion Dollar Assessment: The Economic Value of the Long Island Sound Basin."

	● Lentz et al. 2015. "Coastal landscape response to sea-level rise assessment for the northeastern United States." ● Pomeroy et al. 2013. "Valuing the Coast: Economic Impacts of Connecticut's Maritime Industry."

4. Encourage research to understand the effects of potential adaptation approaches and develop new, innovative approaches to support adaptive management	
Recommended Implementation Action Description	Conduct research to classify and quantify current ecosystem services, to project how these services will change under future climate scenarios, to assess how adaptation strategies might affect change, and to measure actual changes into the future. Examples of key services include, but are not limited to, carbon storage and sequestration, denitrification, flood control, pollutant removal, biodiversity protection, and recreational opportunities. Initiate a process to prioritize where research is needed. Study potential to modify land management policy to support the protection of key services, and determine the feasibility of implementing new policies at sufficient scale to effect adaptation benefit using the best emerging science, technologies, and policies.
Indicators and Targets	**Target 1.** Develop strategies for quantifying all major ecosystem services likely to be affected by climate change and monitoring guidelines for each service. **Target 2.** Quantify current services and project effects of climate change under different adaptation strategies. Include cost-benefit analysis of each strategy. **Target 3.** Establish a long-term monitoring strategy with regular assessment of the economic and other societal consequences of failure to implement adaptation strategies, and regular assessment of the cost-effectiveness of adaptation actions. **Target 4.** Identify legislative policy modifications that would facilitate the implementation of adaptation strategies at sufficient scale to effect change. **Target 5.** Implement policy changes that maintain current ecosystem services. ● Indicator: State enabling legislation that simplifies transfer of development concepts for ecosystem based conservation purposes.
Completion Timeframe	**Less than 2 years** ● Ecosystem services monitoring strategy and guidelines

	● Policy modification strategy that are useable by developers, residents, etc. **3-5 years** ● Quantification of current and projected services ● Policy changes ● State enabling legislation for transfer of development rights focused on protection of ecosystem services **Ongoing** ● Long-term monitoring program
Implementation Entities	CT DEEP, UConn CIRCA, Academic Institutions
Climate challenges addressed	Addresses the loss of ecosystem services and attends to costs of development in communities. Additionally, the transfer of development rights can enable the protection of coastal and inland wetland resources that serve to buffer increasing sea level rise and mitigate impacts caused by longer duration and more intense flooding events.
Protection of vulnerable communities	Vulnerable communities often rely on ecosystem services that are threatened by climate change. Adaptive management procedures ensure that the best available science and methods will be used to preserve ecosystem functioning. Additionally, because wetland and flood hazard zones land values are cheaper, these lands are often identified for development of affordable housing. Environmental justice usually looks at bringing a nuisance/hazard to a community (e.g. landfills). In this case, using lands that are marginal for development is bringing communities to the nuisance/hazard and should be avoided. Converting land back to wetlands and restoring ecosystem services can serve to protect vulnerable communities from unsustainable development practices which often result in direct harms to community health, economic prosperity, and stability.
References for action	● CIRCA: Restored vs Natural Shorelines ● Local Leaders Council: Transfer of Development Rights蜉

5. Advance regional research and modeling to guide conservation efforts	
Recommended Implementation Action Description	Climate change adaptation research and modeling should be conducted on a regional scale to inform adaptation collaboration and planning with other states and federal agencies. Research should focus on the inventory of existing and future key habitats and species, and identify habitats and species that are more effectively conserved in Connecticut, in neighboring states or jointly.

Indicators and Targets	**Target 1.** Development of a habitat suitability model for restoring inland and coastal wetlands, identifying areas which provide the greatest increase in ecosystem benefits when protected or restored, including inventorying closed developments that could be candidates for retreat from floodplains/wetlands. ● Indicator: Areas modeled (area of coastal wetlands, area of inland wetlands). ● Indicator: Number of projects funded to assess climate impacts on wetlands. **Target 2:** Implement conservation strategies based on research and modeling results identifying critical areas. ● Indicator: Outreach to impacted or involved communities, inland wetland agencies, and agencies involved with tidal wetland conservation. ● Indicator: Area of land conserved or restored. Inland wetlands: Creating wetlands along headwater streams for P removal, restoring floodplain wetlands lower in the watershed for N removal and flood abatement from rainfall, creating and restoring wetlands to connect existing wetlands to enhance biodiversity. Coastal/tidal wetlands: area of tidal wetlands improved through soil enhancements (e.g. thin-layer deposition), area of uplands protected to allow for inward marsh migration, creation of or enhancement of living shorelines.
Completion Timeframe	**Less than 2 years** ● Development of a habitat suitability model for restoring inland and coastal wetlands, identifying areas which provide the greatest increase in ecosystem benefits when protected or restored. **3 to 5 years** ● Implement conservation strategies based on research and modeling results identifying critical areas.
Implementation Entities	Academic Institutions; Long Island Sound Study, proposed CT National Estuarine Research Reserve, UConn CIRCA; CT Sea Grant; CT DEEP; Inland Wetland Commissions; Federal Agencies (USDA FS, USDA NRCS, US EPA, NOAA, USF&WS)
Climate challenges addressed	Add to data sets supporting climate modeling to improve climate change predictions, while also increasing insight into region-specific impacts of climate change.
Protection of vulnerable communities	Taking a more regional/local approach to research and modeling will ensure that conservation efforts taken by the state are specifically tailored to the state's unique ecosystems, allowing conservation efforts to focus on preserving the ecosystems whose services are most relied on by vulnerable communities, including supporting improved

	water quality, flood protection, biodiversity, and maintaining and improving access to and appreciation for Connecticut's open spaces.
References for action	• Basso et al. 2015. "Status and Trends of Wetlands in the Long Island Sound Area." • CIRCA: Dredge Material • CIRCA: Restored vs Natural Shorelines • Costanza, R. W. et al. 1997. "The value of the world's ecosystem services and natural capital. Nature 387, 253–260." • Craft, C. 2016. "Creating and Restoring Wetlands. Elsevier, Boston. 348p." • DEEP: Inland Wetlands and Watercourses • Long Island Sound Comprehensive Conservation and Management Plan • Millenium Ecosystem Assessments • NOAA: Sea Level Affecting Marshes Model • UCONN: Sea Level Effects on Roads and Marshes蜉

Recommendation 2020.W.2: Communicate the value of wetlands to Connecticut home and business owners through engagement on climate resilience efforts.

