



CENTER FOR COASTAL RESOURCES MANAGEMENT

2021 Annual Report

CCRM activities from January 1, 2021 to December 31, 2021

CENTER FOR COASTAL RESOURCES MANAGEMENT



**VIRGINIA INSTITUTE OF MARINE SCIENCE
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DAVIS HALL, 2nd FLOOR
GLOUCESTER POINT, VA 23062**

The year 2021 was another year of challenge and innovation for CCRM. Even with COVID-19 issues still restricting the ability for in-person group activities, the CCRM staff was able to increase productivity and deliver science-based solutions to challenges impacting coastal environments and the communities that rely on them.

We continue to lead in resilience, conservation, and sustainability efforts and to foster partnerships that promote science in action enabling impactful research important to communities. We recognize that solutions to environmental issues must include an understanding of the place of humans in the natural environment. This social-ecological perspective has helped us to identify viable societal actions to conserve and restore coastal environments. Our research and outreach on living shorelines has built awareness and acceptance of these practices.

In addition to monitoring the Commonwealth's invaluable natural resources, we have adapted our shoreline management tools that were originally designed for Virginia coasts for use in Maryland and in the Gulf of Mexico. We are assessing the status and trends of the Nation's wetlands and coastal marsh carbon sequestration potential. Our work in hydroscience modeling, and sea-level rise impacts on vulnerable communities and road infrastructure is recognized nationally and globally. Our work on marine debris, lost fishing gear, and biopolymer alternatives to plastics continues to generate international interest.

2021 was challenging but also very exciting for the Center. New tools have been developed and existing tools updated and enhanced to empower community engagement and help address society's most pressing environmental challenges. I am proud of all we have accomplished in 2021 and excited for all that is to come in 2022. The work CCRM staff is doing helps fuel positive change locally, nationally, and globally.

A handwritten signature in black ink, appearing to read "KJ Havens".

Dr. Kirk J. Havens, Director
Center for Coastal Resources Management

MISSION & PRIMARY ACTIVITIES

The Center for Coastal Resources Management has a general mission to support informed decision making on resource management issues at all levels of government, including private and corporate citizens.

The Center has specific responsibilities for:

- (1) providing technical support for the Commonwealth's tidal wetlands management program, including maintenance of a continuing inventory of the state's tidal wetlands;
- (2) maintaining a continuing inventory of the status and trends of tidal shorelines;
- (3) providing technical support to the Commonwealth's non-tidal wetlands program;
- (4) providing technical support on the issue of coastal marine debris;
- (5) providing support to the Commonwealth Center for Recurrent Flooding Resiliency; and,
- (6) providing support for the Commonwealth's Wastewater Infrastructure Policy Working Group.

In addition to these primary and continuing obligations, CCRM has provided continuing involvement in the state's Coastal Zone Management Program, significant involvement in the Chesapeake Bay Program and its Scientific and Technical Advisory Committee, as well as significant involvement and official state representation to the Albemarle-Pamlico National Estuary Partnership and its Leadership Council.

At CCRM, we conduct **ACTIONABLE SCIENCE**. Actionable science links science to action with the aim of improving the quality of life for citizens and includes not only information, but also guidance on the appropriate use of that information. This means that our research and advisory activities are closely intertwined with scientific findings underpinning the guidance we provide to help shape environmental and economic policy decisions. CCRM is providing actionable science towards the goal of resilient and thriving communities, sustainable fisheries, clean water, and healthy productive ecosystems in the Commonwealth.

To fulfill this mission, the Center actively fosters a diverse and inclusive environment to maintain excellence in our research, advisory service, and outreach education. The strength of the Center is based on the diverse interests, perspectives, beliefs, and identities of all of our members, who are committed to the advancement of the William & Mary **CORE VALUES**. ([link](#))

PERSONNEL

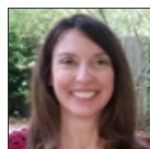
The Center has a staff of about 25 individuals and supports several graduate students.



