2022 Annual Climate Report to the Maryland Commission on Climate Change and the Governor

Introduction

Climate change is an important consideration under the mission and operations of the Maryland Department of Natural Resources (DNR). The department uses science, data, monitoring and modeling to inform investment decisions, determine impacts to habitat, and understand the potential effects climate change has on our waterways and our communities. The department also leads the Maryland Commission on Climate Change Adaptation and Resilience (formerly "Response") Working Group (ARWG), which recommends actions on preparedness from sea level rise and more intense storms.

The Maryland Greenhouse Gas Reduction Act (GGRA) requires a 25 percent reduction in greenhouse gas (GHG) emissions from 2006 levels by 2020. The law, reauthorized during the 2016 legislative session, further extended the goal to a 40 percent reduction by 2030, and has since been enhanced to 60 percent by 2031 and net zero by 2045 by the Maryland Commission on Climate Change. The department contributes to mitigating greenhouse gasses through managing public and private forests, planting trees, and restoring streams and wetlands. This report does not reflect changes in how we calculate carbon benefits of the programs for the 2030 plan unless specifically referenced. This document details what the department has done in the past year to contribute to greenhouse gas mitigation and our progress towards the goals laid out in the GGRA plan. It also details our work providing guidance for climate adaptation and response and what we have done to educate the public on how climate change will impact them.

Highlight Facts/Figures

- Both planting and managing forests have exceeded the 2020 goal and are progressing towards the 2030 goals
- 50,327 forest acres managed in 2021 - 117% percent of 15 year average.
- 1,972.4 forest acres planted in 2021 - 70% percent of 15 year average.
- The Chesapeake and Atlantic Coastal Bays Trust Fund restored 239.5 acres of wetlands and 20.5 acres of riparian buffers in FY22 and has funded the restoration of 3,527 acres of wetlands and 1,608 acres of riparian buffers since 2009.

Table of Contents

DNR will continue to track all the programs currently included in the GGRA for meeting Maryland's 2030 GHG reduction goals. There are changes in the 2030 plan relative to what was included in the original 2020 plan to reflect new scientific data, understanding, and tools. For example, emission of methane from wetlands makes the net GHG impact of Creating and Protecting Wetlands uncertain so we now only include tidal wetland restoration where methane emissions are typically negligible. While DNR did not realize GHG benefits from 2006-2020 associated with Biomass for Energy Production, Geological Opportunities to Store Carbon, or Creating Ecosystems Markets, work is underway that will likely produce results during the 2020-2030 period. For example, Maryland is one of eight partner states in the Midwest Region Carbon Sequestration Partnership whose role is to identify, locate, and characterize potential geologic storage opportunities.

Maryland is actively working to promote biomass to energy in the state as an important part of our forest industry and anticipates new installations prior to 2030 if feasible. The Maryland Forest Service was awarded nearly $250,000 for a Wood Innovations Grant from the U.S. Department of Agriculture (USDA) to develop priority projects with the Maryland Wood Energy Team. This partnership with the Maryland Clean Energy Center, Maryland Department of Commerce, University of Maryland Extension, the USDA Forest Service, and others aim to develop wood energy facilities that will produce new jobs and develop renewable energy markets for underutilized forest products, which will in turn benefit the health of Maryland's sustainable forests. The funding is supporting the hiring of a woody biomass energy coordinator who staffs the new Maryland Wood Energy Team to identify wood energy opportunities throughout the state. DNR's Maryland Forest Service will collaborate with experts at the USDA Forest Service to provide design assistance to five to ten facilities in the state that have high probability for conversion to wood fuel.

Maryland is also actively working to advance markets for the forest industry, including advocating for policy changes related to thermal Renewable Energy Credits that would provide greenhouse gas benefits. Diverse markets that include outlets for low-value wood from thinning and timber stand improvement help land managers carry out sustainable forestry and generate a mix of forest products.

The US Climate Alliance (USCA) has funded a project led by the University of Maryland which is working with partners including DNR, Delaware Department of Natural Resources and Environmental Control, and the World Resource Institute to combine high resolution LiDAR based estimates of forest carbon with annual estimates of forest cover change from satellite imagery. This will improve Maryland's greenhouse gas inventory by better understanding both how much forest is being lost or gained and how that translates into our carbon budget. This will allow us to more frequently and accurately track progress towards our forestry goals. The estimates of forest change and trees outside of forests will be used to supplement the USFS Carbon Inventory[1] based on Forest Inventory and Analysis data. The USFS uses annual field monitoring to update the forest carbon inventory, but relies on more approximate methods to estimate the sink from "settlement trees" or trees outside of what is defined as forests. Land-use change data from the (updated every 5 years) National Land Cover Dataset is utilized in the USFS inventory whereas annual change data is utilized in the new approach. The resulting inventory estimates are now

---

[1] Domke, Grant M.; Walters, Brian F.; Nowak, David J.; Smith, James, E.; Ogle, Stephen M.; Coulston, J.W.; Wirth, T.C. 2020. Greenhouse gas emissions and removals from forest land, woodlands, and urban trees in the United States, 1990-2018. Resource Update FS-227. Madison, WI: U.S. Department of Agriculture, Forest Service, Northern Research Station. 5 p. https://doi.org/10.2737/FS-RU-227.

available for use in Maryland's 2020 GHG inventory and have been backcasted to 2006 for use in assessing progress.

Environmental Justice

Environmental Justice (EJ) is an important consideration in creating and maintaining sustainable communities, and forests and forest management practices can significantly impact the health of our neighborhoods and towns. Tree canopy has been shown to remove air pollutants and reduce risk of respiratory and cardiac health problems[2]. DNR works to expand the tree canopy in Maryland through various programs including tree planting in urban areas. For example, DNR has funded organizations that have planted over 12,000 trees in Baltimore City over the past 10 years.

Environmental justice is also a concern when considering how climate change is impacting our coastal wetlands and communities. Saltwater intrusion is causing farm acreage to become non-arable and forests to die off, particularly on Maryland's lower eastern shore. The Maryland Department of Planning has created a saltwater intrusion plan to identify problem areas and suggest viable paths forward, and DNR is examining ways their land conservation and easement programs might allow landowners to receive compensation for lands they are losing by converting them to wetlands.

Additionally, DNR uses tools such as the EJ Screening Tool and the Maryland Park Equity Tool in public lands planning and ecological restoration project selection to help identify appropriate areas for infrastructure investment.

Greenhouse Gas Mitigation Programs

1. <u>Managing More Forests to Capture Carbon</u>

<u>Program Description</u>
Managing more forests to capture carbon will promote sustainable forestry management practices in existing Maryland forests on both public and private lands. Enrolling unmanaged forests into management regimes enhances forest productivity which increases rates of carbon sequestration in forest biomass and the amount of carbon stored in harvested durable wood products. This translates to economic benefits and increased availability of renewable biomass for energy production.

This increased forestry management in Maryland is estimated to result in a 1.80 million metric tons of carbon dioxide equivalent (MMtCO2e) cumulative reduction in the state's greenhouse gas (GHG) emissions by 2020. The 2020 goals of this program are to improve sustainable forest management on 30,000 acres of private land annually, and ensure 50 percent of state-owned forest lands will be third-party certified as sustainably managed. This program is performing as designed, and the 2020 15 year target goal for cumulative acres managed was exceeded in 2018. The 2030 goals of this program are to improve sustainable forest management on 38,000 acres of

---

[2] U.S. EPA. Environmental Benefits Mapping and Analysis Program: Community Edition (BenMAP-CE) User Manual and Appendices. Research Triangle Park, NC, USA. April, 2017. www.epa.gov/benmap

private land annually, and ensure greater than 50 percent of state-owned forest lands will continue to be third-party certified as sustainably managed. This annual acreage target was exceeded in both 2020 and 2021.

Program Objectives

By 2020 the potential emission reductions from the program are estimated to be 1.80 MMtCO2e. This number represents an estimate of the cumulative carbon sequestered through the program relative to a baseline of no management. Appendix C of the 2015 GGRA Update provides a more detailed description of the process used to quantify greenhouse gas reductions for the 2020 goal presented here, and the 2030 GGRA Plan provides details on the 2030 goal and methodology used to determine it.

Implementation Milestones

Public Lands:
- Since 2006, 211,000 acres of state forests have been certified with dual third party certification for forest sustainability to the Sustainable Forestry Initiative and Forest Sustainability Certification standards.
- DNR is developing similar sustainable forest management practices on wildlife land. Forest stewardship plans are being developed for state park lands to control invasive species and improve the health of the forest.
- DNR's Wildlife and Heritage Service is developing forest stewardship plans on several wildlife management areas.
- The DNR has accelerated the pace of silvicultural activity:
  - Savage River State Forest will increase the number of timber sales from 14 to 20.
  - State forest annual work plans included 2,324 acres of timber harvests for FY19, that will be naturally regenerated.

Private Lands:
- Since 2006 we have implemented:
  - 356,512 acres of stewardship plans
  - 207,841 acres of sediment control
  - 121,691 acres of forest stand improvements (eg., tree planting, timber stand improvements, wildlife habitat)
  - Total of 686,044 acres of forest management planning activities on private lands
- DNR has met the 2020 goal.

Technical Assistance Provided:
- Forest stewardship plan preparation
- Forest stewardship plan implementation – expanded special rivers project
- Financial assistance – state and federal cost sharing
  - Woodland Incentive Program
  - Healthy Forests/Healthy Waters
    - Working on the next round of projects
  - Backyard Buffer Program
  - Environmental Quality Incentive Program (EQIP)

- ○ Conservation Reserve Enhancement Program (CREP)
- ○ Income Tax Modification (TAXMOD)
  - ■ Expanded eligibility of forestry practices in 2014
- ○ Forest Conservation and Management Program
- ○ Woodland Assessment Program
- Completed the development and application of the University of Maryland remote sensing capability for forest carbon assessment. This work was the basis for the forest carbon sink that was included in the 2020 GHG Inventory, released by MDE in October 2022.
- Launch of National Aeronautics and Space Administration, U.S. Department of Agriculture and U.S. Department of Energy climate science project for remote sensing, modeling and field-based measurements to quantify the carbon consequences of alternate development and management plans across rapidly changing forests in Maryland.
- Forest Management Study

  DNR identified a forest management site that utilizes three forest management plans: Low Management (100 percent hardwoods), Moderate Management (50-70 percent pines: 30-50 percent oaks) and High Management (100 percent pine). DNR's Resource Assessment Service continues to evaluate the below ground carbon sequestration on these management plots to complement the determination of carbon sequestration in the above-ground forest. Baseline data was collected annually from 2011 to 2014. After analysis of the 2014 data, this project was changed to a 5-year sampling interval. Expected project completion is 2030.
- ○ DNR worked with federal partners at the US Department of Commerce and an array of Maryland conservation and economic development agencies to conduct an Economic Adjustment Strategy for the forestry industry in Maryland.

Estimated Emission Reductions for CY2021
- Forest management on private land in Maryland reduced carbon emissions by 0.26 MMtCO2e.
- Forest management on public land in Maryland reduced carbon emissions by 0.21 MMtCO2e.
- Both exceed yearly reduction goals.

Table 1 Acres of Forest Management

Calendar Year	Stewardship Plan(1)	Sediment Control(1)	State Forest Regeneration(2)	Timber Stand Improvement(1)	Wildlife Habitat(1)	Total Acres
2006	13,834.10	9,113.10	2,417.00	3,092.90	2,172.60	30,629.70
2007	14,135.00	11,204.80	1,731.00	5,925.60	3,331.40	36,327.80
2008	26,787.30	11,692.20	1,823.50	5,611.20	4,146.40	50,060.70
2009	17,936.90	11,044.40	2,234.10	3,789.20	3,212.80	38,217.40
2010	14,921.20	9,539.80	2,158.20	3,178.00	2,070.60	31,867.80
2011	22,012.10	11,585.80	1,891.80	4,496.00	3,302.10	43,287.80

Year						
2012	19,486.40	12,177.60	1,723.60	3,910.00	2,705.80	40,003.40
2013	18,945.00	12,235.90	1,524.90	5,054.90	1,062.50	38,823.10
2014	16,580.00	13,100.60	1,249.20	3,072.90	434	34,436.60
2015	23,111.60	13,973.80	1,803.70	5,373.80	279	44,541.90
2016	35,224.30	18,022.10	1,866.60	3,802.10	696.2	59,611.30
2017	24,795.10	18,048.60	2,504.70	3,506.30	1,223.40	50,078.00
2018	26,369.10	16,571.80	2,469.60	3,233.80	525.6	49,170.00
2019	25,145.40	11,547.70	2,324	3,940.40	608.4	43,566.00
2020	26,128	11,466	1,500.00	3,486	716	43,296
2021	31,100.5	16,516.8	1,374.0	1,007.7	328.5	50,327.4
Total	356,512.0	207,841.0	32,394.9	62,480.6	26,815.3	686,043.8
Average Annual	22,282.0	12,990.1	2,024.7	3,905.0	1,676.0	42,877.7
15 Year Target Goal	270,000.0	165,000.0	22,500.0	67,500.0	42,000.0	567,000.0
Percent of Goal Obtained	132%	126%	144%	93%	64%	121%

(Red indicates projections)

From the Maryland Forest Service PMAS report where a calendar year is defined as Quarters 3 & 4 of the preceding year, and Quarters 1 & 2 of the current Fiscal Year. For example, the number for 2006 represents the reported values from PMAS for Q3 & Q4 of 2006 and Q1 & Q2 of 2007.