1. Continue to develop and update all municipal emergency preparedness plans for extreme weather events	
Recommended Implementation Action Description	All municipalities should have emergency preparedness and hazard mitigation plans for extreme weather events specific to their jurisdiction. It is important that these plans be kept up to date. Local Health Departments in coordination with the CT Department of Emergency Management and Homeland Security (DEMHS) should ensure these plans are kept current. To test these plans, exercises and drills should be conducted. In particular, state and local Natural Hazard Mitigation Plans should recognize the value of wetland as critical green infrastructure that provide important ecosystem services for mitigation, adaption, and resiliency. Key services include, but are not limited to, flood protection and wave attenuation, reduction in erosion and sediment control, drinking water supply protection, and drought modification.
Indicators and Targets	**Target 1.** Development of a model severe weather event plan template for use by Connecticut's municipalities and administered at the regional planning level that includes the five key elements of an

	emergency management plan (prevention, preparedness, response, recovery and mitigation). **Target 2.** Municipal severe weather event plans are revised to address winter snow loads, hurricanes, coastal and/or inland flooding, droughts, extreme heat, and tornadoes. **Target 3.** Municipal severe weather event plans must include preparedness and mitigation measures necessary to minimize impacts from these events before these events occur and to address protection of the lives and health of citizens and the natural and manmade infrastructure that sustains the public health, safety and general welfare. Target 4. Review state and local Natural Hazard Mitigation Plans and ensure that wetlands are incorporated as essential green infrastructure.
Completion Timeframe	**Less than 2 years** ● Model severe weather event plan template ● Include wetlands as green infrastructure in State Natural Hazard Mitigation Plan **3 - 5 Years** ● Revised severe weather event plans for all municipalities statewide to address a comprehensive range of threats ● Revised severe weather event plans that deal with the five phases of emergency management (prevention, preparedness, response and recovery and mitigation) ● Include wetlands as green infrastructure in local Natural Hazard Mitigation Plans **Ongoing** ● Completion of severe weather simulations (years 4 to 6 and annually thereafter) ●
Implementation Entities	Department of Emergency Management and Homeland Security, Chief Elected Officials of each municipality, Town planners, Municipal Public Works Departments, Local and Regional Health Departments, Council of Governments
Climate challenges addressed	Robust emergency preparedness plans for extreme weather events improve economic, public health, infrastructure climate resilience efforts.
Protection of vulnerable communities	Extreme weather events affect vulnerable communities at a disproportionately higher rate when compared to communities that have advantages in resources. Emergency preparedness plans improve a community's ability to adapt to and/or resist the economic and social hardships brought on by these catastrophic events both prior to, during, and after these events occur.

References for action	● CT Department of Emergency Management and Homeland Security: Coastal Inundation and SLOSH Maps ● CT Department of Emergency Management and Homeland Security: Severe Weather links ● CT Division of Emergency Management and Homeland Security: Cold Weather Protocol ● Ready.gov: Severe weather preparedness ● Resilient MA蜉

2. Educate and assist private landowners and developers in the management of their lands to minimize impacts to wetlands and reduce risk from climate change.	
Recommended Implementation Action Description	Charge the CT Council on Soil and Water Conservation to develop an education/outreach program, in coordination with local conservation districts targeted at private landowners and developers in both urban and rural communities on the benefits of wetlands on climate change mitigation and adaptation that includes information on federal and state funding programs. Coordinate program priorities with USDA Natural Resource Conservation Service, USDA Forest Service, and NOAA to expand use of programs in Connecticut that provide funding for technical and financial assistance to private landowners and that benefit wetlands and protect ecosystem services. Expand the CT Flood and Erosion Control Act to provide funding, including match dollars for federal funds, for private land management. Set protection of wetlands as a priority for open space funding in Connecticut. Improve integration of education and outreach to stakeholder communities such as boaters, municipal harbor commissions, and landowners about conservation of tidal wetland habitats. This should include values of associated seagrass meadows and shellfish reefs as well as the need to minimize introductions of invasive species and the impacts of existing invaders.
Indicators and Targets	**Target 1.** Increase in federal dollars for assistance to private landowners in CT. **Target 2.** Increase in acres of protected wetlands.
Completion Timeframe	**Less than 2 years** ● Program development and implementation ● Coordinate with federal agencies ● Set wetlands as a priority in open space protection **3 - 5 years** ● Expansion of E&S Control Act

Implementation Entities	Lead: CT Council on Soil and Water Conservation, Conservation Districts, USDA, DEEP; Support: CACIWC, COGs, Municipalities, NGOs, CT Sea Grant UConn CIRCA.
Climate challenges addressed	The more information and technical assistance landowners have on the risks and potential impacts climate change has on their lands, the more informed decisions they can make concerning what private action they will take in order to manage their land. This is especially important because 85% of forested lands, including wetlands and floodplains, in Connecticut are privately owned and Connecticut has a well developed shoreline. Additionally developers need to be informed of the potential impacts their projects may have on wetlands in order to both give them the information they may need to apply for ACOE permits or decide to focus their development in areas where impacts will be minimized.
Protection of vulnerable communities	Vulnerable communities receive numerous ecosystem services from wetlands including clean water, flood protection, vector control. In Connecticut, our 3 largest urban centers are located "downstream" of inland wetlands and 2 of these are located on Long Island Sound. LMI will benefit from healthy wetlands that result in clean and abundant water supply, provide protection for severe storm events, and reduce mosquitos. Additionally, LMI landowners are underserved by USDA programs and need to be educated and have access to these programs.
References for action	CT Council on Soil and Water Conservation NRCS Landscape scale programs NRCS Wetlands Reserve Program CGS - Secs. 25-69 to 25-102 Flood Control and Beach Erosion蜉