KIRK HAVENS
Director, CCRM
Research Professor



DAWN FLEMING
Finance & Business Manager



DONNA BILKOVIC
Assistant Director, CCRM
CCRM Operations & Research Manager
Research Professor



KARINNA NUNEZ
CCRM Geospatial Modeling Manager
Assistant Research Scientist



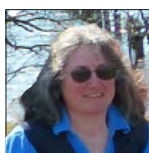
Y JOSEPH ZHANG
CCRM Hydrodynamic Modeling Manager
Research Professor



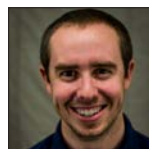
PAMELA MASON
CCRM Extension Manager
Senior Research Scientist

Operations

Research



JULIE HERMAN
Sr. Research Scientist



ROBERT ISDELL
Assistant Research Scientist



MOLLY MITCHELL
Research Assistant Professor



KORY ANGSTADT
Scientist II



DAVID STANHOPE
Scientist II



DAVID WEISS
Database Analyst

Geospatial Modeling



TAMIA RUDNICKY
Sr. Programmer/Analyst



DAN SCHATT
Sr. Programmer/Analyst



EVAN HILL
GIS Analyst



SHARON KILLEEN
GIS Specialist

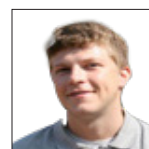


JESSICA HENDRICKS
Scientist I



CATHERINE DUNING
GIS Analyst

Numerical & Hydrodynamic Modeling



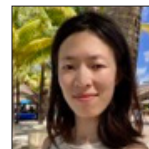
J DEREK LOFTIS
Research Assistant Professor



FEI YE
Assistant Research Scientist



HAO-CHENG (DAN) YU
Assistant Research Scientist



WEI HUANG
Postdoc Research Associate



LINLIN CUI
Postdoc Research Associate



ZHENGUI WANG
Postdoc Research Associate

Extension



KAREN DUHRING
Scientist III



**CHRISTINE
TOMBLESON**
Scientist III

GRADUATE STUDENTS



NICOLE CAI earned a Master of Science in Marine Science in 2018 under her co-advisors, Dr. Joseph Zhang and Dr. Jian Shen. Nicole continued her studies at VIMS as a doctoral student working with CCRM's modeling research program. She is finishing her program in the coming spring, 2022. Nicole started an ORISE (Oak Ridge Institute for Science and Education) Fellowship at the EPA Chesapeake Bay Program, EPA Region 3 in August 2021. This program connects the most talented and diverse college students to STEM internships and fellowships closely aligned with the interests of federal research facilities. Some of her projects include evaluating the impacts of sea-level rise on hypoxia in the Chesapeake Bay, building up vegetation models in the Chesapeake Bay, and studying impacts of sea-level rise on estuarine biochemical processes and tidal marshes.

JAIME CALZADA is pursuing his doctorate in Physical Oceanography at VIMS under the supervision of his advisor Dr. Joseph Zhang. He currently researches and develops scientific software aimed to provide client level interfaces to the SCHISM numerical model, as well as development of modular components to support the modeling infrastructure. His main research area aims to provide a scalable interface that uses a data driven approach for the generation unstructured meshes used in ocean and atmospheric planetary numerical modeling to accelerate the scientific discovery from modeling and simulation.

EMMA DODSWORTH is pursuing her Master of Science at VIMS under her joint advisors, Dr. Mark Brush and Dr. Molly Mitchell. She is creating a model of the nutrient removal capabilities of living shoreline that can be used to understand how the CCRM shoreline management model's recommendation for living shoreline locations might help reduce nutrient inputs to the waterways.

AMANDA GUTHRIE is pursuing her doctorate in Marine Science at VIMS under her advisor Dr. Donna Bilkovic. She researches how living shorelines help support fish communities in the Chesapeake Bay, and if and how people make decisions to mitigate shoreline erosion on their property. Amanda's research about fish communities has been published in the journal Ecological Engineering, in the paper titled "Ecological equivalency of living shorelines and natural marshes for fish and crustacean communities". She also helped author two other publications in the peer-reviewed journals. Amanda was awarded a 12-week graduate fellowship position at the National Academies of Science Gulf Research Program where she worked with stakeholders in the Gulf to provide community-informed guidance for the Gulf Research Program. Amanda is wrapping up her time as a Co-PI on a SESYNC Graduate Pursuits grant where she is leading six PhD students on an interdisciplinary research project to understand the social and ecological dimensions of offshore net pen aquaculture in the Gulf of Mexico.