State Forest harvest acres are only tracked by Fiscal Year. The number reported is from the annual State Forest Harvest Report and harvest data from WMAs and demonstration forests for the same fiscal year.
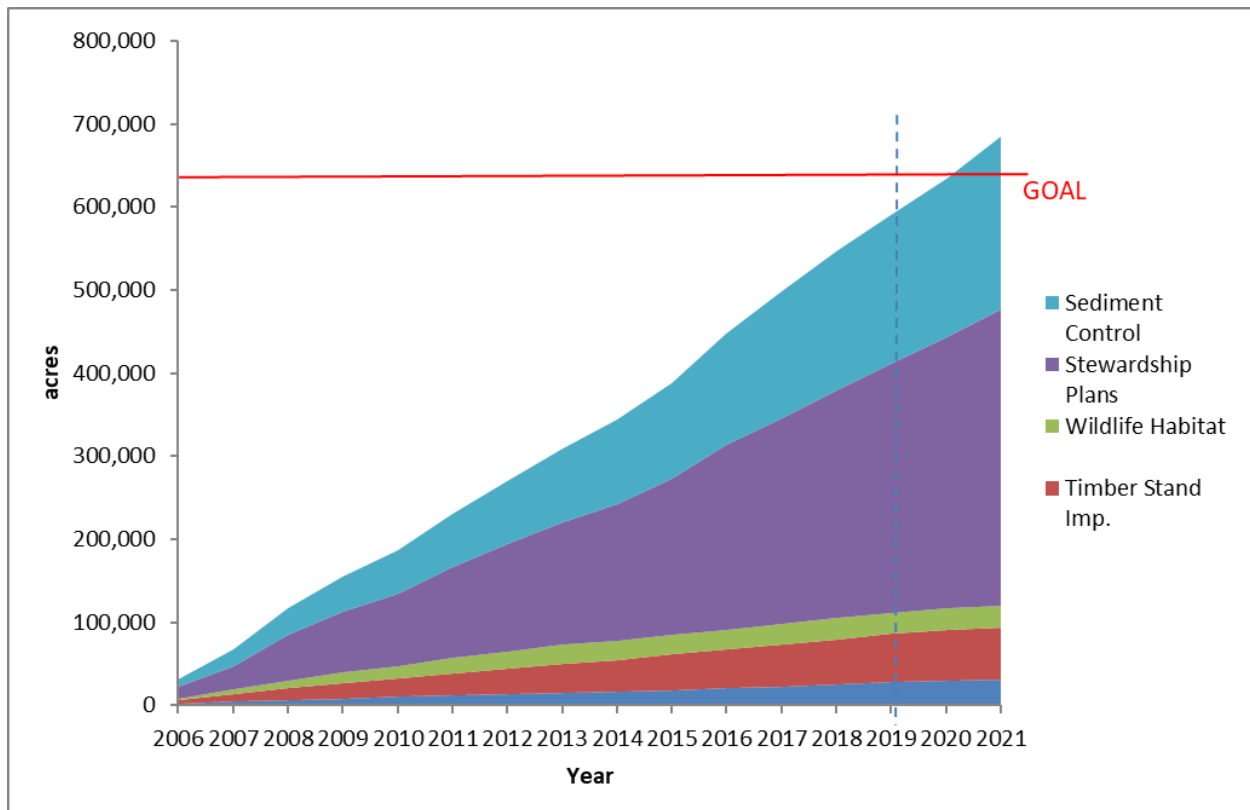
Figure 1: Managing Forests to Capture Carbon. The Maryland Department of Natural Resources is promoting sustainable forestry management practices in existing forests on public and private land through a suite of efforts, policies and programs.

Enhancement Opportunities

There are many potential actions by federal and non-profit partners other than Maryland state government that could result in increasing natural and working lands' carbon sinks in the state, contributing toward our 50 by 30 goal and beyond. Market-based solutions that incentivize public-private partnerships, enhanced outreach to landowners, and additional incentives are examples. In 2019 the United States signed on to the UN Trillion Tree's Challenge and launched the US chapter of the effort in August of 2020. At its formation the chapter has commitments from 30 corporations, municipal governments, and NGO's to plant over 850 million trees in the United States by 2030, contributing towards the global 1 trillion trees planted goal. Maryland recently joined this challenge, pledging to plant 5 million trees by 2030. At this point there are no new federal incentives for contributing to the goal, but a bill was introduced at the beginning of 2020 (the Trillion Trees Act) that would have created regional reforestation goals and incentives for reforestation and forest management.

Another recently introduced federal bill, The Growing Climate Solutions Act of 2020, would create a USDA carbon credit certification program. The goal of this program would be to break down barriers of entry for forest and agricultural landowners through technical assistance. It is costly for landowners to engage in the carbon credit certification and verification process; projects generating carbon credits are typically only cost-effective for large acreages (>2,000 acres). There are efforts in the Chesapeake Bay region by timber investment management organizations (TIMOs) and NGO's to overcome the cost barrier by grouping multiple landowners for single carbon credit projects. However, this is more challenging than dealing with single landowner large holdings. Similarly, the Nature Conservancy and the American Forest

Foundation have partnered to create the Family Forest Carbon Program targeted towards smaller forest landowners. They are working with the carbon verifier Verra and are backed by Amazon to conduct carbon friendly forest management practices on smaller forest parcels and create a practice-based protocol with a much lower cost (~75% less) for verification than traditional approaches. This program has recently expanded to Maryland, and landowners in Garrett, Allegany, Washington, Frederick, and Carroll counties with between 30 and 2,400 acres of forest are eligible to enroll. Landowners sign a contract and agree to conduct specific forest management practices shown to reduce carbon in exchange for regular annual payments over the contract period. Maryland Forest Service foresters began assisting forest landowners with enrollment in November, 2021.

Funding
The Woodland Incentive Fund is the progenitor of much of the activity on private lands. This fund receives revenues from a number of sources including fees for service and assistance in implementation of an approved practice, funding from the Chesapeake and Atlantic Coastal Bays Trust Fund (under § 8-2A-04 of § 5-307), and subject to approval by the secretary and the Board of Public Works, a portion of the revenues derived from the forestry practices on designated lands owned and managed by DNR. Another important revenue source is property tax from the transfer of forest lands (up to $200,000 per year).

Challenges
The lack of a reliable market for low quality wood is a challenge because without the ability to sell wood after thinning, the landowner will bear a cost, even with cost share from the state and often chooses to forgo forest management without the ability for it to pay for itself. Educating the public on the benefits of climate-smart and forest health-driven forest management will likely increase the willingness of landowners to implement management actions.

2.   Planting Forests in Maryland

Program Description
Planting trees expands forest cover and associated carbon stocks by regenerating or establishing healthy, functional forests through practices such as soil preparation, erosion control and supplemental planting. These actions help to ensure optimum conditions to support forest growth. By 2020, the implementation goal of this program is to achieve the afforestation and/or reforestation of 43,030 acres in Maryland. This goal was exceeded in 2019 with 44,931 cumulative acres planted through 2020. By 2030, the implementation goal of this program is to achieve the afforestation and/or reforestation of 68,530 acres in Maryland. To meet this goal we plan to plant approximately 4.6 million trees from 2021 through 2030. Achieving the target should reduce greenhouse gas (GHG) emissions in the state by 300,000 metric tons of CO_2 equivalent (0.3 MMtCO2e) annually.

Program Objectives

The potential emission reductions from the Planting Forests in Maryland program by 2020 are estimated to be 1.79 MMtCO2e. This represents an estimate of the cumulative sequestration achieved through this program. Appendix C of the 2015 Greenhouse Gas Reduction Act Update provides a more detailed description of the process used to quantify GHG reductions by 2020, and the 2030 GGRA Plan provides the goal for 2030 and associated methodology.

We expect to plant or regenerate between 2,000 and 4,000 acres of forest per year from 2020-2030, with the expected average estimate being 2,550 acres per year over that period. This equates to 25,500 acres by 2030. The state will also still be benefiting from the annual growth and carbon sequestration of the approximately 45,000 acres planted and regenerated from 2006-2020. In total, the GHG benefit will range from 0.28 MMtCO2e per year to 0.36 MMtCO2e per year of additional GHG sink, with the expected estimate being 0.3 MMtCO2e per year. Carbon estimates from forest planting were derived from analysis of carbon sequestration in Maryland forests for the 2006-2030 period done by the University of Maryland. Supporting methodology and data can be found in Huang et al. 2019 and Hurtt et al. 2019, respectively.

Implementation Milestones
The department is implementing this program through a suite of efforts, policies and programs, including:

Public Lands:
- State Forest annual work plan implementation

Private Lands:
- Technical Assistance
  - Forest Stewardship Plan implementation
  - Forest Conservation Act (FCA) implementation

 Financial Assistance – Rural Lands: State and federal Cost Sharing:
- Woodland Incentive Program (WIP –MD Forest Service)
- Income Tax Modification (TAXMOD)- expanded eligibility of forestry practices in 2014
- Environmental Quality Incentive Program (EQIP – federal/NRCS)
- Conservation Reserve Enhancement Program (CREP – federal/NRCS)

Estimated Emission Reductions for CY 2021
On track with previous years, reductions totaled 0.18 MMtCO2e for 2021.

Table 2 Forest Planted in Maryland

	Year	Afforestation(1)(2)	Reforestation(1)(3)	Riparian Buffers(4)	Private Natural Regeneration(5)	Total Acres
	2006	845.7	3,318.00	388.2	1,400.00	5,951.90
	2007	343.4	1,990.20	242.8	1,400.00	3,976.40
	2008	404.9	1,598.20	191.2	1,400.00	3,594.30

Year					
2009	531.1	1,497.40	162.6	1,400.00	3,591.10
2010	596	417.4	545.6	1,400.00	2,959.00
2011	1,223.60	633.9	503.1	1,400.00	3,760.60
2012	433.7	615.3	320.1	1,400.00	2,769.10
2013	198.1	593.6	237	1,400.00	2,428.60
2014	409.8	559.2	287.3	1,400.00	2,656.20
2015	294.1	633.1	213.7	1,400.00	2,540.90
2016	180	638.9	263	1,400.00	2,481.90
2017	97.6	434	127.4	1,400.00	2,059.00
2018	134.2	423.4	212.9	1,400.00	2,170.50
2019	107.3	254.2	115.6	1,400.00	1,865.90
2020	239	312	163.6	1,400.00	2,114.60
2021	168.8	234.6	169.0	1,400.0	1,972.4
Total	6,207.0	14,153.2	4,146.6	22,400.0	46,906.8
Average Annual	387.9	884.6	259.2	1,400.0	2,931.7
15 Year Target Goal	6,000.0	10,500.0	6,000.0	21,000.0	43,500.0
Percent of Goal Obtained	103%	135%	69%	107%	108%

(Red Indicates Projections)

(). From the Maryland Forest Service PMAS report where a calendar year is defined as Quarters 3 & 4 of the preceding year, and Quarters 1 & 2 of the current Fiscal Year. For example, the number for 2006 represents
the reported values from PMAS for Q3 & Q4 o

(2) PMAS field CREP/HEL Afforestation plus the Other Afforestation Acres.

(3) PMAS field Reforestation Acres.