3. Encourage adaptation strategies, including natural habitat conservation, Low Impact Development (LID) Best Management Practices (BMPs), agriculture water BMPs and drinking water treatment standards that will ameliorate the effects of water inundation	
Recommended Implementation Action Description	While projections show the overall annual increase in precipitation is expected to be only about five percent, changes in timing of precipitation could have a more pronounced impact. Precipitation patterns, especially in the form of winter rain and extreme precipitation events, while unpredictable, may increase the quantity of water at times when existing natural habitats are less capable of attenuating the flows that otherwise contribute to property and environmental destruction caused by flooding and groundwater related impacts. Furthermore, water quality may be impacted by the resulting increased stormwater runoff, which could in turn increase

	water treatment requirements for drinking water and nutrient and chemical loading to surface waters, as well as to natural terrestrial habitats and agricultural systems. The functionality of natural habitats, which naturally filter and retain precipitation, should be bolstered by reducing existing stressors such as invasives and habitat fragmentation, and by increasing natural habitat conservation within and around developed areas. These approaches not only provide relief from any immediate impacts, but also build resilience to future climate change impacts. Reducing stressors and increasing habitat conservation could be encouraged through state matching grants, cost sharing programs and tax incentives. LID BMPs could help minimize increased water runoff by encouraging more pervious development surfaces and green infrastructure measures that incorporate existing hydrology and mimic water retention of natural systems (e.g., rain gardens, green roofs, retention ponds). Agricultural systems could reduce water runoff by planting cover crops, installing vegetated swales, and handling manure through alternative manure technologies (e.g., manure biodigester). Guidelines could be developed for drinking water treatment facilities that adjust standards to compensate for potential increased water contamination.
Indicators and Targets	**Target.** Adoption of standards for the maximum impervious ground cover in municipal zoning regulations statewide.
Completion Timeframe	**Less than 2 years** ● State enabling legislation enacted to encourage municipalities to limit maximum impervious lot cover standards. **3 - 5 years** ● Local adoption of maximum impervious ground cover in municipal zoning regulations.
Implementation Entities	Connecticut State Legislature, Municipal Planning and Zoning Commissions, Council of Governments, CT Dept of Energy and Environmental Protection, CT Office of Policy and Management, UConn CLEAR.
Climate challenges addressed	Increases the climate resilience of built infrastructure by reducing the effects of flooding during high precipitation events. Increases the ability of wetland habitat to function as a water filtration buffer increasing water quality. Reduces impervious surface coverage in new development to increase on site storage of high precipitation events.
Protection of vulnerable communities	Many vulnerable communities live in urban areas around the state. These areas are particularly susceptible to water quality impacts of increased stormwater runoff because of their high land cover percentage of hard surfaces. Additionally, increasing the natural habitat within and around built infrastructure will be more

	concentrated near and in vulnerable communities, allowing them to receive the direct benefits of LID's and BMP's.
References for action	● Brabec et al. 2002. "Impervious Surfaces and Water Quality: A Review of Current Literature and Its Implications for Watershed Planning." ● Center for Watershed Protection: Impacts of Impervious Cover on Aquatic Systems ● CT DOT MS4 - Storm Quality Management Program ● EPA: Recovery Potential Metrics SUmmary Form蜉

4.Implement new or modified policies that would encourage appropriate land use and reduce repetitive losses	
Recommended Implementation Action Description	Historically, development in Connecticut has taken place in or near floodplains and wetlands. Increases in sea level rise and precipitation from severe storm events are changing flood boundaries. At present, the real estate market does not adequately account for the risks of climate change, especially sea level rise. Connecticut should develop new or updated land use policies related to flood plain management. Specifically, policies should acknowledge the role that CT tidal and inland wetlands play as important green infrastructure in reducing impacts of flooding including flood reduction, wave attenuation, velocity/scouring reduction, and sedimentation reduction. Flood plain management policies should include provisions for the protection, improvement, and restoration of wetlands and the flood control ecosystem services they provide.
Indicators and Targets	**Target 1.** Provide municipalities guidance for updating and addressing deficiencies in FIRM maps relating to sea level rise, severe storm events, and changes in development. This should include looking at near coastal riverine flood mapping being impacted by sea level rise and/or increased storm surge elevations. **Target 2.** Adopt state and local policies that account for the useful life expectancy of new construction including residential and apply sea level rise projections, changes in riverine flooding, and the role of wetlands to these standards when evaluating flood risks. **Target 3.** Adopt statewide and local strategies that address all existing infrastructure , including residential, located in floodplains or have experienced coastal or riverine flooding. Develop a tool for *Up (lift) and Out (remove)*, that looks at the life expectancy of infrastructure that determines if it is best to lift or remove the