KATI GRIGSBY is pursuing her a Master of Arts in Marine Science at VIMS under her advisor Dr. Donna Bilkovic. She is a member of the first Professional MA class at VIMS. Kati's studies focus on the restoration and conservation of resilient tidal shorelines. Kati has a position with the Chesapeake Bay Foundation and will conduct her internship with the Elizabeth River Project working with their Restoration Director, Joe Rieger.

CANDICE VINSON is pursuing her Masters of Arts in Marine Science under her advisor Dr. Kirk Havens. She is a member of the first Professional MA class at VIMS. Candices's studies focus on the synthezation and translation of science into useable knowledge for the public and ways to incorporate accessibility in all public facing products and presentations. Candice has a position with VIMS as the Outreach and Events Coordinator.

INTERNS

ERIN FERRARE a senior at Hampton Roads Academy worked with CCRM to identify how rare, threatened, and endangered coastal species respond to environmental conditions as part of her Virginia Governor's School Marine Science Apprenticeship Program.

MIRANDA LV is a geospatial data analyst at William & Mary, who is working with CCRM on advancing the computer code for the shoreline inventory and the WetCat tool.

MAYA REESE a senior at Lafayette High School and the Governor's School for Science and Technology used GIS technology to study the relationship between shoreline characteristics and submerged aquatic vegetation (SAV) habitats in the Mobjack Bay, VA for her Senior Research and Mentorship project.

JACOB SMOUSE an undergraduate student at Christopher Newport University worked with Amanda Guthrie to age a common marsh fish in support of living shoreline ecology research.

JOSEPH SNITZER an undergraduate student from the University of Virginia worked with CCRM as part of UVA's Environmental Resilience internship program. Joseph tackled the issue of social and environmental vulnerability in the Elizabeth River Watershed. The project contributed to the Elizabeth River Project's Social Justice Viewer.

SCHYLER VANDERSCHAAF an undergraduate student from the University of Virginia worked with CCRM as part of UVA's Environmental Resilience internship program. Schyler tackled the issue of septic system failure in the Northern Neck and climate resilient adaptation.

JES WATTS a Master of Arts in Public Policy student at William & Mary is reviewing shoreline modification permit applications to help identify the key factors that relate to property owner decision making.

AWARDS & RECOGNITION

MARCIA BERMAN retired after serving as CCRM's lead GIS expert for 28 years. She specialized in coastal modeling and mapping and managed all GIS activities for the Center. Marcia's career ended with a long list of professional accomplishments and work products, including high-resolution shoreline inventory methods and shoreline management suitability models now in use around the nation.

DR DONNA BILKOVIC was appointed to serve on Albemarle-Pamlico National Estuary Partnership's Scientific and Technical Advisory Committee (STAC).

DR KIRK HAVENS was recognized for his long-time service on the Albemarle-Pamlico National Estuary Partnership Scientific and Technical Advisory Committee. APNEP strives to bring together diverse groups to identify how they can act together to create a healthy Albemarle-Pamlico estuarine system, from headwaters to the coast.

DR J DEREK LOFTIS and DR Y JOSEPH ZHANG were recognized as publishing the most highly cited paper in the international Journal of Marine Science and Engineering: "*The Storm Surge and Sub-Grid Inundation Modeling in New York City during Hurricane Sandy*" ([link](#))

PAMELA MASON was appointed as chair of the Chesapeake Bay Program STAC Wetlands Workgroup.

DR KARINNA NUNEZ was the recipient of 2021's Diversity & Inclusion Award for her unrelenting commitment to the VIMS Principles of Community and the widespread impact she has had to advance the Diversity & Inclusion mission within CCRM, at VIMS, and beyond. ([link](#))

SCHISM The U.S. Environmental Protection Agency has chosen a computer model developed by Dr. Joseph Zhang with a team of VIMS researchers as its next-generation tool for monitoring and managing Chesapeake Bay restoration in an era of rapid climate change. Selection of the SCHISM model is the first step in a 6-year, \$1.65M cooperative agreement. SCHISM is slated to begin operating in 2025 and will replace a model that has been used to monitor and guide the Bay Program's restoration efforts since the early 1990s. ([link](#))

ACTIVITIES

The Center for Coastal Resources Management (CCRM) at VIMS has a formal mission to support informed decision-making on coastal resource management issues from global to local scales. To fulfill this mission, the Center undertakes cross-disciplinary research, provides advisory service, and conducts outreach education.