(4) Acres reported by the Maryland Forest Service Riparian Forest Buffer Restoration Program. http://dnr.maryland.gov/forests/Pages/programapps/rfbrestoration.aspx

(5) Estimated area of privately owned forest regenerated annually following timber harvest. Assumes 20
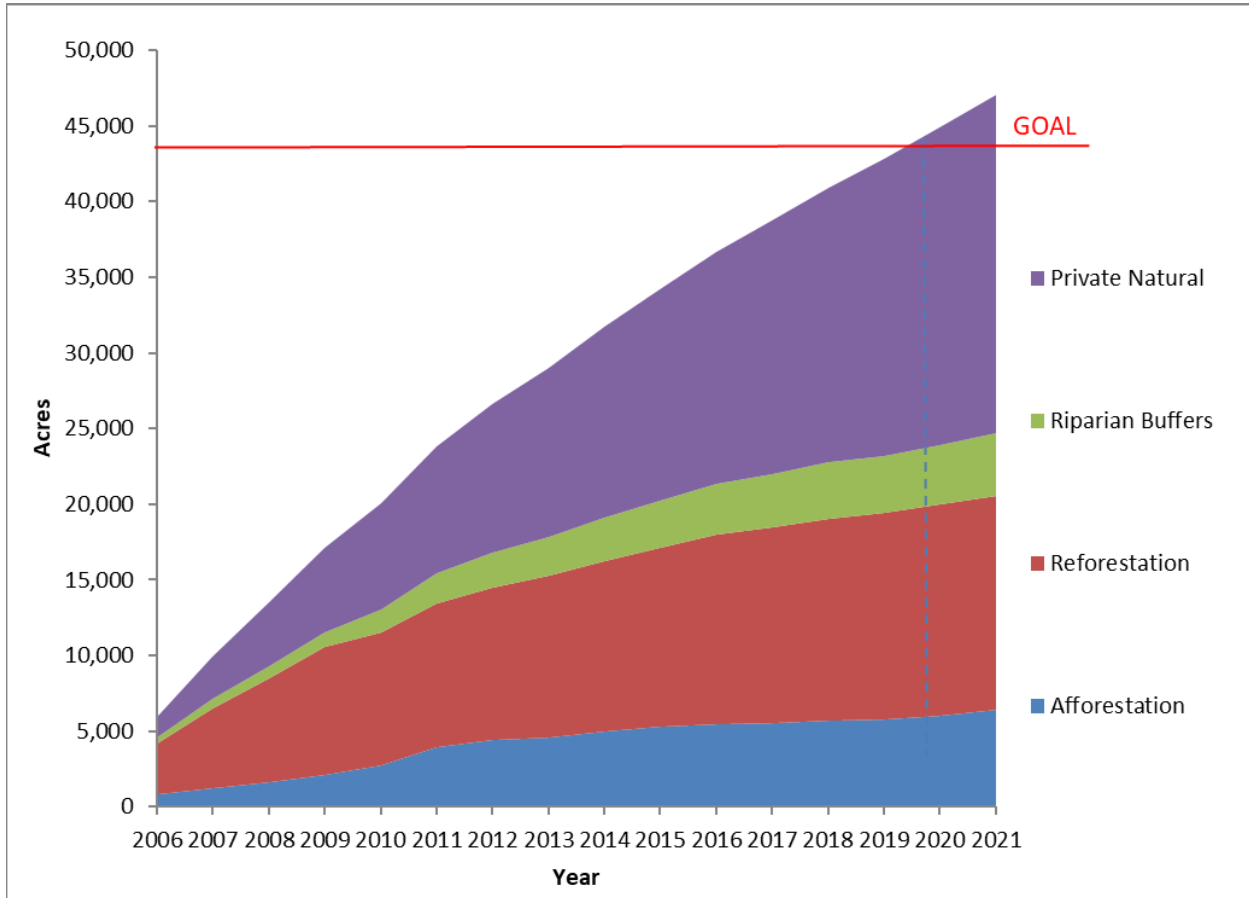
Figure 2 Planting Forests in Maryland.

Enhancement Opportunities

The Tree Solutions Now Act - House Bill 991 - was passed by the Maryland legislature in 2021 and requires that five million trees be planted in the state by 2031. These trees must be in addition to trees already projected to be planted in Maryland's 2030 Greenhouse Gas Reduction Plan and 10% must be planted in urban underserved areas, as defined in the bill. The bill dedicates $10 million per year for urban tree plantings to be administered by the Chesapeake Bay Trust and $2.5 million from the Chesapeake and Atlantic Coastal Bays Trust Fund will go towards tree planting per year and support 13 additional staff. The bill also stipulates that the Maryland Department of Agriculture can pay an additional $1000 per acre for tree plantings through MDA and the Conservation Reserve Enhancement Program (CREP).

The additional 13 positions to DNR from [HB991](#) will provide technical assistance, planning, and coordination related to tree plantings, tree buffer management, and forest management, including invasive vine removal, on public, private, and agricultural lands and in "underserved areas." These positions can expand awareness of existing and new planting programs to accelerate progress towards GGRA goals. See prior section for emerging federal and non-governmental actions that present opportunities for tree planting beyond 2030.

Funding
Important challenges faced by this program include engaging landowners willing to plant more trees, funding site preparation for successful tree planting in challenging urban locations, and maintenance needs after grants for establishment have ended.

Challenges
The Maryland Department of Planning projects the state's population to grow by 800 thousand people by 2045. Population growth and associated demand for land will need to continue to be balanced with land conservation and forest cover.   Tools to facilitate that balance include priority funding areas, transfer of development rights, land conservation programs, and the Forest Conservation Act.

3.   Creating and Protecting Wetlands and Waterway Borders to Capture Carbon

Program Description
In addition to forests, wetlands are known to be very efficient at sequestering carbon. DNR is planting forested stream buffers and pursuing the creation, protection and restoration of wetlands to promote carbon sequestration through several means including the Natural Filters Program provided through the Chesapeake and Atlantic Coastal Bays Trust Fund, which restores wetlands and buffers on state and public lands to meet water quality goals. The objectives of the Coastal Wetlands Initiative include restoring natural tidal marsh hydrology to coastal wetlands through ditch plugging practices and the development of a terrestrial carbon sequestration protocol.

The department is including another best practice for terrestrial carbon sequestration through its Shoreline Conservation Service projects to install Living Shorelines. These are additional coastal wetland restoration practices that function to sequester carbon.

Program Objectives
By 2020, the cumulative carbon storage from the Creating and Protecting Wetlands and Waterway Borders to Capture Carbon program is estimated to be 0.047 MMtCO2e. See Table 3.1 for estimated carbon benefit by 2030.

Implementation Milestones
On the ground wetland and waterway restoration projects:

The Natural Filters Program restored 32 acres of wetlands and planted 10 acres of streamside forest buffers on state and public land in fiscal year 2022, working towards the state's Watershed Implementation Plan (WIP) goals. Funded through The Chesapeake and Atlantic Coastal Bays Trust Fund, these projects are designed to accelerate bay restoration by focusing limited financial resources on the most efficient, cost-effective, non-point source pollution control projects which include wetland and buffer restoration projects.

As of the end of state fiscal year 2022, The Chesapeake and Atlantic Coastal Bays Trust Fund has,, funded the restoration of 239.5 acres of wetlands and 20.5 acres of riparian buffers, totalling 3,527 acres of wetlands and 1,608 acres of riparian buffers funded since 2009. These totals include restoration gains from the Natural Filters Program, as documented above, and projects that have occurred on private lands. From this point onward, implementation tracking will be expanded to include both public and private land restoration projects that are funded through the Trust Fund, to more accurately reflect potential carbon sequestration gains.

Through a partnership between DNR, The Nature Conservancy (TNC), U.S. Fish and Wildlife Service, Natural Resources Conservation Service and National Oceanic and Atmospheric Administration, we were able to restore 2,174 acres via a 5 year grant agreement between TNC and DNR (Chesapeake and Coastal Bays Trust Fund). The Pocomoke project's primary focus was to reconnect the mainstem and to channelize the Pocomoke River with its historic floodplain. The wetlands restored were mostly forested riparian wetlands, with some emergent wetlands restored in agricultural fields in the watershed.

Coastal Wetlands Initiative Program: As of 2023, 505.6 acres of coastal wetlands have been restored by plugging existing drainage ditches to restore these drained wetlands.

Living Shorelines through the Shoreline Conservation Service: Between 2006 and 2020 13.24 acres of Living Shoreline have been created or restored.

As of June 2022, the Resiliency through Restoration program has constructed 2.36 acres of wetlands.

Wetland restoration and enhancement by federal agencies: The US Fish and Wildlife Service has restored or enhanced 211 acres of tidal wetlands in the Blackwater National Wildlife Refuge over the past 10 years. The US Army Corps of Engineers has created, restored, or enhanced 1875 acres of tidal wetlands in the Maryland portion of the Chesapeake Bay since 2006, with the most significant projects being a wetland enhancement project on Deal Island and wetland creation on Poplar Island. Recent research has shown that the Poplar Island created wetlands are sequestering carbon at rates similar to natural wetlands.

Tidal Wetlands Restored from 2006-2021 and Estimated Carbon Benefit

For this initial estimate we only consider tidal wetlands restored from 2006 to 2020 and use the default rate of 2.17 Mt of CO2e per acre per year for restored wetlands as determined by the Verified Carbon

Standard.[3] We assume an additional 3,000 acres of tidal wetlands will be restored by federal partners and the state. Existing USACE documents show 2,000 acres of planned tidal wetland creation and restoration at Poplar Island, Barren Island, and James Island. Given the current rate, we expect restored, created, and enhanced wetlands in Maryland to total over 5500 acres and sequester approximately 0.011 million metric tons of carbon dioxide equivalent per year by 2030.

Table 3.1 Carbon Sequestration Estimate from Coastal Wetlands

Funding Source	Acres Restored	Carbon Sequestration Mt CO2e per year	Estimate for 2020-2030 acres per year
Coastal Wetland Initiative	505.6	1095.3	50
DNR Trust Fund	3.8	8.2	0
DNR Resiliency through Restoration	2.36		
Federal Partners	2096.9	4542.8	250
Total	2608.66	5646.4	300
Estimate of Annual Carbon Sequestration in 2030=	11,062.5		

Enhancement Opportunities

A key enhancement opportunity is to utilize market-based solutions to increase wetland restoration and enhancement projects.
The Sea Level Affecting Marsh Model (SLAMM) has been completed for Maryland coastlines and is being actively used for a variety of wetland management practices including:
- Factoring climate change and resiliency into DNR's land acquisition scoring process.
- Developing new easement opportunities for landowners that own land within these wetland adaptation area transition zones.
- Factoring climate change into restoration design.

---

[3] Restore America's Estuaries, Silvestrum Climate Associates, and the University of Maryland. 2015. Estimation of Baseline Carbon Stock Changes and Greenhouse Gas Emissions in Tidal Wetland Restoration and Conservation Project Activities. Verified Carbon Standard Module.

- Identifying the value of current and future wetlands for protecting communities and infrastructure from coastal flooding and shoreline erosion through DNR's Coastal Resiliency Initiative.

Ongoing work funded by the NOAA Ecological Effects of Sea Level Rise project awarded to George Mason University, DNR, and the Maryland chapter of The Nature Conversancy has updated the SLAMM model using the latest elevation and wetland data to more accurately determine the potential loss or gain of tidal wetlands from 2020 to 2100 under six different global carbon emission scenarios. These results help to build an understanding of the effect of sea level rise on carbon storage pools in current and future wetlands.

The US Climate Alliance (USCA) funded a collaboration with Duke University, North Carolina, Virginia, Delaware, New Jersey and New York on modeling coastal blue carbon and coastal resiliency. The coastal blue carbon model simulates change in wetlands over a 100 year period (2020-2120) under different emission scenarios spatially across Maryland and the other participating states. The model results help build our understanding of the range of outcomes for wetland carbon storage and sequestration, both informing our GGRA plan and helping us prioritize projects for increasing coastal resiliency.

The University of Maryland Center for Environmental Science (UMCES), partnering with Restore America's Estuaries and COMPASS, will be conducting a series of webinars on Blue Carbon starting in Summer 2020. These webinars will synthesize our knowledge of blue carbon, with one of the stated goals to better understand how blue carbon fits into Maryland's GHG inventory and reduction goals. Additional blue carbon workshops were conducted in 2021 and 2022 with the final topic focusing on enhancing coastal resilience through living shorelines.

Maryland's Innovative Technology Fund (ITF) expanded its scope of eligible techniques and technologies to include consideration of climate aspects. In addition to the traditional technologies focused on nutrient and sediment reductions, the state will also invest in the research, development, and commercialization of solutions addressing climate mitigation to help accelerate the adoption of climate resiliency and GHG mitigation. In 2022, a research and development grant was awarded to Belloso Motor Company for an engine modification for improved fuel efficiency. Three additional research and development grants were awarded to NextGlass who will continue development of a vacuum insulated glass that can cut energy loss through windows; N5 Sensors will monitor for wildfire enabling quicker and more precise response times to reduce the size of wildfires and their associated emissions; and Beitzel Corporation aims to reduce emissions from diesel generators through the use of a mobile solar power plant with battery storage. In addition, the program is currently under due diligence to invest in a technology that will reduce emissions from the transportation sector.