	building from the floodplain. Policy to remove from should include plans to restore floodplains and adjacent wetlands as green infrastructure. **Target 4**. Develop, in coordination with the LMI community, a specific *"Up and Out"* strategy for existing low-middle income neighborhoods that recognizes the needs and limitations of the community in a high hazard area and that addresses the overnight gentrification that often happens as a result of a severe event. Include wetlands, as green infrastructure, as important tool in serving the LMI community. **Target 5.** Identify transportation corridors and land vulnerable to flooding from sea level rise or storm events and avoid siting new development in high risk areas. ● Indicator: incorporation of SLAMM results into assessments of development plans. ● Indicator: effective protection of inland wetlands that serve to buffer against flooding. ● Indicator: outreach material available to decision makers regarding the science driving the policy requirements. **Target 6.** Expand the use of Transfer of Development Rights enabling legislation to focus its use on the protection of riparian corridors, coastal and inland wetlands. ● Indicator: Revise transfer of development rights legislation to provide incentives for its use in protecting coastal and inland wetlands and riparian corridors. ● Indicator: Develop case studies and municipal guidance to implement transfer of development rights concepts for ecosystem services. ● Indicator: Provide legislative incentives for transfer of development rights that protect coastal wetlands and their adjoining buffer zones.
Completion Timeframe	**Less than 2 years** ● Identifying the strategies to follow for implementing new policies. **3 to 5 years** ● Implementation of new policies **Ongoing** ● Transportation
Implementation Entities	CIRCA, CT Sea Grant; CT DEEP; Inland Wetland Agencies; NGOs (Connecticut Audubon Society, Audubon Connecticut, The Nature Conservancy), Long Island Sound Study, land conservancies / trusts, CGA, municipal planning and zoning commissions, COGs, CT DOT

Climate challenges addressed	Promotes accounting for climate change risks when initiating any new developments. This will not only have climate mitigation benefits but help to adequately price climate risk in development
Protection of vulnerable communities	Existing state statutes, regulations, and policies regarding development in vulnerable areas should be evaluated, and the viability of implementing new or modified policies that would encourage appropriate land use and reduce repetitive losses should be investigated. Affordable housing must also include recognition of compliance to high hazard area regulations. Such policies could discourage building or rebuilding in high-hazard and projected inundation areas through such means as the Statewide Plan of Conservation and Development, zoning regulations, rolling easements and tax incentives.
References for action	● Hurricane Sandy Floodplain Easements ● Basso et al. 2015. "Status and Trends of Wetlands in the Long Island Sound Area." ● CIRCA homepage ● Craft, C., 2016. "Creating and Restoring Wetlands. Elsevier, Boston. 348p." ● DEEP: Inland Wetlands and Watercourses ● Johnston et al. 2018. "Using Ecosystem Service Values to Evaluate Tradeoffs in Coastal Hazard Adaptation" ● Kocian et al. 2015. "The Trillion Dollar Assessment: The Economic Value of the Long Island Sound Basin ● Millenium Ecosystem Assessment ● NOAA: Sea Level Affecting Marshes Model ● Pomeroy et al. 2013. "Valuing the Coast: Economic Impacts of Connecticut's Maritime Industry." ● UCONN: Sea Level Rise Effects on Roads and Marshes蜉

Recommendation 2020.W.3: Further develop policies that encourage protections for wetlands.

1. Update and develop wetland protection policies, including regulatory programs, to ensure that they include protection for climate change mitigation, adaptation, and resiliency benefits of wetlands and near coastal waters.	
Recommended Implementation Action Description	Review state policy/laws relating to wetland protections, including the Tidal Wetland Act and the Inland Wetland and Watercourses Act, and update as needed to include climate change mitigation/carbon sink/sequestration, adaptation, and resilience benefits and strategies of wetlands including, but not limited to, the following: a. Tidal Wetland Act - review the impact of the 4x40" general permit for docks on the physical integrity of tidal wetlands needed for GHG mitigation, to attenuate wave action, control erosion, and function in a healthy manner to control vector diseases. Add in policy that would allow for marsh migration to adapt to sea level rise. Add subaqueous soils to the Tidal Wetland Act. b. Inland Wetland and Watercourses Act - update the Act to include provisions for source water protection, water quality and quantity functions, and healthy ecosystem to control vector diseases. Specifically include the importance of forested wetlands and wetland soils in carbon sequestration and that address water regimes and impacts of flashy precipitation. c. Include recommendations for using the newest rainfall data modeling for establishing criteria for modeling stormwater provided by DEEP/UConn CLEAR. d. Ensure that FIRM maps and base flood elevations are augmented for municipal use by CIRCA data for sea level rise and storm events. e. Review impacts on affordable housing by legislation that incentivizes development in flood hazard areas, essentially bringing LMI families to the nuisance/hazard.
Indicators and Targets	**Target 1.** Legislative initiative to strengthen the Inland Wetlands and Watercourses Act and Tidal Wetlands Act so they specifically mention the role of wetlands in carbon sequestration and other climate change adaptation functions. **Target 2.** Increase in acres of functional wetlands and reduction in acres impacted by land use. **Target 3.** Promote restoration of wetlands. **Target 4.** Improve vector disease control by protecting and restoring wetlands to healthy ecosystems. **Target 5.** Our congressional representatives push for strengthening the definition of Waters of the U.S. under the Clean Water Act.

Completion Timeframe	**Less than 2 years** - Policy review and legislative proposals prepared for consideration
Implementation Entities	CT DEEP, CT Council on Soil and Water Conservation, Conservation Districts, Municipal Land Use Commissions, CACIWC, CT State Legislature, NGOs, Academic Institutions,
Climate challenges addressed	Curbs loss of wetland functions from development. Promotes climate mitigating effects of wetlands (carbon sink/sequestration, temperature moderation). Promotes climate adaptation through improving quality and quantity of drinking water, flood protection and sediment control, healthy wetlands to control vector diseases, healthy wetlands to maintain biodiversity and fishing/shellfishing industry in LIS.
Protection of vulnerable communities	Vulnerable communities receive numerous ecosystem services from wetlands including clean water, flood protection, vector control. In Connecticut, our 3 largest urban centers are located "downstream" of inland wetlands and 2 of these are located on Long Island Sound. LMI will benefit from healthy wetlands that result in clean and abundant water supply, provide protection for severe storm events, and reduce mosquitos. Additionally, because wetland and flood hazard zones land values are cheaper, these lands are often identified for development of affordable housing. Environmental justice usually looks at bringing a nuisance/hazard to a community (e.g.) land fills). In this case, using lands that are marginal for development LMI housing is bringing the community to the nuisance/hazard and should be avoided. Converting land back to wetlands and restoring ecosystem services can serve to protect vulnerable communities from unsustainable development practices which often result in direct harms to community health, economic prosperity, and stability.
References for action	Hurricane Sandy Floodplain Easements SSM - Ch. 10. Subaqueous Soil Survey | NRCS Soils Coastal Permitting - CTDEEP