ADVISORY



COASTAL RESILIENCE

ADAPT VA

We maintain the AdaptVA website that serves as a gateway to information for individuals, local programs, and agencies engaged in climate adaptation. This resource provides legal and policy resources, stories that explain adaptation through maps and pictures, and mapping tools that address short and long-term predictions for rising water levels.

GOVERNOR'S COASTAL RESILIENCE MASTER PLAN

We are assisting the Governor's Special Assistant for Coastal Adaptation and Protection and the Commonwealth's Chief Resilience Officer in the development and refinement of Virginia's Coastal Resilience Master Plan.

TRACKING CLIMATE RESILIENCE FOR WATERSHED COMMUNITIES

We are building a climate resilience scorecard for communities within the Chesapeake Bay watershed to provide watershed communities with a unified and consistent data-rich method of tracking the implementation and outcomes of policies and actions to improve their climate resilience and compare their progress to others in the region.

CONSERVATION TARGETING FOR RESILIENCE

We are developing future projections of likely migratory patterns and abilities of natural habitat and species guilds to shift under climate change and sea-level rise.

NEW GUIDANCE TO BUILD RESILIENCY AND MITIGATE FOR SEA-LEVEL RISE AS ELEMENTS OF THE CHESAPEAKE BAY PRESERVATION ACT

We are developing a guidance document and future Resource Protection Area (RPA) GIS layer to assist localities with implementation of the Chesapeake Bay Preservation Act, to facilitate integration of adaptations to recurrent flooding with water quality protections afforded by coastal management approaches.

SEA LEVEL RISE AND COASTAL COMMUNITIES

COMMONWEALTH ROAD INFRASTRUCTURE

We are collaborating with the Virginia Department of Transportation to develop tools to identify management strategies for road segments subject to current or future flooding by tidal waters and provide a forecast of impacts and mitigation options for transportation infrastructure interaction with coastal ecosystems that provide habitat for fish and wildlife.

ASSESSING VULNERABILITY OF PRIVATE WELLS TO FLOODING

We are developing a spatially explicit drinking well characteristics database for Northumberland and Lancaster Counties to examine the capacity to identify the growing risks for contamination of drinking water aquifers by flood waters entering private wells in rural populations in Virginia's coastal zone.

PREDICTION OF FUTURE SEPTIC SYSTEM FAILURE SITES (WASTEWATER ISLANDS)

We are analyzing failed septic systems (repair permits) data throughout Virginia to help identify current and future areas of concern.

SEA LEVEL RISE REPORT CARDS

We use Monthly Mean Sea Level (MMSL) data collected from 1969-present for 33 water level sensors in the continental US to compute linear and quadratic sea level forecasts with 95% confidence intervals (high and low) from quadratic trends established from data. Updated annually.

WASTEWATER INFRASTRUCTURE WORKGROUP

We advise the Secretary of Natural and Historic Resources and the Virginia Department of Health in a multi-agency effort to identify areas of potential septic system failure in the coastal plain and across the state (§ 62.1-223.2).

VIRGINIA WASTEWATER INTERACTIVE MAP & VIRGINIA WASTEWATER DATA VIEWER

We developed and continue to update and maintain the Virginia Wastewater Interactive Map Tool used by the Virginia Department of Health and other agencies to collect knowledge from local agency staff on the locations and attributes of wastewater problem areas throughout Virginia. We also developed and continue to maintain the Virginia Wastewater Data Viewer that illustrates, among other layers, the temporal hotspot analysis of septic failure in coastal localities, conducted for the Wastewater Infrastructure Workgroup.

EVALUATION OF THE IMPACT OF FLOODING ON ROAD NETWORK ACCESS –YR 2

We are providing flood inundation maps and road network analysis to specific localities.