The protocol for tidal and seagrass restoration and other research efforts quantifying coastal wetland sequestration opens up opportunities to account for the GHG benefits of carbon sequestration through Submerged Aquatic Vegetation restoration and re-establishment. There may also be emerging avenues for investing in coastal restoration to reduce the risk of damage to infrastructure from coastal flooding. A number of studies (Naryan et al. 2017, Costanza et al. 2011) have shown a direct causal link between coastal wetlands and damage from storms; if this

benefit is better incorporated into the insurance market it could provide another funding source for coastal wetland protection, creation and enhancement. DNR has been working with The Nature Conservancy to determine a path forward to blue carbon crediting of SAV restoration efforts, is partnering on the development of Technical Guidance Manual and Outreach Materials for Small-scale Submerged Aquatic Vegetation Restoration in the Chesapeake Bay and its tidal tributaries, sits on the steering committee for the STAC workshop on Evaluating a Systems Approach to BMP Crediting, serve as SAV Element Lead for STAC workshop on rising watershed and bay water temperatures, lead the "Modeling Climate Impacts on Submerged Aquatic Vegetation (SAV) in the Chesapeake Bay" Project, and conduct Living Shoreline and Submerged Aquatic Vegetation Compatibility Study.

Funding

The Chesapeake and Atlantic Coastal Bays Trust Fund: In 2007, the Maryland General Assembly created the Chesapeake and Atlantic Coastal Bays Trust Fund (Trust Fund) to provide financial assistance to projects that advance Chesapeake Bay restoration. A large portion of this funding is targeted at local grants for counties and municipalities to reduce nutrient pollution to waterways which includes forested buffers, reforestation, wetland restoration, stream and floodplain restoration, stormwater retrofits and other bioremediation projects. In FY22, $21.16 million was allocated for these projects.

Resiliency through Restoration Initiative: Since 2011, Maryland has experienced seven hurricane, tropical storm and flood events warranting presidential disaster declarations, resulting in more than $145 million in federal public assistance. Recognizing that coastal habitats help buffer communities from these climate-related impacts, the Maryland Department of Natural Resources' Chesapeake and Coastal Service (CCS) launched a new Resiliency through Restoration Initiative. This Initiative, funded by Governor Hogan through the State Capital Budget, provides technical and financial assistance to restore, enhance and create coastal habitat with the goal of protecting Maryland communities and public resources from extreme weather and climate-related events. To date, the Initiative has led to the design of 24 living shoreline, coastal, and inland restoration projects around Maryland.

Coastal Wetlands Initiative (CWI): There are no dedicated funds currently allotted to CWI. Funding is typically acquired through a competitive grant process using state transportation and other federal funding sources.

Shoreline Conservation Services: This program is funded through the Shore Erosion Control Construction Loan Fund through DNR. One loan was issued in 2022.

Department of Natural Resources/Department of Transportation Memorandum of Understanding: The Maryland Department of Natural Resources has partnered with the State Highway Administration (SHA) in an effort to lead by example in restoring the Chesapeake Bay and local waters. State parks will provide opportunities for the State Highway Administration to implement restoration projects required by their Federal Stormwater Permit (MS4) and their nutrient and sediment reduction goals required under the Bay Total Maximum Daily Load (TMDL). A Memorandum of Understanding was signed in 2013 to initiate this program, which

will increase the rate of restoration projects on state and public lands. In addition, there is a new agreement between DNR and MDOT that builds upon the SHA-DNR MOU but has a wider purview and an expanded scope of partnership. This new MOU applies to all MDOT transportation business units and supports common objectives including (but not limited to) Chesapeake Bay watershed restoration; climate resiliency, adaptation and mitigation efforts; and environmental compliance, stewardship and sustainability activities.

Challenges

While wetland restoration, in both inland, freshwater and tidal environments, are practices that significantly contribute to terrestrial carbon sequestration rates throughout the state, the highly variable rate of methane emissions has a marked effect on net greenhouse gas benefits. Research by state, regional, national and global entities continues to evolve and narrow in on more precise methods to evaluate the greenhouse gas benefits of wetland restoration.

New wetlands will be created and many wetlands will migrate inland with SLR, but there may also be wetland loss due to sea level rise, should it occur.

There is a need to improve the design of Coastal Wetland Initiative projects to ensure success in future efforts. Ongoing monitoring is underway to measure the success of various methodologies.

Removing barriers to accessing federal funds could also incentivize landowners to participate in restoration projects. DNR is actively working with the Maryland Department of Agriculture and the United States Department of Agriculture on removing those barriers.

4.   Biomass for Energy Production

Program Description

Maryland is working to promote the use of locally-produced woody biomass for the generation of thermal energy and electricity. Energy from forest byproducts can be used to offset fossil fuel-based energy production and associated GHG emissions. There are many end users in the United States that are successfully employing wood heating and cooling, and Maryland could benefit from such a program. For example, schools, hospitals, and municipalities could utilize local woody biomass for their energy needs. Creating a woody biomass fuel market would provide an incentive for harvesting low grade wood, a key component of healthy forest management.

The goals of this program are to develop policies that recognize wood as a renewable energy source, the largest source of bioenergy production in Maryland, and offer incentives to utilize locally produced wood to meet thermal energy needs.

Program Objectives

The potential emission reductions from the Biomass for Energy Production program by 2020 were estimated to be 0.33 MMtCO$_2$e in the Greenhouse Gas Reduction Act plan. While there have not been any biomass to energy facilities built in the state yet, Maryland continues to explore opportunities for new facilities.

Implementation Milestones

- DNR is actively working with partners including the Maryland Energy Administration, and the Maryland Department of Commerce to facilitate installation of wood energy systems and has committed to a pilot program on the Eastern Shore and in Western Maryland.

- The Maryland Energy Administration has an existing grant program for wood to energy systems that could be reinstated if adequate demand is demonstrated.

- A webinar series on the potential of woody biomass to energy in Maryland was presented in 2020. This series was sponsored by the Maryland Forestry Foundation and Maryland Clean Energy Center in partnership with DNR and the Sustainable Forestry Council. More information and recordings can be found at https://www.mdcleanenergy.org/biomass/.

- The U.S. Department of Commerce Economic Development Administration awarded a grant to the Western Maryland Resource Conservation and Development Council, who partnered with DNR and the Maryland Department of Commerce to develop an Economic Adjustment Strategy for Maryland's forestry industry. The plan, which has been finalized, serves as a roadmap for capitalizing on new opportunities in the forest industry including biomass for energy production and creating jobs, particularly in Opportunity Zones.

- Wood resources are quantified and an analysis of "wood sheds" is conducted to determine the feasibility of an area to support industrial scale biomass to energy. The Eastern Shore Regional GIS Center (ESRGC) at Salisbury University recently partnered with DNR, the Western Maryland Resource Conservation and Development Council, and the Maryland Department of Commerce to assist in determining feasibility of industrial scale biomass to energy. A Maryland Forest Inventory Resource Viewer (MFIRV) was also developed so potential investors and forestry-related businesses had access to information on potential markets and market viability.

Estimated Emission Reductions for CY 2021
None.

Enhancement Opportunities
Allowing thermal renewable energy credits (TRECs) to be generated from combined heat and power systems using woody biomass would provide an additional incentive to use this type of system. A statutory change would be needed to accomplish this.

Funding
See 'Challenges' section.

Challenges

Awareness of wood energy technology is the primary barrier to this program, in particular adequately informing the managers of commercial and institutional spaces of the opportunities to save money while improving environmental outcomes that are offered by the simple switch to wood fuels. Establishing some demonstration projects in Maryland would greatly assist with DNR's ability to showcase available technology.

The Maryland Energy Administration has temporarily discontinued its Commercial Wood Boiler grant incentive program; however, they have stated that the program could be reinstated if sufficient industry demand is demonstrated.

5. Increasing Urban Trees to Capture Carbon

Program Description

Trees in urban areas are extremely important to Maryland's carbon budget because they help offset some of the greenhouse gas emissions from urban pollution sources such as energy production and vehicle emissions, and reduce heating and cooling costs and energy demand by moderating temperatures around buildings and slowing the formation of ground level ozone as well as the evaporation of fuel from motor vehicles. Implementation is supported by several Maryland laws and programs that include outreach and technical assistance for municipalities to assess and evaluate their urban tree canopy goals and plant trees to meet those goals.

The immediate goal of this program is to plant 12.5 million trees in urban areas through the Forest Conservation Act, Marylanders Plant Trees, Tree-Mendous Maryland, and 5-103 State Highway Reforestation Act planting programs.

Going forward, the long-term goal of this program is to plant an additional 2.65 million trees in urban areas through the Forest Conservation Act, Marylanders Plant Trees, Tree-Mendous Maryland and 5-103 State Highway Reforestation Act planting programs by 2030 from our 2020 tree planting progress.

This program is performing as designed.

Program Objectives

The potential emission reductions from the Increasing Urban Trees to Capture Carbon program by 2020 are estimated to be 0.02 $MMtCO_2e$. This number represents a conservative estimate of the cumulative carbon sequestered through this program. Appendix C of the 2015 GGRA Update provides a more detailed description of the process used to quantify greenhouse gas reductions. From 2020-2030 we estimate that on average, between 150,000 to 500,000 urban trees will be planted in Maryland per year. This will equate to 1.5 to 5 million total trees planted from 2020-2030. DNR estimates that the average number of tree plantings of the past three years is reasonable to expect for a projected annual average during the 2020-2030 period. The average over the past three years has beene 265,000 trees planted per year. The low estimate of GHG

benefit is 0.0023 MMtCO₂e per year, and the high estimate is 0.0046 MMtCO₂e per year, with the expectation of 0.0035 MMtCO₂e per year of additional carbon sink in 2030.

Implementation Milestones

To date, 10,434,479 trees have been planted from 2006 to 2021 (total for this program and Planting Forests in Maryland).

DNR's Maryland Forest Service (MFS) has developed two tree planting assistance programs that reach landowners within the urban/suburban areas of Maryland. The new programs target the 1.1 million acres of turf statewide. Each program targets different lot sizes and available planting space.

- The "Lawn to Woodland" program, a partnership with the Arbor Day Foundation, targets small lots with 1-5 acres of plantable space or turf. The Foundation does outreach while MFS handles the tree planting at no cost to the lot owner. In the spring of 2014, a pilot was done with 14 acres planted on 12 lots. In the spring of 2015, 100 acres were planted on 84 sites and in the spring of 2016, 60 acres were planted on 55 sites, totalling 174 acres planted on 151 sites.
- The "Marylanders Plant Trees" program is a $25 coupon reimbursement program targeting individuals wishing to plant a tree through advertisements on the MD Forest Service portion of DNR's website and at participating nurseries. Landowners with small lots can purchase a tree valued at $50 or more and reduce their cost by $25. 85 nurseries across the state participate in the coupon reimbursement program. From the program's inception in FY09 to FY19, over 49,000 coupons have been reimbursed and 49,000 trees planted.
- Financial Assistance – Urban Lands: Public/Private Partnerships.
  - Tree-Mendous Maryland.
  - 1,865 trees planted in 2021.
- Marylanders Plant Trees/Private Nurseries.
  - Reimbursed coupons for 4,035 trees in 2020.
- Lawn to Woodland
  - Kicked off in spring 2014 with 4.3 acres planted.
  - 100.73 acres on 84 sites planted in spring 2015.
  - 60.33 acres on 55 sites planted in spring 2016.
- Maryland Urban and Community Forestry Committee Grants.
  - In 2019, $6,000 was awarded and contributed to seven tree planting projects throughout the state.
- Small Community Urban Tree Canopy (UTC) Grants led to the planting of 0 trees in 2020. Gatherings for tree plantings were prevented due to COVID-19.

Estimated Emission Reductions for CY 2021
Urban tree plantings are estimated to sequester 0.002 MMtCO2e in 2019.

Table 4. Urban Tree Planting (number of trees).