2. Reevaluate Connecticut's Green Plan and open space grant programs to prioritize acquisition of land and conservation easements for ecosystem services most at risk from climate change	
Recommended Implementation Action Description	Land protection, through acquisition or easement, is an important tool for the protection of ecosystem services,including those provided by wetlands. The State's Green Plan should be updated to reflect not only the effects of climate change on wetland ecosystems but also the role that these systems play in both climate change mitigation of GHG and

	adaptation/resiliency. The current 2016-2020 Green Plan does include habitats identified as most at risk from climate change, including forested swamps, land adjacent to freshwater and tidal wetlands, riparian lands adjacent to cold water streams and beaches and dunes. While work by CT DEEP and partners has made progress on several of these habitats, more work is needed in prioritizing these habitats and other ecosystem services provided by wetlands. (Adaptation Subcommittee to the Governor's Steering Committee on Climate Change 2011).
Indicators and Targets	**Target 1.** Identification and development of needed data analyses and maps to assist in the prioritization of parcels for conservation based on climate impacts. (see comment on easements). **Target 2.** Update the CT Green Plan to include land protection guidelines reflecting the most current information on climate change mitigation and adaptation needs, as well as available habitat assessments (e.g. SLAMM, UConn Clear riparian corridor analysis and forest fragmentation analysis, NWI). **Target 3.** Promote the new CT Green Plan acquisition priorities with partners, particularly with regard to open space grants. ● Indicator: Increase in applications for grants focused on priority ecosystem services and habitats. ● Indicator: Increase in protection of ecosystem services and priority habitats ● Indicator: Increase in connectivity of protected land parcels **Target 4**. Identify landscape scale projects/opportunities, working with other state and federal agencies, that will leverage funding for land protection.
Completion Timeframe	**Less than 2 years** ● Identification and development of needed data analyses and maps to assist in the prioritization of parcels for conservation based on climate impacts **3 - 5 years** ● Update the CT Green Plan to include land protection guidelines reflecting the most current information on climate change and adaptation needs, as well as available habitat assessments **Ongoing** ● Promote the new CT Green Plan acquisition priorities with partners, particularly with regard to open space grants
Implementation Entities	CT DEEP, USDA NRCS, CT Forest and Park, CT Land Conservation Council, Land Trusts across the state, The Nature Conservancy, Audubon, Trout Unlimited and other NGO's, Municipalities, Council for Environmental Quality, Utilities

Climate challenges addressed	Promotes habitat connectivity, particularly in riparian zones which in turn increases the long-term climate resilience of the ecosystem by decreasing edge habitat and habitat fragmentation effects. Riparian systems are naturally resilient to extreme weather events and provide hydrological benefits by increasing infiltration and mitigating flood impacts. Riverine habitats function as corridors for many species and may aid in providing both habitat and corridors for distributional shifts in species due to climate change. Protection of riparian corridors provides shade to watercourses, cooling water temperatures; in addition, riparian areas absorb heat (water has high heat capacity) and protect riparian corridor organisms against extreme temperatures. Protection of lands promotes carbon sequestration. Provides for tidal marsh migration with sea level rise (see 3c).
Protection of vulnerable communities	Prioritizing land acquisitions of habitats most at risk from climate change will ensure that those habitats, such as wetlands, that provide massive benefits to climate resiliency (as in the case of salt marsh soils that are large carbon sinks) are protected from development. Additionally, increasing land acquisition of critical habitats increases the amount of green space available for public use. Because many tidal and inland wetlands abut vulnerable communities, protecting these lands through state acquisition or easement will ensure that those communities without the resources to acquire these lands will continue to receive the benefits of their "ecosystem services".
References for action	● Audubon CT Forest Focal Bird Areas ● Janowiak et al. 2018. "New York and Northern New England Forest Ecosystem Vulnerability Assessment and Synthesis." ● Naiman, et al. 2007. "Riparia: Ecology, Conservation and Management of Streamside Communities." ● Seth et al. 2019. "Connecticut Physical Science Assessment Report." ● UConn CLEAR - forest fragmentation analysis ● UConn CLEAR - riparian corridor analysis蛑

3. Acquire land and conservation easements to provide upslope — advancement zones adjacent to tidal marshes	
Recommended Implementation Action Description	As sea level rises, tidal marshes will move inland to upslope "advancement zones" as elevations allow. However, tidal marshes will not be able to move to advancement zones if barriers such as private development and infrastructure impede natural migration. Tidal marshes and the benefits they impart on the Connecticut coast, such

	as flood and storm protection, will be lost if current undeveloped land adjacent to tidal marshes is not protected through direct purchase, conservation easements or setbacks. These advancement zones should be identified and prioritized for protection. CT DEEP has worked with Warren Pinnacle Consulting, Inc. to apply Sea Level Affecting Marshes to Connecticut's shoreline. The model results for Connecticut's 21 largest marshes and all coastal roads provides key information in determining which upland areas are key for marsh migration. In addition, CT Sea Grant worked with CT DEEP to develop a prioritization protocol for these upland areas. CT DEEP has also developed a fact sheet specific to the East River Marsh complex on marsh migration.
Indicators and Targets	**Target 1.** Land owners adjacent to coastal wetlands understand the importance of marsh migration in protecting marshes for the long term. ● Indicator: Education and outreach to land owners on the importance of marshes and marsh migration (community engagement). ● Indicator: Develop fact sheets for these marshes using the East River marsh fact sheet as a template. **Target 2.** Prioritization of upland areas for the state's 21 largest marshes based on SLAMM results. ● Indicator: Tracts of land suitable for marsh migration adjacent to these 21 marshes are identified. ● Indicator: Tracts are prioritized using tools developed by CT DEEP and CT Sea Grant. ● Indicator: High priority lands as identified above are protected through various means (eg, fee, easement etc.) Caveat: Protection of priority uplands through land acquisition and conservation easements (though see Field et al. 2017 below which suggests that easements alone may not be enough to mitigate marsh losses on the scale needed.) **Target 3.** Development of new conservation strategies in addition to acquisition and easements.
Completion Timeframe	**3 to 5 years** ● Develop fact sheets for these marshes using the East River marsh fact sheet as a template. ● Tracts of land suitable for marsh migration adjacent to these 21 marshes are identified. ● Tracts are prioritized using tools developed by CT DEEP and CT Sea Grant. **Ongoing** ● Education and outreach to land owners on the importance of marshes and marsh migration (community engagement).