ELIZABETH RIVER INITIATIVE – SOCIAL JUSTICE TOOL

We developed an online mapping tool to assist the Elizabeth River Project and other community partners with proactively incorporating environmental justice issues into restoration and planning efforts.

MARISA 2.0: CONTINUITY & EXPANSION OF COMMUNITY-BASED ENGAGEMENT AND SUPPORT.

We are working with rural localities to identify at risk rural infrastructure and explore adaptation.

INCREASING THE RESILIENCY OF NEWPORT NEWS COMMUNITIES VULNERABLE TO FLOOD IMPACTS

We collaborated with the Commonwealth Center for Recurrent Flooding Resiliency to develop updated inundation model depth grids for the VA Department of Emergency Management in the Salters Creek and Newmarket Creek watersheds in southern Newport News. We also surveyed structures within the 100-year floodplain to establish new First Floor Elevation measurements for buildings. This enhanced the accuracy of critical decision-making resources in frequently-inundated floodplains to decrease uncertainty in predictive damage assessments, and aided the City in proactive decision-making for projected stormwater infrastructure projects.

MARINE POLLUTION

CHESAPEAKE BAY NO DISCHARGE ZONE – PHASE 1

We collected data to estimate the population of all non-recreational type vessel traffic that included commercial, governmental, and military vessels that may navigate within the mainstem of the Virginia portion of the Chesapeake Bay or its tributaries. We conducted a data gap analysis for commercial vessel data and current pump-out station availability and assessed potential pump-out needs if a No Discharge Zone were to be implemented.

MARINE DEBRIS

We contributed to the development of the updated 2021-2025 Virginia Marine Debris Reduction Plan and the NOAA Mid-Atlantic Marine Debris Action Plan.

CRAB TRAP APP

We worked with High School students to develop an App for citizen volunteers to collect data on derelict crab traps in the winter when the blue crab fishery is closed. The community science project is conducted each winter.

SHORELINES AND WETLANDS

LIVING SHORELINE POLICY

We provided reports on shoreline management outcomes over the past 40 years for the Secretary of Natural and Historic Resources and Virginia Department of Environmental Quality.

GARDEN CLUB OF AMERICA COASTAL WETLANDS STUDIES SCHOLARSHIP

We serve as a technical review committee for GCA merit-based scholarships that promote wetlands conservation through the support of young scientists in their field work and research.

VIRGINIA MASTER NATURALIST PROGRAM

We serve as a sponsoring agency for the statewide volunteer program, offer basic training and continuing education for coastal chapters, and provide a chapter advisor for the Middle Peninsula Master Naturalists.

RESTORATION

CHESAPEAKE BAY RESTORATION

We assist in the science of Chesapeake Bay restoration with staff and faculty membership on Chesapeake Bay Program committees, goal implementation teams, and workgroups.

ELIZABETH RIVER WATERSHED ACTION PLAN

We participated on the stakeholder team that developed the 5th edition of a community-based plan for improving the environmental health of the Elizabeth River through community-wide restoration and education efforts.

AQUACULTURE

EXPANDING VIRGINIA'S OYSTER INDUSTRY WHILE MINIMIZING USER CONFLICT

We examined potential opportunities for the expansion of aquaculture activity within Virginia's Chesapeake Bay and proposed alternative strategies for Virginia policy makers.

COMMONWEALTH CENTER FOR RECURRENT FLOODING RESILIENCY



DEVELOPMENT OF A STREET-SCALE HYDRODYNAMIC MODEL: CALIBRATION & FUTURE SCENARIOS

We assessed flooding in the City of Portsmouth under different sea level rise and subsidence scenarios to explore potential storm surge in 2040 and 2075 using actual tropical and extratropical storm events.

TIDEWATCH

We maintain an interactive map for the visualization of the magnitude and impacts of coastal flooding within the Chesapeake Bay and along Virginia's Eastern Shore. The data are generated in 36 hour forecasts each morning and evening and the display is updated twice daily.

DEVELOPMENT OF HIGH-RESOLUTION FLOOD GRIDS FOR GUIDANCE IN BUILDING-LEVEL DAMAGE ASSESSMENTS

We are collaborating with the Virginia Department of Emergency Management (VDEM), the Virginia Institute of Marine Science, and Old Dominion University, to build a dynamic inundation model scenario builder and real-time visualization engine for Salters Creek and Newmarket Creek in Newport News as a demonstration of candidate technologies that may be integrated into VDEM's Integrated Flood Warning System (IFLOWS).