Year	Forest Conservation Act (FCA)[1]	Reforestation 5-103[1]	Tree-Mendous & Marylanders Plant Trees Programs	Total Trees
2006	623,700	33,750	8,178	665,628
2007	473,400	27,000	6,057	506,457
2008	499,500	9,900	2,160	511,560
2009	450,900	13,950	39,020	503,870
2010	337,950	308,250	23,000	669,200
2011	481,050	15,750	17,200	514,000
2012	42,300	68,850	21,700	132,850
2013	119,250	23,850	23,800	166,900
2014	140,580	24,615	21,500	186,695
2015	142,875	6,251	8,435	157,561
2016	341,640	37,557	8,798	387,995
2017	412,300	8,388	12,545	433,233

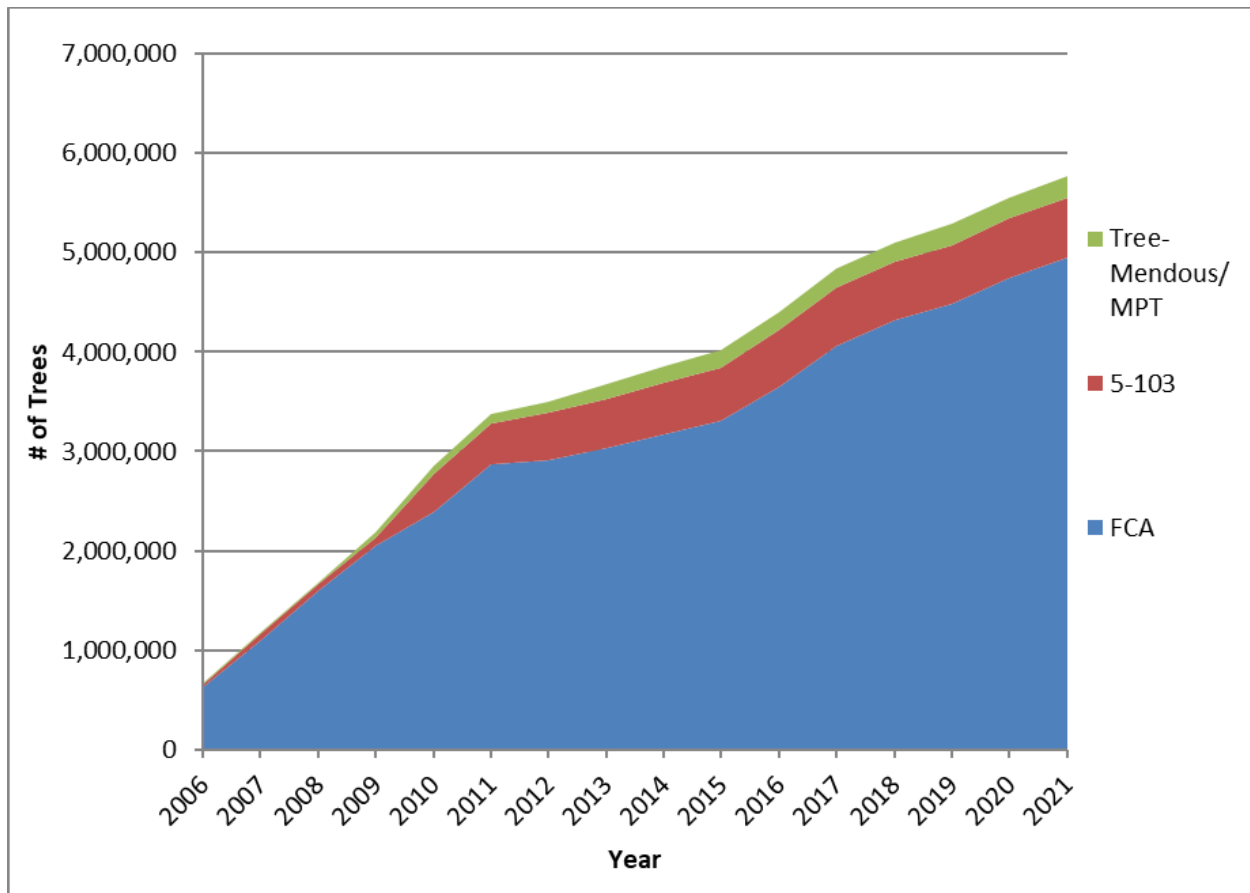|			
2018	256,050	5,913	7,718	269,681
2019	158,535	10,697	10,166	179,398
2020	262,971	2,560	5,900	271,431
2021	200,579	10,980	7,364	218,923
Total	4,943,580.0	608,260.5	223,541.0	5,775,381.5
Average Annual	308,973.8	38,016.3	13,971.3	360,961.3
Average of Last 3 Years (Rounded)	207,362	8,079	7,810	223,251
(1).	Assumes 450 trees planted/acre.			

Figure 3. Increasing Urban Trees to Capture Carbon.

Enhancement Opportunities
The Tree Solutions Now Act includes a goal of planting 500,000 trees in urban areas by 2030. Efforts to expand and diversify buffer and urban tree canopy plantings related to Chesapeake Bay restoration will also benefit greenhouse gas reduction efforts. Additional funding mechanisms are being explored, from revolving loan funds repaid through purchase of MS4 credits or local government climate resilience bonds. The quantification of carbon sequestration for tree planting, soil carbon sequestration, and forest management estimates could form the basis for aggregating private forest management and tree planting for the voluntary carbon credit market.

Funding

Year to year variability in program availability and funding levels creates a challenge in building program awareness in the public and perception of programs as reliable funding sources

The "Lawn to Woodland" and the "Marylanders Plant Trees" programs are both funded through forest mitigation funds received as a result of highway construction projects complying with Reforestation Law (NRA 5-103). This makes the funding variable from year to year, and for the past several years the "Lawn to Woodland" program was on hold due to limited available funds. Identifying an alternative funding source when mitigation funds are limited or not available

would allow for these programs and others to be consistently offered to the public. Options are being pursued through 5 Million Trees programs and other fund sources, such as federal funds from the Infrastructure Investment and Jobs Act.

Challenges
See Funding section above.

6. Geological Opportunities to Store Carbon

Program Description
Geological carbon sequestration differs from other discussed sequestration methods because it captures carbon at the source and transports it to a sequestration site. Maryland, through DNR's Maryland Geological Survey, is one of eight partner states in the Midwest Region Carbon Sequestration Partnership whose role is to identify, locate, and characterize potential geologic storage opportunities. This has evolved into the MidWest Region Carbon Initiative which is a coordination of over 12 states, the nonprofit Battelle Memorial Institute, and the U.S. Department of Energy. More than 10 gigatonnes of storage capacity has been identified within the terrestrial portion of Maryland (103 years of storage capacity at current CO2 estimated production rate of 97 million metric tons per year). In the offshore region ranging from Maryland to New York, an estimated 450 gigatonnes of geologic capacity has been calculated.

The goal of this program is to identify and assess geologic storage opportunities. The program is performing as designed, however, no quantification target has been assigned.

Program Objectives
The potential emission reductions from the Geological Opportunities to Store Carbon program have been aggregated with the estimated emission reductions from the Terrestrial Sequestration bundle (Forestry and Wetlands).

Implementation Milestones
Previous Geological Carbon Sequestration funding has come from the US Department of Energy through the nonprofit Battelle Memorial Institute. Research funds for geologic carbon sequestration ceased in 2020 with a refocusing of DOE funds into implementation of geologic carbon sequestration. Maryland is funded at $28,000 per year to assist in educating policymakers and other interested parties about geologic carbon sequestration opportunities. An additional twenty thousand dollars per year is provided through the state's Environmental Trust Fund.

The Department of Natural Resources' Resource Assessment Service (RAS) has completed or is currently working on the following implementation milestones.

- Total organic carbon content in Maryland black shales (e.g., Marcellus) has been evaluated as a precursor for determining the viability of these as storage units for carbon dioxide. This data is incorporated into regional and national databases for various integration projects. This project is completed.
- The potential for offshore carbon sequestration has been evaluated in partnership with Harvard University, Battelle, U.S. Department of Energy, Rutgers University, University of Texas and the surrounding Mid-Atlantic States. Focus areas of this study included geologic characterization, capacity evaluations, injectability and risk analyses. This project has provided foundation knowledge and an assessment of potential for carbon sequestration offshore in the Baltimore Canyon Trough. Projections from this study state over 450 gigatonnes of carbon sequestration are possible within our region using offshore sequestration targets. This project is completed.
- In the offshore environment, the state has identified the need for the U.S. Bureau of Ocean Energy Management to balance renewable energy development with future geologic carbon sequestration opportunities
- The potential of saline aquifers located under the Coastal Plain in Maryland as a target for carbon sequestration is being evaluated in cooperation with multiple state Geological Surveys. There is currently no funding for this research and saline aquifers remain a potential, but unvalidated, sink for the greenhouse gas carbon dioxide (CO_2).
- Baseline data has been collected to provide the foundation for conducting risk analyses for the potential development of stray gas migration into potable aquifers. This project is complete.
- Research is ongoing to assess the CO_2 chemical adsorption capacity of power plant combustion by-products and the organic shales and clays in the closest geologic formations.
- Research has been completed to assess the possibility of CO_2 sequestration as both structural and chemical storage within triassic rift basins. The exposed Gettysburg-Culpepper basin has been characterized and documented as a proxy of the buried rift basins located throughout Maryland. Further research is planned to study the collected cores through the Taylorsville Basin, however those cores are currently difficult to access and located out of state. Phase I of this project is complete. Phase II is pending the availability of collected cores.
- Research is being performed in the Western MD retired gas fields to understand the current abandoned well bores. Documentation of this is necessary as a precursor to evaluation of this area as a CO_2 sequestration site. Discussions are occuring between Lehigh Cement, Warrior Run Powerplant, Battelle, and the Maryland Energy Administration to determine if this site could be a pilot site for Maryland to evaluate geologic carbon sequestration.

.

Other Resources Assessment Service program notes include:

- Site testing (carbon capture, transport and storage) continues in Michigan and Ohio (regional partners to Maryland in CO_2 sequestration projects) and has been completed in Kentucky. A large-scale project is currently being performed in Illinois capturing 6.5

million tonnes of CO2 annually. These programs are being evaluated at a national level and the results continue to be favorable at this time.

- Depleted gas fields present the most immediate option for permanent storage of carbon dioxide in Western Maryland. Maryland Geological Survey is currently working on identifying the site characteristics of individual wells to assist MEA in determining a pilot project injection site.
- A methane emissions study of the Deer Park Anticline by the Western Maryland Regional GIS Center has ruled out using this Anticline for structural storage of CO2 due to observed methane leaks primarily from the old Mountain Lake Park Gas Field. It could still have potential for chemical adsorption of CO2.
- In collaboration with Maryland Energy Administration, a CO2 Sequestration conference was held in November 2019. MEA recorded the talks and are using these talks as educational material for legislators and their staff.
- The Maryland Geological Survey is working with NASA to identify technologies that would assist in identifying methane emitters such as transmissive geologic faults, poorly abandoned wells, fissures, etc. There is presently no funding for this activity; this project is in its infancy.

Estimated Emission Reductions for CY 2021
None.

Enhancement Opportunities
A federal, regional, or state action to put a cap on carbon emissions would potentially create a demand for geologic sequestration, if it is cost-competitive with other options to offset emissions. If the price of carbon offsets reaches parity with the cost to do geologic sequestration this would also spur action.

A pilot project currently being discussed at the Maryland Energy Agency will allow Maryland to understand the execution of a geologic carbon sequestration program.

The Maryland Geological Survey, through the MRCI partnership and relationships with the Illinois Geological Survey, are working together in evaluation of the Illinois Carbon Sequestration pilot project that has currently sequestered over 4 million metric tons of CO2. This relationship and the lessons learned throughout its development and operations provide vital knowledge for Maryland should the state proceed with geologic carbon sequestration.

Funding
Previous Geological Carbon Sequestration funding has come from the US Department of Energy through Battelle. Research funds for geologic carbon sequestration will cease in 2019 with a refocusing of DOE funds into implementation of geologic carbon sequestration. Twenty thousand dollars per year is provided through the state's Environmental Trust Fund.

Challenges
The cost of capturing CO2 using current technologies involves a parasitic loss of approximately

8-20 percent at the generation site depending upon the source. This cost has decreased over the last 10 years by 30-40 percent due to developing methods to capture the CO_2 and the concentration of the CO_2 in the smokestack. However, the IRS has created a section 45Q tax credit incentive that allows businesses that geologically sequester carbon to receive a significant offset which is \$85 per metric ton for geologically sequestered carbon beginning in 2022. This tax incentive significantly offsets the cost of carbon capture and geological sequestration, allowing for profit making business plans using current technology.

A significant, but often overlooked cost for sequestration, is transportation of the CO_2 from its source to the sequestration site. Ideally, the sources would be located on top of the sequestration site making this cost minimal. However, it is likely that pipelines will need to be created to efficiently pipe the CO_2 from the production location to the sequestration location. Significant legislative support has occurred in the last year supporting CO_2 pipelines and a nationwide plan is being developed.

Retrofitting equipment onto existing power plants and industrial processing plants is often cost and space prohibitive. CO_2 capture will need to be part of the design of new power generation plants and industrial processing plants (cement, fertilizer, steel).

7. Creating Ecosystems Markets to Encourage Greenhouse Gas Emission Reductions

Program Description
Increased attention to the benefits and cost efficiencies that ecosystem markets could provide has spurred evaluation of the potential its programs and policies may have for fostering carbon market development. Maryland's Forest Conservation Act and Critical Area Act require mitigation for natural resource impacts generated through land development, and mitigation banking is an option to address these requirements.

The goal of this program is to explore the establishment of ecosystem markets, create a tracking mechanism and develop protocols to assess/quantify GHG benefits of individual markets. However, no quantification target has been assigned.