	• High priority lands as identified above are protected through various means (eg, fee, easement etc.) Caveat: Protection of priority uplands through land acquisition and conservation easements . • Development of new conservation strategies in addition to acquisition and easements.
Implementation Entities	CT DEEP, USFWS, Audubon, coastal land trusts, coastal municipalities, COG's, Long Island Sound Study, CT Sea Grant, University of Connecticut and other local universities, CT DOT
Climate challenges addressed	Protects against the impacts of sea level rise.
Protection of vulnerable communities	Prioritizing land acquisitions of habitats most at risk from climate change will ensure that those habitats, such as wetlands, that provide massive benefits to climate resiliency (as in the case of salt marsh soils that are large carbon sinks) are protected from development. Additionally, increasing land acquisition of critical habitats increases the amount of green space available for public use. Because many tidal and inland wetlands abut vulnerable communities, protecting these lands through state acquisition or easement will ensure that those communities without the resources to acquire these lands will continue to receive the benefits of their "ecosystem services".
References for action	• Field et al. 2017. "Landowner behavior can determine the success of conservation strategies for ecosystem migration under sea-level rise. Proceedings of the National Academy of Sciences 114:9134-9139." • Field et al. 2017. "Landowner behavior can determine the success of conservation strategies for ecosystem migration under sea-level rise." • Field et al. 2019. "Quantifying the return on investment of social and ecological data for conservation planning." • UCONN: Sea Level Rise Effects on Roads and Marshes

Appendix

The following is a list of actions that the Wetlands subgroup identified in the 2011 GC3 report as actions that it will continue to augment or support efforts by other subgroups under the Working and Natural Lands Working Group.

- Encourage development practices that ensure water recharge (Intersections, pg. 18)
- Increase active management of upland forests and reduce non-climatic stressors (Natural Resources, pg. 57)
- Consider the public health needs of vulnerable populations in climate change adaptation planning (Public Health, pg. 64)
- Evaluate current early extreme weather events warning system and emergency response plans (Public Health, pg. 65)
- Develop decision tools to evaluate replacement, modification, and design life for infrastructure (Infrastructure, pg. 49)
- Minimize water use across all agricultural sectors (Agriculture, pg. 35)
- Assess future flooding risks to natural and built infrastructure, including agricultural operations and public health and safety (Intersections, pg. 15)
- Develop educational campaigns for climate change adaptation awareness in Connecticut targeted at multiple sectors (Intersections, pg. 25)
- Identify champions for each adaptation strategy (Intersections, pg. 25)
- Identify research needs and disseminate current climate change adaptation research and technical resources to the appropriate stakeholders, and encourage future efforts through state grants (Intersections, pg. 25)
- Determine the critical public buildings, including public health facilities, schools and cultural/historic buildings that will be impacted by coastal and inland flooding, and recommend appropriate adaptation strategies that will not adversely impact natural resources (Intersections, pg. 27)
- Determine vulnerable transportation routes and transportation options that may adversely impact natural resources and human mobility needs under future climate change projections (Intersections, pg. 28)
- Build public consensus for adaptation strategies through education and outreach (Natural Resources, pg. 59)
- Perform a comprehensive modeling assessment of the extent of inland migration of tidal marshes essential for directing adaptation actions (Natural Resources, pg. 59)
- Partner with educational institutions or organizations that conduct research (Natural Resources, pg. 59)
- Identify and collaborate with educational partners (Intersections, pg. 25)
- Educate other sectors of state government about public health climate change impacts and adaptation (Public Health, pg. 68)
- Educate local health department staff on climate change impacts (Public Health, pg. 68)
- Assist local health departments with climate change adaptation (Public Health, pg. 68)
- Incorporate climate change preparedness strategies into public health education (Public Health, pg. 69)
- Increase airborne pollen monitoring (Public Health, pg. 69)

- Analyze the competing demands on Connecticut water quantity and quality statewide in a consistent and comprehensive manner and develop new approaches to ensure public health, agricultural sustainability, ecosystem health, while supporting multiple and conflicting needs (Intersections, pg. 21)
- Assess the impact of climate change on wastewater treatment facilities, and encourage the development of facility-specific adaptation plans (Intersections, pg. 24)
- Develop Connecticut - specific climate change projections for temperature, precipitation and sea level rise and support monitoring efforts for these climate drivers (Intersections, pg. 24)
- Proceeds from RGGI auctions should support climate change adaptation work identified in this report and in accordance with Section 22a-200c(c). (Intersections, pg. 28)
- Protect critical soil landscapes (Agriculture, pg. 40)
- Collaborate among state agencies, municipalities and non-profits within Connecticut to implement regulations and policies that promote and facilitate the conservation of habitats and species most at risk from climate change (Natural Resources, pg. 60)
- Further regulate the introduction and spread of invasive species (Natural Resources, pg. 61)
- Collaborate with other states and federal agencies on coordinated regional adaptation plan (Natural Resources, pg. 61)
- Continue to support regional cooperation on climate change adaptation through involvement in regional planning activities (Intersections, pg. 28)
- Continue to support funding to provide for adequate updates to municipal sewage infrastructure (Public Health, pg. 72)
- Support funding to provide for adequate updates to municipal water infrastructure (Public Health, pg. 72)
- Target headwaters for protection throughout the state (Intersections, pg. 17)
- Provide support for agriculture climate change adaptation education and research (Agriculture, pg. 38)
- Minimize combined sewer overflows (Agriculture, pg. 40)

References

Arkema, K.K., Guannel, G., Verutes, G., Wood, S.A., Guerry, A., Ruckelshaus, M., Kareiva, P., Lacayo, M., and Silver, J.M. 2013. Coastal habitats shield people and property from sea-level rise and storms. Nat. Clim. Chang., 3, 1–6.