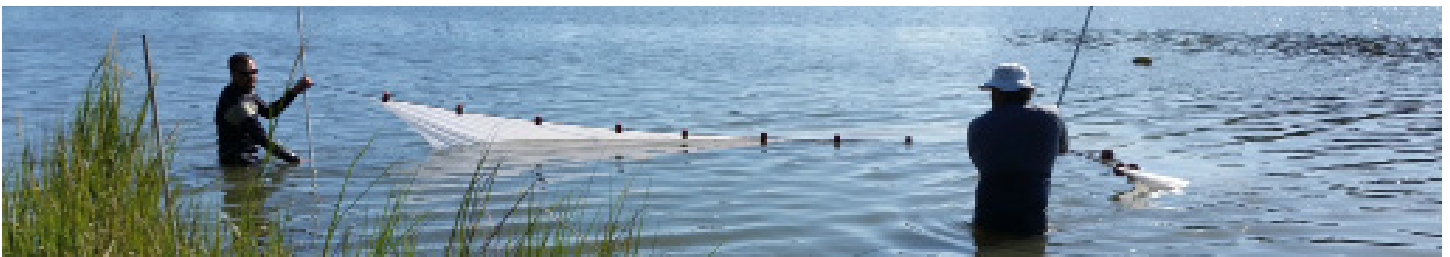
VIRGINIA KING TIDE MONITORING VIA SEA LEVEL RISE APP

We coordinate volunteers to collect data annually during the Catch the King tidal flooding event using the Sea Level Rise Mobile Application.

STORMSENSE-VIMS, A VIRTUAL MONITORING SYSTEM USING AMAZON WEB SERVICES (AWS) DEEPLENS AI

We are commercializing a video camera system that is capable of detecting water level data in real-time, named the StormSense-Video Inundation Monitoring System (StormSense-VIMS).

RESEARCH



TIDAL SHORELINES AND WETLANDS

TIDAL MARSH INVENTORY

We conducted tidal marsh inventories for King William and King and Queen Counties. The completion of these two counties concludes the Tidal Marsh Inventory layer for the entire coastal plain of Virginia.

TIDAL MARSH MODEL

We developed an open-access, high-resolution dynamic model of marsh evolution using the SCHISM model framework for hydrodynamic and sediment processes. Model outputs allow coastal planners to more accurately identify the potential future location of marsh habitats where protection and restoration activities can be focused.

TIDAL WETLANDS MANAGEMENT TECHNICAL SUPPORT

The Center provides routine advisories; produces materials for outreach education and newsletters; hosts a website for joint permit application records; and maintains two databases all supporting tidal wetlands management. Shoreline guidance is provided to the general public and decision-makers to support the Commonwealth's policy preference for living shorelines as an erosion control practice.

LIVING SHORELINE SITE SUITABILITY MODEL TRANSFER FOR SELECTED WATER BODIES WITHIN THE GULF OF MEXICO: A GIS & REMOTE SENSING-BASED APPROACH

We provided support to five Gulf Coast regions for running the Shoreline Management Model; including a User Manual for GIS specialists wishing to implement the model in different regions and an interactive Shoreline Decision Support Tool.

COASTAL SEES: SUSTAINABILITY IN CHESAPEAKE BAY SHORESCAPES, CLIMATE CHANGE, MANAGEMENT DECISIONS & ECOLOGICAL FUNCTIONS

We investigated the linkages and feedback between human and natural components of Chesapeake Bay shorescapes (a shoreline zone which includes riparian, intertidal, and littoral areas) to inform decision-making for sustainability.

EXPANDING THE USE OF NATURAL & NATURE-BASED INFRASTRUCTURE – COASTAL RESILIENCY

We investigated ways to increase the use of natural and nature-based features (NNBFs) to increase resilience of coastal communities to tidal flooding. We ranked NNBFs (tidal marsh, nontidal wetlands, beaches, dunes, forest/wooded and living shorelines) for provision of flooding, water quality and National Flood Insurance credits. We identified restoration targets for any coastal building lacking benefits from existing NNBFs. We developed decision support tools and assessed the exportability of the modeling approach to other coastal states.