Program Objectives
The potential emission reductions from the Creating Ecosystems Markets to Encourage greenhouse gas (GHG) Emission Reductions program in 2021 are estimated to be 0.11 MMtCO2e. Appendix C of the 2015 GGRA Update provides a more detailed description of the process used to quantify GHG reductions. No reduction target has been established for the 2030 goal due to uncertainty in how carbon markets are developing, and the concern for potentially double counting carbon removal with sequestration estimates found elsewhere in the GGRA.

Implementation Milestones

- Ecosystem co-benefits from forests, wetlands, cropland, and pastureland have been spatially quantified across Maryland. Spatial models for co-benefits are available on Maryland GreenPrint.[4]
- The Nontidal Wetlands Mitigation Banking bill removes barriers to mitigation banking in Maryland, with the goal of reducing the cost for meeting mitigation requirements in an ecologically beneficial way.
- Under FCA banking, several counties in Maryland allow offsite mitigation for forest loss through purchasing credits in a forest bank. Over 2,000 acres of forest loss have been mitigated in this way over the past 15 years.
- The Maryland Department of Agriculture received a National Fish and Wildlife Foundation (NFWF) grant to enhance healthy soil practices in the state. One of the outcomes will be to create a carbon sequestration module of the Nutrient Trading Tool, allowing for the quantification of carbon sequestration by different Best Management Practices alongside the nutrient benefits.
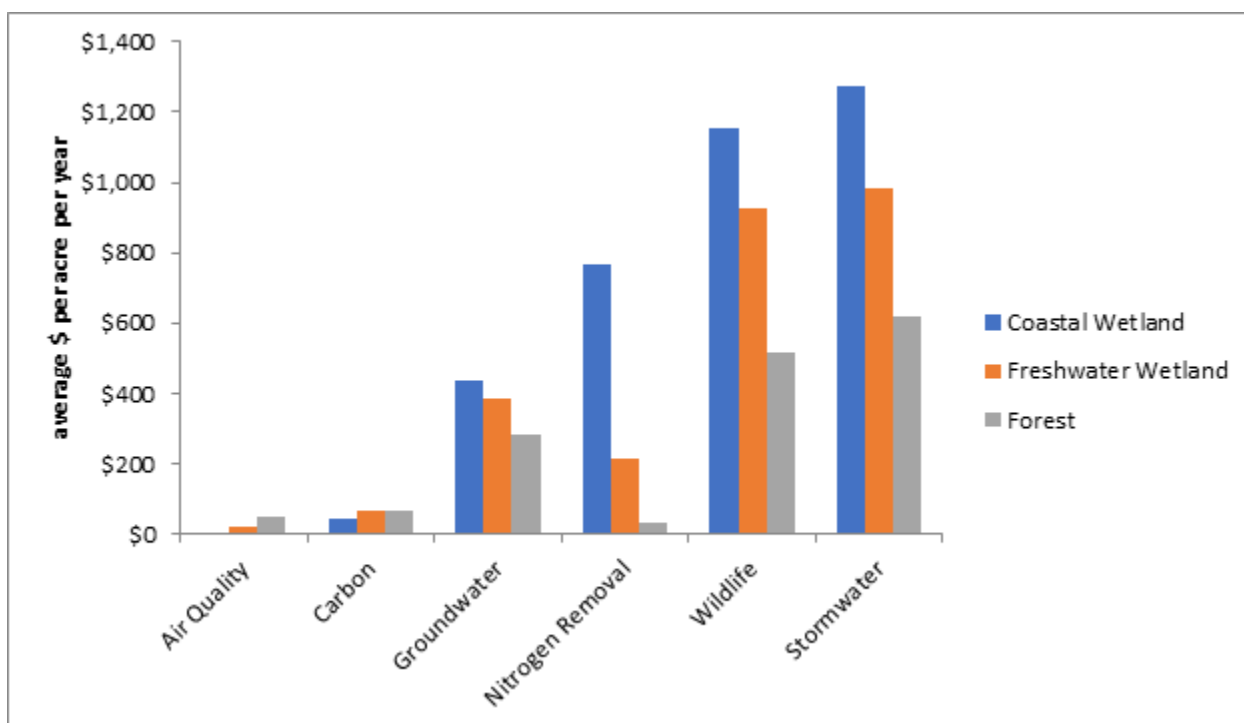

Figure 4. Ecosystem Service Non-Market Value in Maryland.

Enhancement Opportunities

Enhancement opportunities include the expansion of voluntary, market-based approaches for carbon offset and streamlining the verification and certification process for existing carbon markets available to Maryland landowners. For example, Maryland landowners can potentially sell offsets on the California Air Resources Board market, the voluntary carbon market or through the Regional Greenhouse Gas Initiative (RGGI). However, given the typical size of forest land held by a landowner, the cost of going through the verification and certification process is not typically worth it. As a result, there have not been carbon credits generated from offsets sold in these markets The price of offsets for all three of the aforementioned markets is projected to increase from the current prices ~$5 (VCS), ~7 (RGGI) and $15 (CA) per Mt of carbon reduction. Increases in price, combined with efforts by NGOs and for-profit

---

[4] www.geodata.md.gov/greenprint/

companies to lower the barrier of entry for smaller forest landowners, could allow for participation of many more landowners in these markets. In the mitigation sector, banks for forests and wetlands could prioritize habitat types that have high potential for carbon sequestration, like higher salinity coastal wetlands, forested wetlands, or deciduous forests on productive soils. Increasing investment in the conservation and restoration of natural lands, and projects that promote co-benefits will create a positive trend in the ecosystem services provided, including the sequestration of carbon.

Funding
See "Challenges.

Challenges
Working within the boundaries of currently functioning ecosystem marketplaces for wetlands, forests and habitat presents limited opportunities for generating net carbon reductions. RGGI does allow for carbon emissions offsets to be generated through forest planting or management activities, however they are not currently cost-competitive with emission allowances on the RGGI market.

Adaptation, Resiliency, Education, and Outreach

Overview

The Department of Natural Resources actively works with commissions, working groups, partnerships, and collaboratives to collectively address climate change. Many of the specific projects and programs highlighted in this report directly support goals, outcomes and milestones of those collaborations.

1. Maryland Coast Smart Council

The Coast Smart Council (CSC) was created in 2014 with the passage of HB615 for the purposes of adopting specific Coast Smart siting and design criteria to address impacts associated with sea level rise and coastal flooding on future capital projects. The council is chaired by the DNR Secretary and staffed by DNR employees. The original Coast Smart Construction Program (CSCP) Siting and Design Guidelines (Guidelines) were published in 2015. The CSCP Guidelines were updated in September of 2020 following the passage of HB 1350 and HB 1427 in 2018 and 2019 respectively. The updates expanded the applicability of the guidelines and provided a new boundary for determining flood risk, the Coast Smart Climate Ready Action Boundary (CS-CRAB) available online here.

2. Adaptation and Resiliency Working Group of the Maryland Commission on Climate Change

DNR is a member of the Maryland Commission on Climate Change (Commission) and the chair of the Adaptation and Resiliency Working Group (ARWG). The ARWG is chaired by the DNR secretary and staffed and coordinated by DNR employees. The ARWG supports the Commission by hosting quarterly meetings and coordinating the development of a comprehensive strategy aimed at reducing the vulnerability of Maryland to climate change impacts and providing tools to state and local governments. ARWG's membership is composed of a working group of representatives from state agencies, including three DNR employees, General Assembly members, and public sector representatives.

3. Maryland and FEMA Seek Expedited Review for Recovery and Resilience Actions

In May 2021, the Department of Homeland Security, Federal Emergency Management Agency - Region III requested an expedited federal review process from the Maryland Coastal Zone Management Program (MD CZMP) to support FEMA-funded recovery and resilience actions in Maryland. In response to FEMA's request, staff from MD CZMP partner agencies held conference calls with FEMA and each other to develop a formal concurrence letter to FEMA. The General NEgative Determination letter was completed in 2022 and is on file for MD CZM-FEMA REgion III. The letter includes: (1) how to distinguish between projects with no or minimal coastal effects (Tier I) and those with significant coastal effects (Tier II), (2) procedural review guidelines for Tier I, Tier II and After-the-Fact reviews of emergency response actions,

and (3) establishes annual reporting and follow-up steps to enhance FEMA-Maryland coordination.

4. Chesapeake Bay Program, Management Board and Work Groups

DNR employees from across the agency participate actively in the Chesapeake Bay Program, the regional partnership aimed at achieving set goals for Chesapeake Bay Health. DNR staff serve on the Management Board, as chairs for multiple Goal Implementation Teams (GIT), and participate actively in a number of the working groups including Sustainable Fisheries, Habitat Goal, and Climate Change Resiliency.

In 2019, Maryland's Phase III WIP to reduce nutrients and sediment entering the Chesapeake Bay devoted a chapter to climate change. The plan identifies nutrient and sediment control strategies that can assist in mitigating the increase in GHGs and adapting to anticipated climate impacts. The Plan acknowledges Maryland's role in helping to understand how nutrient control practices might be impacted by climate change. It also affirms Maryland's partnership with the Chesapeake Bay Program to estimate the effects of climate change on future nutrient and sediment loads to the bay.

2022 Project and Program Updates

1. Practice and Place

Maryland Coastal Adaptation Indicators: The University of Maryland Center for Environmental Science (UMCES), with funding from the Chesapeake and Coastal Service, completed their year-long research and stakeholder process to identify key indicators to measure progress on adaptation in Maryland. The final report card includes 15 indicators across 4 topical areas (socioeconomic, flooding, planning and ecosystem) that will serve as essential tools in the tracking of adaptation progress. The State of Maryland is fairly well-adapted to handle continuing threats of climate change and earned an overall score of B-. Some indicators that were measured already meet, or are close to meeting, current adaptation goals, while others require significantly more investment to achieve goals. This effort is included as a climate milestone in Maryland's Phase III WIP.

Maryland Climate Change Adaptation & Resiliency Framework (Framework): In 2021, the Adaptation and Resiliency Working Group of the Maryland Commission on Climate Change, led by a team from Chesapeake and Coastal Service and the University of Virginia, Institute for Engagement and Negotiation completed the initial phase of evaluating and updating the state's adaptation strategy. Through sector and focus group working sessions, co-led by sector appropriate leaders on adaptation, a draft framework document was put together identifying key goals, strategies and activities needed to move adaptation and resiliency efforts forward. In 2022, the Adaptation and Resiliency Working Group started to use the resilience strategies identified in the draft framework to begin developing a Next Generation Adaptation Plan which will span a 10-year roadmap to resilience and help meet the state's GHG reduction goals. To be completed in 2023, this effort is included as an Adaptation and Resiliency Working Group recommendation for the MCCC 2022 annual report and is a climate milestone in Maryland's Phase III WIP.

Targeted Resiliency Areas: The Chesapeake and Coastal Service Unit continued efforts to develop "Targeted Resiliency Areas" (previously referred to as *Resiliency Opportunity Zones*) to demonstrate how restoration and conservation projects can work together synergistically to generate area wide resiliency benefits to protect natural resource based economies, high value ecosystems, public lands and at-risk communities. In 2021, the team worked to refine the scope, approach and criteria used to determine the TRA's and map out next steps to incorporate these areas into the development of "Comprehensive Water Quality and Climate Resiliency Project Portfolios" that reduce climate risks in vulnerable areas and also generate water quality, carbon sequestration, and habitat co-benefits. These area-specific plans for resiliency will provide the basis for robust funding partnerships and long-term financing strategies. In 2022, the City of Hagerstown and the lower Pocomoke River region, including Pocomoke City, were selected as pilot geographies. This effort is included as a climate milestone in Maryland's Phase III WIP.

Innovative Technology Fund: Expanded the scope of eligible techniques and technologies to include consideration of climate aspects of Innovative Technology and project proposals. In addition to nonpoint source water quality projects, the state invested in the research, development, and commercialization of solutions addressing climate mitigation to help accelerate the adoption of climate resiliency and GHG mitigation. The program provided a research and development grant for N5 Sensors to refine their wildfire monitoring and adaptation platform. Additional funding was provided for climate mitigation and is discussed in that section of the report.

Chesapeake and Atlantic Coastal Bays Trust Fund (Trust Fund): Although the focus of the Trust Fund is to support the most effective and efficient non-point source pollution reduction projects, many of these projects also yield climate resilience and mitigation co-benefits. Since its inception in 2009, the Trust Fund has provided more than $602 million in support of over 3,007 projects, including wetland restoration, stream buffer planting, stream restoration, and bioretention facilities. Wetland restoration and forest buffer planting practices are very efficient at sequestering carbon. Establishing broad riparian buffers along stream corridors also allows for channel migration resulting from increased precipitation. The Trust Fund prioritizes stream restoration practices that enhance and restore wetlands by reconnecting the stream to its floodplain, which also helps to spread and slow flood waters. Bioretention projects have been identified in federal and state vulnerability studies as a recommended best management practice for water quality improvement, increasing stormwater retention capacity, and tidal flooding resiliency.