ASCE. Failure to Act: Closing the Infrastructure Investment Gap for America's Economic Future; ASCE: Reston, VA, USA, 2016; 32 pp. https://www.infrastructurereportcard.org/wp-content/uploads/2016/10/ASCE-Failure-to-Act-2016-FINAL.pdf

Basso, Georgia, Jamie M. P. Vaudrey, Kevin O'Brien, Juliana Barrett. 2018. "Advancing Coastal Habitat Resiliency Through Landscape-Scale Assessment." 2018. Coastal Management. https://www.tandfonline.com/doi/full/10.1080/08920753.2018.1405328. Cited. 183 C. 532; 211 C. 416; 227 C. 71.

Bridges, T. S., Bourne, E. M., King, J. K., Kuzmitski, H. K., Moynihan, E. B. and Suedel, B. C. 2018. Engineering With Nature: an atlas. ERDC/EL SR-18-8. Vicksburg, MS: U.S. Army Engineer Research and Development Center. http://dx.doi.org/10.21079/11681/27929.

Bridges, T. S., Wagner, P. W., Burks-Copes, K. A., Bates, M. E., Collier, Z., Fischenich, C. J., Gailani, J. Z., Leuck, L. D., Piercy, C. D., Rosati, J. D., Russo, E. J., Shafer, D. J., Suedel, B. C., Vuxton, E. A., and Wamsley, T. V. 2015. Use of natural and nature-based features (NNBF) for coastal resilience. U.S. Army Engineer Research and Development Center, ERDC SR-15-1, Vicksburg, MS, 479 pp. https://ewn.el.erdc.dren.mil/pub/Pub_4_NNBF_Final_Report_v2.pdf

"Chapter 440 - Wetlands and Watercourses." 2011. Ct.Gov. 2011. https://www.cga.ct.gov/current/pub/Chap_440.htm#sec_22a-29.

Connecticut Blue Plan. 2019. Ecological Characterization Summary. Connecticut Department of Energy and Environmental Protection, Hartford. Available at: https://portal.ct.gov/-/media/DEEP/coastalresources/LIS_blue_plan/BluePlanEcologicalCharacterizationSummarypdf.pdf

"Connecticut Wetlands." 2020. CT.Gov - Connecticut's Official State Website. 2020. https://portal.ct.gov/DEEP/Water/Wetlands/Connecticut-Wetlands.

DeFries, R., Edenhofer, O., Halliday, A., Heal, G., Lenton, T., Puma, M., Rising, J., Rockström, J., Ruane, A.C., Schellnhuber, H.J., Stainforth, D., Stern, N., Tedesco, M., and Ward, B. 2019. The missing economic risks in assessments of climate change impacts. The Grantham Research Institute on Climate Change and the Environment, The Earth Institute, and The Potsdam Institute for Climate Impact Research, Policy Insight, 15 pp. https://www.lse.ac.uk/granthaminstitute/publication/the-missing-economic-risks-in-assessments-of-climate-change-impacts/

Dupigny-Giroux, L.A., Mecray, E.L., Lemcke-Stampone, M.D., Hodgkins, G.A., Lentz, E.E., Mills, K.E., Lane, E.D., Miller, R., Hollinger, D.Y., Solecki, W.D., Wellenius, G.A., Sheffield, P.E., MacDonald, A.B., and Caldwell, C. 2018.Northeast. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 669–742. doi: 10.7930/NCA4.2018.CH18. https://nca2018.globalchange.gov/chapter/18/

EPA 2020. Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2018. EPA 430-R-20-002, 733 pp. https://www.epa.gov/sites/production/files/2020-04/documents/us-ghg-inventory-2020-main-text.pdf or https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

Fargione, J.E., Bassett, S., Boucher, T., Bridgham, S.D., Conant, R.T., Cook-Patton, S.C., Ellis, P.W., Falcucci, A., Fourqurean, J.W., Gopalakrishna, T., Gu, H., Henderson, B., Hurteau, M.D., Kroeger, K.D., Kroeger, T., Lark, T., Leavitt, S.M., Lomax, G., McDonald, R.I., Megonigal, J.P., Miteva1, D.A., Richardson, C.J., Sanderman, J., Shoch, D., Spawn, S.A., Veldman, J.W., Williams, C.A., Woodbury, P.B., Zganjar, C., Baranski, M., Elias, P., Houghton, R.A., Landis, E., McGlynn, E., Schlesinger, W.H., Siikamaki, J.V., Sutton-Grier, A.E., and Griscom, B.W. 2018. Natural Climate Solutions for the United States. Sci. Adv. 2018; **4** : eaat1869

Fleming, E., Payne, J., Sweet, W., Craghan, M., Haines, J., Hart, J.F., Stiller, H., and Sutton-Grier, A. 2018: Coastal Effects. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 322–352. doi: 10.7930/NCA4.CH8. https://nca2018.globalchange.gov/chapter/8/

Governor's Steering Committee on Climate Change Adaptation Subcommittee. 2011 "Connecticut Climate Change Preparedness Plan." n.d. Accessed August 5, 2020. https://portal.ct.gov/-/media/DEEP/climatechange/ConnecticutClimatePreparednessPlan2011pdf.pdf.