BUILDING ADAPTIVE SHORELINES & RESILIENT COMMUNITIES IN TIDEWATER VIRGINIA

We assisted the James River Association with site selection, design and construction of three living shoreline demonstration projects, conducted related training workshops, and provided advisory assistance on the content and execution of Living Shoreline Collaborative Summits for stakeholders in the lower James River.

LIVING SHORELINE SUITABILITY MODEL FOR MARYLAND

We updated the shoreline inventory for selected localities in MD, and then used that data and others to run the Shoreline Management Model in support of MD's Department of the Environment and their initiative to increase the efficiency for implementation and decision making related to MD's living shoreline policy along tidal shorelines.

SURVEYING PROPERTY OWNERS FOR RESILIENT COMMUNITIES

We conducted a mail survey of property owner's shoreline modification decisions and found that property owners with living shorelines were often more interested in restoring the shoreline, when compared to those with shoreline armoring. Parcels with a high percentage of natural cover or agricultural use are less likely to be modified while parcels with primary structures closer to the shoreline are more likely to have shoreline armoring.

CHARACTERIZING GEOSPATIAL VARIATION OF BLUE CARBON STOCKS ACROSS TIDAL MARSHES AT DIFFERENT SCALES TO IMPROVE PREDICTIVE SOIL TYPE RELATIONS

This project examines the spatial variability in tidal marsh and submerged aquatic vegetation (SAV) blue carbon stocks at different scales including variation across the intertidal continuum within a single marsh, between adjacent marshes, and between marshes in similar geographic settings.

WETLANDS CONDITION ASSESSMENT TOOL (WetCAT)

In coordination with the Virginia Department of Environmental Quality, we develop and maintain this tool that assesses wetland capacity to perform habitat and water quality ecosystem services to inform wetland managers and policy makers on wetland conditions. 2019 winner of the Governor's Technology Award.

ENABLING ENHANCED DECISION MAKING IN PROTECTING WETLAND RESOURCES IN VIRGINIA

We extended the current online Virginia Wetlands Condition Assessment Tool (WetCAT) to include both tidal and nontidal wetlands as well as nontidal wetlands vulnerable to changing precipitation patterns. Provides for coordinated wetland management by providing comprehensive watershed level maps of wetlands in waterways shared by both Virginia and North Carolina.

DEVELOPMENT OF STRATEGIES TO ENHANCE THE CONSERVATION & ADAPTATION OF VIRGINIA WETLANDS IN A CHANGING CLIMATE

We provided new marsh maps, inundation maps for field sites, marsh bird surveys, and marsh characteristics inventory.

NATIONAL WETLANDS CONDITION ASSESSMENT

We conducted wetlands condition assessments for Virginia in coordination with the U.S. Environmental Protection Agency and Virginia Department of Environmental Quality.

ESTIMATING BLUE CARBON STOCKS IN COASTAL WETLANDS TO ENHANCE NRCS SOIL SURVEYS

This project calculates blue carbon stocks in tidal marshes of Virginia and North Carolina from field samples and examines statistical relationships to enhance NRCS soil surveys.

EVALUATION OF THE APPLICATION OF OYSTER REEFS IN SHORELINE PROTECTION

We evaluated wave attenuation and shoreline stabilization by US Atlantic and Gulf coast oyster reef living shorelines in collaboration with University of Melbourne and leading researchers in the living shoreline field in the United States.

EVALUATION OF WAVE ATTENUATION & SHORELINE PROTECTION BY US ATLANTIC & GULF COAST – EESLR

We evaluated the effectiveness of oyster reef living shorelines at providing coastal protection and oyster habitat during storm events.

LIVING SHORELINE DESIGN GUIDELINES & CONTRACTOR TRAINING

We assisted the VIMS Shoreline Studies Program with updates for the Living Shorelines Design Guidelines (2017) and provided related shoreline professional virtual training.

SYNTHESIS OF SHORELINE, SEA LEVEL RISE, MARSH MIGRATION RESTORATION TARGETING DATA FOR WETLAND RESTORATION TARGETING

We are developing a methodology for using results from marsh migration models combined with social, land use, and environmental data to inform marsh management, conservation, and restoration under sea level rise.