Coast Smart Council and CSCP: Following the 2020 update to the Coast Smart Construction Program Siting and Design Guidelines, the Coast Smart Council worked with MDP and DBM to incorporate the Siting and Design Guidelines into the review processes for capital project proposals in the state. The Coast Smart Climate Ready Action Boundary (CS-CRAB) and the updated Siting and Design Guidelines were also used in an effort to design a new ranger station at Assateague State Park through a partnership between DNR Chesapeake and Coastal Service and the University of Maryland School of Architecture through the PALS program. The Siting and Design Guidelines and additional information can be found at the Coast Smart Councils website - https://dnr.maryland.gov/climateresilience/Pages/cs_Council.aspx

Community Resilience Grants/Resiliency through Restoration: DNR solicited and funded community-based resilience projects in 2022 through the Community Resilience Grant Program. The program leverages federal dollars with state "Resiliency through Restoration" capital funding to promote and support comprehensive, holistic planning and implementation projects that address both water quality and quantity issues. Through these projects, DNR is helping Maryland communities become more resilient to flood risks, and enhance the protection and management of the state's resources including the bay and the ocean. Examples of some projects funded in 2022 include; completing a resilience plan for Middle Hoopers Island in Dorchester County; identifying flooding adaptation strategies for Byrd Park in the Town of Snow Hill, conducting a stormwater nuisance flood assessment and plan for Prince George's County; designing flood adaptation solutions for an identified flood prone area in Charles County; designing green infrastructure practices for a church-owned alley and courtyard in Baltimore City, as well as a grant to construct 600 linear feet of living shoreline in Anne Arundel County. This work continues a decade-long effort to provide support to local communities to assess risk, plan risk-reduction efforts and implement projects. This effort is included as a climate milestone in Maryland's Phase III WIP.

Resiliency and Land Conservation: In 2022, the Stateside Program Open Space scorecard, used to evaluate potential properties for acquisition, continued to provide ecological, resiliency and management justifications to the Board of Public Works, including evaluating properties for their coastal community resilience to climate change benefits. These benefits are provided by areas along the shoreline where natural habitats, such as marshes and coastal forests, have the potential to reduce the impact of coastal hazards to the adjacent coastal communities by dampening waves, stabilizing sediment and absorbing water. Board of Public Works approval of these acquisitions allows our land conservation programs - Stateside Program Open Space, the Conservation Reserve Enhancement Program (CREP) permanent easements, Maryland Environmental Trust (MET) and Maryland's Rural Legacy Program - to permanently protect land that provides coastal resilience to climate change as well as land important for priority wetlands to migrate inland as sea level rises.

Maryland's Parcel Evaluation Tool: As a complement to the Stateside Program Open Space scorecard, DNR also developed a public-facing, web-mapping tool which allows for rapid valuation and comparison of parcel level ecological benefits and values provided by Maryland's natural resources. The Parcel Evaluation Tool - accessible through the Maryland Greenprint Map - can be used to support stateside land conservation in all of the programs mentioned above as well as support the activities of external conservation partners. The tool generates an instant report that includes an Ecological Benefits Assessment and an Economic Co-Benefits Assessment. Among the Ecological Benefits assessed are the Coastal Community Resiliency and Future Wetland Habitat scores. The Coastal Community Resiliency score describes the potential of a parcel's existing natural habitats, such as marshes and coastal forests, to reduce the impact of coastal hazards to adjacent coastal communities. The Future Wetland Habitat score identifies areas important for inland wetland migration resulting from sea level rise that will support high value coastal habitats of the future. Among the ecological co-benefits assessed are the parcel-level biophysical and economic values of annual Net Carbon Sequestration in forests and wetlands. Carbon sequestration directly offsets carbon emissions within the state of Maryland and represents a critical component to the GGRA work plan. This component of the tool allows

for identification and conservation of natural habitats providing high carbon sequestration benefits.

Beneficial Use of Dredged Material: Once approved by DNR senior leadership, DNR policy and supporting processes will proactively identify environmentally and economically sound beneficial use of dredged material practices to improve coastal resiliency. Through the development and maintenance of a mapping tool - Beneficial Use: Identifying Locations for Dredge (BUILD) - project managers are able to quickly identify beneficial use opportunities. BUILD has been merged into the Maryland Coastal Atlas where the data is now available. DNR is funding or partnering on several coastal resiliency projects plan to utilize dredged material in 2023.

Clean and Resilient Marinas and Waterway Improvement Projects: The Maryland Clean Marina Initiative continues to provide extensive climate change and severe weather resiliency information to marinas via workshops, on line, and via newsletters. Updated resources related to adaptation and resiliency have also been added to the Maryland Clean Marina website: http://dnr.maryland.gov/boating/Pages/Hurricane-Storm-Preparations.aspx. In addition, beginning in 2021, the state Waterway Improvement Fund Program began incorporating climate vulnerability information into the application, Waterway project manual, review process, and grant issuance processes.

Maryland Park Service (MPS) Strategic Management Planning: MPS is actively engaged in a methodic park-by-park strategic management planning effort. These plans identify specific threats to park resources (such as storm-related flooding) and identify tasks to address those threats. An example can be found here: https://dnr.maryland.gov/publiclands/Documents/Smallwood_StrategicMmgtPlan.pdf

Building resilient landscapes - MPS is working with Land Acquisition and Planning and Chesapeake and Coastal Service staff to identify marginal agricultural lands on park properties that can be converted to more resilient, natural landscapes such as wetlands, meadows and forests. This has resulted in the protection of sensitive resources (e.g., hydric or highly erodible soils) while also improving park aesthetics and addressing identified erosion concerns. Maps were created for Kings Landing, Merkle NRMA, Tuckahoe SP, and Wye Island to highlight agricultural areas impacted by sea level rise.

Electric Vehicle (EV) Charging: DNR has an internal EV Charging Task Force with representatives from several units who work together on EV charging-related projects. Over the past year, Task Force members representing MPS have developed a regional assessment of potential locations for charging infrastructure installation. MPS has also facilitated the installation of EV charging stations as part of larger park improvement projects at several locations around the state. Key Task Force initiatives have also included working with utility companies on the evaluation of DNR owned lands for charging infrastructure through the Public Service Commission's EV Pilot Program, developing right of entry agreements for pilot program projects, and coordinating with DGS on the installation of two charging projects at the Tawes complex.

Energy upgrades at existing park buildings: Two parallel efforts are being made to improve energy efficiency at existing park facilities. First, all park sites are being analyzed for the potential installation of solar panels on existing park buildings. A successful installation at Sandy Point State Park is documented here: https://news.maryland.gov/dnr/2018/01/29/energy-efficient-upgrades-completed-at-sandy-point-state-park/. In addition, MPS is working with the Maryland Energy Administration to conduct energy audits of existing park facilities that will examine everything from HVAC systems to light fixtures. Wherever possible, inefficient fixtures or equipment will be replaced.

Targeted climate change acquisitions: In recognition of the increasing frequency of flooding and storm events and the resulting impacts on park operations and visitors, MPS is working with Land Acquisition and Planning to identify potential sites for relocating popular campgrounds and day use areas if the time comes where "retreating" from flooded or flood prone areas is the only viable option. While some level of further investment in existing facilities is likely, catastrophic storm events are not out of the realm of possibility. Planning ahead and ensuring sites meet the needs of our visitors will ensure visitor enjoyment despite flooding events..

Nuisance Flood Plan Guidance: DNR, MDP and MEMA collaborated on the review of all plans submitted prior to 2022. Preparation began for the plans to be updated in 2023 to include more detailed recommendations and specific ways to document flooding, including the use of MyCoast MD.

Climate and Fisheries Coastal Management Fellow: In August 2022, a 2022-2024 Coastal Management Fellow was placed at DNR to support work advancing climate adaptation priorities related to fisheries management and natural resources-based economies. Since then, the fellow has undertaken work to focus on increased state engagement in regional Fishery Management Council climate scenario planning, reviewing of opportunities to integrate climate change in fishery management plans, and developing processes to prioritize resources-based industry and fishery climate adaptation strategies in the ARWG's NextGen Adaptation Planning process that will take place in 2023.

Saltmarsh Sparrow Habitat Prioritization: CCS staff worked with state, local and federal partners towards prioritization of saltmarsh restoration and protection areas with the goal of protecting habitat for the Saltmarsh sparrow, a tidal marsh obligate songbird of Conservation Concern. The habitat is threatened by sea level rise and marsh degradation. Final draft of the Maryland prioritization areas was published January 2022 and will continue to be updated as progress and projects continue. An online spatial tool was created based on this information in October 2022. CCS is working with various partners to identify and secure funding for saltmarsh restoration projects identified through this work.

Climate Change Adaptation and Resilience Planning on State Lands: CCS continued to collaborate with the Maryland Park Service, Maryland Forest Service, and the Wildlife and Heritage Service to update climate change adaptation and resilience plans on state lands and identify areas in need of future plans. Three plans for Assateague State Park, Pocomoke State Forest, and Browns Branch were finalized for land managers to use and for members of the

public to access through the DNR website. The plans can be found here: https://dnr.maryland.gov/land/Pages/Documents.aspx.

Facilitating Healthy, Just, and Community-Supported Marsh Migration: The Nature Conservancy (TNC) and Maryland Department of Natural Resources (MDNR) are leading initiatives to protect and restore coastal landscapes to ensure the long-term resilience of critical habitats and coastal communities. Working with both organizations, Sabine Bailey, NOAA Digital Coast Fellow 2022-2024 is playing an integral role in facilitating cross-agency conversations to reform land protection activities with equity-oriented implementation and to promote community-supported marsh migration and community resilience. Specifically the fellow is (1) leading landowner engagement on the Lower Eastern Shore to ensure local perspectives are driving the design of a novel resilience easement program with TNC, (2) developing an engagement plan with local indigenous communities to understand how TNC can support their goals, (3) drafting a policy analysis to revise MDNR's Land Acquisition Criteria to incorporate considerations for ecosystem services and equity and justice, and, (4) bringing expertise to MDNR's Targeted Resilience Area Implementation Team on equitable community engagement and land protection.

As a result of this project, CCS also partnered with the University of Maryland Partnership for Action Learning in Sustainability (PALS) to create 10 climate change graphics that summarize the impacts of climate change in the state and propose adaptation strategies. The graphics may be found here: https://www.flickr.com/photos/marylanddnr/albums/72177720298614252.

2. <u>Community Engagement and Communication</u>

2022 Mid-Atlantic Climate Change Education Conference: The 2022 Mid-Atlantic Climate Change Education Conference (MACCE-C) was a unique convening of formal and non-formal educators to share and learn about the latest trends in climate change education. In its third year, the conference was hosted virtually on July 26. There were 310 registered participants, and four session tracks for the conference: Climate Justice; State Breakouts; Climate Teaching Resources and Youth Action..
The conference was made possible through partnerships and collaboration with the following agencies: CBNERR-MD, National Oceanic and Atmospheric Administration (NOAA) Chesapeake Bay Office, DE Sea Grant, DE NERR, and Jacques Cousteau NERR (NJ).,, Funding through SeaGrant made the conference fee affordable to participants ($25).

Mid-Atlantic Climate Change Education FORUM: In 2021, the planning team of the MACCE Conference considered how to expand beyond an annual conference, and began seeking ideas to transform the multiple avenues of education into the ambitious action needed to build a healthy, livable, just future. The team invited bold ideas from around the Mid-Atlantic to lead this conversation, share lessons and leverage lessons learned, scale and celebrate successes, network across sectors, and engage together. Seeking a strategy centered in equity and justice, they co-created a regional forum to advance education for climate action.

The inaugural Mid-Atlantic Climate Change Education Forum was held August 15-17, 2022 at North Bay Adventure Camp in Maryland. The Forum aimed to: Convene and build a community of active climate education stakeholders; Learn and share about the state of climate action education in the region; Create a strategic framework and map the strategies for advancing and funding climate action education; Identify catalysts and influencers essential for building capacity in education for climate action; and, Develop a set of key actions and identify teams willing to work on these actions. The Key Actions and Teams developed:

1. Schools as resource and community hubs
2. Supporting student-led action
3. Systems-level advocacy
4. Career education and workforce development
5. Strengthening strategic networks and supporting climate action plans
6. Intergenerational and community based solutions
7. K-12 and College Programming

The work continues beyond the event as teams learn, connect, create and engage monthly to prioritize the development and implementation of the resulting climate change education vision.