"How Are Inland Wetlands and Watercourses Defined." 2020. CT.Gov - Connecticut's Official State Website. https://portal.ct.gov/DEEP/Water/Inland-Wetlands/How-Are-Inland--Wetlands-and-Watercourses--Defined.

Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. 2016. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, 35 pp. https://www.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf

"Inventoried Roadless Area Acreage by State." 2020. Usda.Gov. 2020. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm8_037652.htm.

Jacobs, J.M., Culp, M., Cattaneo, L., Chinowsky, P., Choate, A., DesRoches, S., Douglass, S. and Miller, R. 2018: Transportation. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 479–511. doi: 10.7930/NCA4.2018.CH12. https://nca2018.globalchange.gov/chapter/12/

Kirwan, M., Temmerman, S., Skeehan, E., Guntenspergen, G.R. and Fagherazzi, S. 2016. Overestimation of marsh vulnerability to sea level rise. Nature Climate Change 6**,** 253–260. https://doi.org/10.1038/nclimate2909

Lipton, D., Rubenstein, M. A., Weiskopf, S.R., Carter, S., Peterson, J., Crozier, L., Fogarty, M., Gaichas, S., Hyde, K.J.W., Morelli, T.L., Morisette, J., Moustahfid, H., Muñoz, R., Poudel,

R., Staudinger, M.D., Stock, C., Thompson, L., Waples, R. and Weltzin, J.F. 2018: Ecosystems, Ecosystem Services, and Biodiversity. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 268–321. doi: 10.7930/NCA4.2018.CH7

McLeod, E., Chmura, G.L., Bouillon, S., Salm, R., Bjork, M., Duarte, C.M., Lovelock, C.E., Schlesinger, W.H. and Silliman, B.R. 2011. A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO_2. Front. Ecol. Environ. 9, 552–560. https://doi.org/10.1890/110004

Metzler, K. and J.P. Barrett. 2006. *The Vegetation of Connecticut: A Preliminary Classification.* Publication of the State Geological and Natural History Survey of the Connecticut Department of Environmental Protection. No. 12. Htfd. 110

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-Being: Wetlands and Water Synthesis. World Resources Institute, Washington, DC., 80pp. https://www.millenniumassessment.org/documents/document.358.aspx.pdf

Narayan, S., Beck, M.W., Reguero, B.G., Losada, I.J., van Wesenbeeck, B., Pontee, N., Sanchirico, J.N., Ingram, J.C., Lange, G.-M., and Burks-Copes, K.A. 2016. The Effectiveness, Costs and Coastal Protection Benefits of Natural and Nature-Based Defences. PLoS ONE, *11*, e0154735, doi:10.1371/journal.pone.0154735.

Savageau, Denise M. 2020. "Wetland and Subaqueous Soils: Climate Change Mitigation and Adaptation."

Shrestha, G., Cavallaro, N., Lorenzoni, L., Seadler, A., Zhu, Z., Gurwick, N. P., Larson, E., Birdsey, R., Mayes, M.A., Najjar, R.G., Reed, S.C. and Romero-Lankao, P. 2018: Highlights. In Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report. [Cavallaro, N., G. Shrestha, R. Birdsey, M. A. Mayes, R. G. Najjar, S. C. Reed, P. Romero-Lankao, and Z. Zhu (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 1-4, doi: 10.7930/SOCCR2. Highlight: https://carbon2018.globalchange.gov/#fn1

"State Summary Highlights." 2020. Usgs.Gov. 2020. https://water.usgs.gov/nwsum/WSP2425/state_highlights_summary.html#:~:text=Wetlands%20cover%20about%20173%2C000%20acres,between%20the%201780's%20and%201980's.

Sutton-Grier, A.E., Gittman, R.K., Arkema, K.K., Bennett, R.O., Benoit, J., Blitch, S., Burks-Copes, K.A., Colden, A., Dausman, A., DeAngelis, B.M., Hughes, A.R., Scyphers, S.B., and Grabowski, J.H. Investing in Natural and Nature-Based Infrastructure: Building Better Along Our Coasts. Sustainability 10(2), 523, 2018. Available at: http://www.mdpi.com/2071-1050/10/2/523/html

Sutton-Grier, A.E., Wowk, K., and Bamford, H. 2015. Future of our coasts: The potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems. Environ.Sci. Policy, 51, 137–148.

"Tidal Wetlands Primer What Are Tidal Wetlands?" n.d. https://portal.ct.gov/-/media/DEEP/coastal-resources/Tidal_Wetlands/TW_Primer.pdf.

Torio, Dante D., and Gail L. Chmura. 2013. "Impacts of Sea Level Rise on Marsh as Fish Habitat." *Estuaries and Coasts* 38 (4): 1288–1303." https://doi.org/10.1007/s12237-013-9740-y.

Wang, F., Lu, X., Sanders, C.J. and Tang, J. 2019. Tidal wetland resilience to sea level rise increases their carbon sequestration capacity in United States. Nat. Commun. **10,** 11 pp. https://doi.org/10.1038/s41467-019-13294-z

Webb, B., Dix, B., Douglass, S., Asam, S., Cherry, C., and Buhring, B. Nature-Based Solutions for Coastal Highway Resilience: An Implementation Guide. FHWA-HEP-19-042, August 2019, 229 pp. https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/green_infrastructure/implementation_guide/fhwahep19042.pdf

Zajac, R.N. L.M. Stefaniak, I. Babb, C.W. Conroy, S. Penna, D. Chadi, and P.J. Auster. 2020. An integrated seafloor habitat map to inform marine spatial planning and management: a case study from Long Island Sound (Northwest Atlantic). p. 199-217 in: P.T. Harris and E.K. Baker (editors), Seafloor Geomorphology as Benthic Habitat: GeoHab Atlas of Seafloor Geomorphic Features and Benthic Habitats, Second Edition. Elsevier Inc., Amsterdam.