Teachers on the Estuary: The 2021 & 2022 Teachers on the Estuary (TOTE) program, offered through a partnership with CBNERR-MD, the Chesapeake Bay Foundation, and NOAA Chesapeake Bay Office, featured a hands-on learning experience for both students and environmental science professionals. Participants collected real data throughout the watershed to address questions about climate change. Participants learned to integrate data into the classroom through cross-disciplinary, hands-on field activities, and online resources. This dynamic course enhances the learning experience by conducting investigations of participants' local environments. This course is designed to model a Meaningful Watershed Educational Experience (MWEE) through participant-driven field experiences and hands-on research.

Shoring Up Resiliency Through Education (SURE): This project aims to support Somerset County Public Schools in addressing regional vulnerability to climate impacts and building community resilience through understanding how environment, science and cultural heritage work together to strengthen a community. Students in fifth, seventh and ninth grades experience, study and analyze trends in local conditions such as weather and water quality that affect the natural resources upon which much of their local economy depends. Participating teachers receive professional development annually, through which they are supported in writing lessons to support this project. Partners include the Maryland Department of Health, Chesapeake Bay Trust, and Somerset County Public Schools.

Maryland's Climate Leadership Academy: The Maryland Climate Leadership Academy (MCLA) is supported with NOAA Coastal Zone Management funds managed by the Chesapeake and Coastal Service Unit of DNR. The MCLA is in its fifth year of operation. In 2021, 144 were enrolled across 8 cohorts of the MCLA Certified Climate Change Professionals (CC-P) program. Additionally, the MCLA offered 3 additional training opportunities of which 22 individuals took part. The MCLA continued to successfully operate in a fully remote capacity this calendar year

in keeping with the continuing health and safety guidance of the COVID-19 response. This effort is included as a climate milestone in Maryland's Phase III WIP.

Maryland Marine Debris Emergency Response Plan: NOAA's Marine Debris Program staff led the planning and preparation of an emergency marine debris response plan for Maryland. The plan's goal is to improve preparedness for response and recovery operations following an acute waterway debris incident in coastal Maryland. As severe weather events become more frequent, the plan will allow better communication and clarify responsibilities and capabilities among agencies.

Maryland Forest Service: The Maryland Forest Service with other partners - including the US Forest Service, UMCES and Extension - released topic-related fact sheets and technical guidance on woodland and climate change stewardship principles. The Forest Action Plan for 2016-2020 now includes the strategy, :Make Landscapes More Resilient to Climate Change" to help guide the management of forests on state and public lands.
http://dnr.maryland.gov/forests/Documents/2015_DRAFT percent20_ForestStrategyUpdate.pdf
http://extension.umd.edu/sites/extension.umd.edu/files/_docs/programs/woodland-steward/MD_Climate_Adaptation_Guide_for_Forest_Landowners_2013.pdf

Communicating Risk to the Public: DNR staff engaged audiences throughout the year on the topic of climate change, including training on the recently released Guidance for Using Maryland's 2018 Sea Level Rise Projections document. Public trainings were also offered to communities to encourage use of the MyCoast MD flood documentation app and website. MyCoast MD can be used to track tides, submit photos of flooding, and identify areas for adaptation strategies. MyCoast MD saw an increase of 185 users in 2022. Staff also participated in conferences for teachers, including the Maryland Association for Environmental and Outdoor Education (MAEOE) where staff presented lessons for understanding climate and Next Generation Science Standards. Partners included NOAA, Audubon Maryland-DC and Partners Advancing Climate Change Education.

Equitable Community Engagement in Climate Action and Resiliency Planning: DNR provided funding to support Defensores de la Cuenca in the creation of their first and second cohorts of a spanish-taught watershed steward academy. The purpose of this academy is to engage people in the Latino/a community in environmental stewardship and awareness of flooding issues in Maryland's Coastal Zone. The class focuses on best management practices for stormwater management, ways to address runoff by incorporating native plantings and encouraging tree growth, and environmental communication. Over 100 people were engaged at various events in 2022.

Building Capacity in Under-Engaged Communities for Resilient Infrastructure Projects:
Through a Coastal Management Bipartisan Infrastructure Law funding opportunity, DNR is expanding is work with the Chesapeake Bay Trust to build on a recent partnership that launched the 'Community Based Organization Capacity Building Initiative (CBO-CBI).' Through five years of funding, the department will be working to address capacity needs in historically under-engaged communities that have not previously participated in core community resilience grant programs. This CBO-CBI partnership will build meaningful connections with historically under-

engaged community-based organizations (referred to as "connector" groups) that focus on reaching out to and engaging new and under-engaged groups to identify resilient infrastructure projects. A second type of partner organization will provide support with green infrastructure design, engineering, and grant proposal writing and will be referred to as "technical assistance providers." Both types of organizations will work closely together to build the capacity of community-based organizations interested in applying to and advancing resilient natural- and nature-based projects.

Climate Impacts in Maryland: Understanding the training and education opportunities across the coastal zone: In 2022, CCS initiated a market analysis and needs assessment of climate-focused education and training opportunities in Maryland. CCS is contracting with Responsive Management to conduct two surveys and a series of in-depth interviews. The surveys will investigate the programs and services offered in Maryland which support climate impact education programs, training and technical assistance.The first survey will be released in early 2023 to service providers to gauge the breadth and scope of existing programs and services in Maryland. The second survey will be distributed to stakeholders to determine gaps in education and training programs and unmet needs of stakeholders. The purpose of this study is to determine where CCS should invest in developing education, training, and technical assistance programs and services to meet stakeholder needs and avoid duplicating the efforts of existing programs.

3. <u>Advancing the Science</u>

Margaret A Davidson Fellowship: The Margaret A. Davidson Graduate Fellowship is a new fellowship program that places a graduate student in each of the 29 NERRs to address key coastal management questions through cross-discipline research projects. CBNERR welcomed Daniella Hanacek as the 2020-2021 fellow. Ms. Hanacek will be working to assess wetland conditions and management actions of Maryland's tidal wetlands by evaluating the carbon sequestration potential of natural and restored tidal marshes in the Chesapeake Bay.

Her research with the reserve is focused on quantifying atmospheric methane and carbon effluxes from Chesapeake Bay marshes, which can then be used in combination with plant productivity and carbon burial rates to estimate the net amount of carbon sequestered by these marshes. Information generated on the role of Maryland's tidal wetlands in capturing carbon will inform future climate mitigation strategies through the conservation and restoration of blue carbon ecosystems.

Ecological Effects of Sea Level Rise: DNR partnered with George Mason University and The Nature Conservancy to launch Maryland's Ecological Effects of Sea Level Rise Project to monitor and model the wave attenuation and flood reduction benefits of marshes, submerged aquatic vegetation and other nature-based features. This four-year project will quantify the protective characteristics of Maryland's natural features and investigate how those characteristics may change as sea levels rise. Wave, water level, and current sensors were deployed in the summer of 2020 and 2021, and the department engaged state, federal and local partners through a Management Transition Advisory Group. In 2022, statewide hydrodynamic and marsh

migration modeling was completed for different sea level rise and storm scenarios. Work is underway to integrate results into existing spatial tools for conservation and restoration decision-making. This study expands on previous monitoring conducted in Somerset County and will assist managers with identifying restoration needs and priorities in areas where natural features can enhance community resiliency to climate change impacts.

Future Projections of Rain Storm Intensity: Climate change is expected to cause more extreme precipitation events in the future. To know whether or how to adapt regulatory permits for stormwater management, sediment and erosion control and waterway construction (culverts and bridges that span streams) it's necessary to have a better sense of how climate change will affect the Intensity, Duration and Frequency (IDF) of rain storms. A state-funded Restoration Research Grant was awarded to a consulting firm in 2019 to estimate potential precipitation IDF curves at 79 Atlas 14 sites across Maryland for mid-century (2055) and late-century (2085). This study also analyzed how peak runoff rates may change in the future and applied those results to evaluate the potential impact on certain types of urban stormwater controls, stream stability and roadway flooding associated with culvert sizing. In 2021, a follow up project to the principal investigators of the above work was awarded to examine how environmental site design at the watershed scale performs in response to various climate change scenarios. The deliverables of these two research projects are fueling discussion among scientists, engineers and the regulatory community about how the research results can appropriately be applied to state programs and what next steps are needed to continue learning about these trends.
https://cbtrust.org/grants/restoration-research/ .

Resource Assessment Service Monitoring: Based on climate change projections, Maryland's streams are likely to become warmer and the flows are likely to become more extreme. Some coastal streams could also become inundated as a result of sea level rise. These changes may alter the ecology, water quality and physical habitat of streams. The Maryland Biological Stream Survey (MBSS) tracks trends in factors such as aquatic species distributions, water temperature, and erosion that are indicators of potential climate change influences on Maryland's streams. Based on temperature and species distribution information, the MBSS has specifically identified stream animals that prefer cold water and, as a result, may be particularly sensitive to stream temperature increases. Detailed stream temperature information from the MBSS may also help identify streams with particularly cold water and thus are likely to be resilient to temperature increases.

In addition to a representative sampling of Maryland's streams, the MBSS has been monitoring 29 "Sentinel" streams since 2000 to specifically examine for potential influences of factors such as climate and weather on Maryland's stream ecology, temperature, water quality and physical habitat. For more information -
http://dnr.maryland.gov/streams/Publications/2014SentinelSiteReportWEB.pdf

Adaptive Management for Resilient Restoration Projects.

The Chesapeake Bay Sentinel Site Cooperative (CBSSC): CBSSC is a group of ecosystem-based study sites across the Chesapeake Bay that: 1.) work together to measure the impacts of sea level rise in the bay; 2.) Work with partners to apply scientific findings produced at sentinel sites to

help communities prepare for coastal flooding and other effects of changing climate conditions; 3.) Work in partnership with coastal managers, decision makers, and community liaisons.

Timing of Striped Bass Spawning in Relation to Changing Water Temperatures: The Chesapeake Bay is the largest spawning area along the Atlantic coast for striped bass and the dominant environmental cue for spawning is water temperature. Since the 1960s, increases in water temperature have been observed in the Chesapeake Bay and climate change projections estimate that water temperatures will increase 2-6°C by the end of the 21st century. This analysis examined data from the striped bass spawning stock survey which has been conducted on the Potomac River and Upper Bay since 1985 using experimental drift gill nets. The analysis focused on the day of the year when specific temperature milestones were reached throughout the time series, specifically 14°C as the water temperature when striped bass spawning occurs and 20°C as the water temperature where striped bass egg survival is diminished. Additionally, the spawning stock data was analyzed for the day of the year across the time series that 25% and 75% of the female striped bass catch per unit effort (CPUE) was observed.

On average, the 14°C milestone is reached on the Potomac River approximately 5 days earlier in more recent years than recorded in the 1980s and the Upper Bay reaches it approximately 3 days earlier. The 20°C milestone, though not measured every year on the spawning stock survey due to survey length, is reached on the Potomac River approximately 3 days earlier in more recent years, and the Upper Bay reaches it approximately 6 days earlier than the 1980s. The Potomac River did not show a trend through time when 25% of the total female CPUE was observed but 75% of the total female CPUE is now observed 6 days earlier. In the Upper Bay, 25% of the total female CPUE was observed 8 days earlier in recent years compared to the 1980s, and 75% of the total female CPUE is now observed about 14 days earlier. On both systems, correlating the CPUEs with average spring water temperatures showed that fish arrive on the spawning grounds approximately 3 days earlier for every 1°C increase in water temperature, similar to other published work. These results also indicate that the spawning season in these systems may not only be moving to an earlier part of the season but that the spawning season is also shortening.

Maryland Blue Carbon Resilience Credit Feasibility Study: Maryland DNR has partnered with The Nature Conservancy (TNC) to support the assessment of blue carbon and resiliency crediting feasibility at selected project sites throughout Maryland. The feasibility study will consist of the gathering of existing data and information to inform whether market project development is viable and to provide recommendations for next steps. Final report from the selected contractor will include detailed assessment of technical, organizational, landscape, and social feasibility factors. MDNR and TNC have partnered to complete the legal and financial feasibility aspects of the assessment. A contractor to perform the feasibility study has been selected as of January 2023, and the project is planned to be completed by November, 2023.

Resiliency through Restoration Monitoring: The Chesapeake Bay National Estuarine Research Reserve developed and implemented monitoring protocols at select restoration sites to track restoration success and inform adaptive management needs. Staff partnered with the University of Maryland Center for Environmental Science (UMCES) to expand monitoring efforts across a portfolio of shoreline projects. In 2022, DNR and UMCES partners monitored 3 sites before

restoration and 3 sites after restoration was complete. . Additionally, students at St. Mary's College of Maryland collected data at 1 site prior to restoration.

Elliott Campbell, PhD
Acting Director, Office for Science and Stewardship
elliott.campbell@maryland.gov

Chesapeake and Coastal Service
580 Taylor Ave., D-2
Annapolis, MD 21401

dnr.maryland.gov