ENHANCING COMMUNITY RESILIENCE TO SEA LEVEL RISE WITH GEOSPATIAL/POLICY ASSESSMENT OF THREATS & OPPORTUNITIES

We are collaboratively engaging with rural localities with low income, minority and tribal communities to design an innovative, long-term adaptive approach through a comprehensive, multi-faceted, geospatial analysis of vulnerabilities to flooding and assessment of low cost-community based adaptation strategies.

TOOLS FOR IMPROVING PROTECTION OF WETLAND RESOURCES IN VIRGINIA

We are developing and improving online tools to enhance the ability of the Virginia Department of Environmental Quality to identify, regulate, and protect wetlands in Virginia.

VALUATION OF ECOLOGICAL & SOCIAL BENEFITS BY NATURAL & RESTORED HABITAT FOR FISHERIES

We are valuing the ecological and societal benefits provided by natural and nature-based approaches to shoreline protection within the Middle Peninsula, Virginia region for local communities and fisheries and providing translation of the outcomes into readily accessible formats for use in decision making.

STATE OF THE YORK: A HOLISTIC SYNTHESIS OF PLACE-BASED DATA FOR INFORMED DECISION-MAKING & OUTREACH

We are partnering with the Chesapeake Bay Virginia National Estuarine Research Reserve to co-produce with stakeholders a comprehensive York River watershed report that consolidates and synthesizes contemporary and complementary place-based science for use in decision-making.

MONITORING TIDAL BANK EROSION USING DRONE & GROUND-BASED LIDAR DATA

In collaboration with USGS colleagues we are periodically collecting erosion data at four tidal river bluffs and comparing accuracies between different equipment and acquisition techniques.

MARINE DEBRIS

BIO-BASED POLYMERS

We are developing, improving, and testing a commercial grade bio-hinge mechanism to reduce bycatch mortality in Dungeness crab traps.

DERELICT CRAB TRAPS – LOUISIANA LAKE PONTCHARTRAIN

In partnership with the Pontchartrain Conservancy, we synthesized landings and derelict trap removal data to analyze the economic impact of derelict crab traps to the Louisiana blue crab fishery.

BIO-HINGE FOR DUNGENESS CRAB TRAPS – PHASE 2

We are working with partners in Alaska and Washington State to test commercial grade biopolymer technology to mitigate the impact of lost Dungeness crab traps.

OTHER MODELING RESEARCH

IMPLEMENTING SCHISM MODEL AS PART OF NOAA INTEGRATED WATER MODELING PROJECTS

We are studying compound flooding hazards in US Eastern and Gulf States as well as for Pacific islands. At the moment, we are transitioning the compound flood forecasts to NOAA for operational tests, and they are expected to become fully operational in summer 2022.

IMPROVING TIDAL-ESTUARY REPRESENTATION IN MPAS-OCEAN

We are coupling the VIMS SCHISM hydrologic model with the MPAS-Ocean model (Los Alamos National Laboratory) in order to improve modeling in estuaries. We have also explored coupling of the biogeochemical components of the two models.

OREGON TSUNAMI HAZARD MITIGATION – UMPQUA RIVER

We delivered the results on combined tsunami and tidal current to the Oregon Department of Geology and Mineral Industry which has been used in maritime evacuation planning. This year, we focused on Clatsop and Tillamook counties to account for recent digital elevation updates using existing local and distant tsunami earthquake scenarios to re-model tsunami inundation.

DEVELOPMENT OF AN OPERATIONAL OCEAN PREDICTION MODEL

We are building up an operational forecasting system around Taiwan. The current focus is to incorporate a data assimilative component to the existing forecast system.

USING TEMPORALLY & SPATIALLY-RICH DATA SETS TO CALIBRATE LINKED HYDRO-BIOCHEMICAL MODELS

We assisted Sacramento with their plan for nutrient reduction in the Delta using a high resolution observation and 3D ecosystem model, in collaboration with CA Department of Water Resources and USGS. The modeling system will be used to assess the impact of the Regional San upgrades on the Sacramento-San Joaquin Delta ecosystem. In addition, DWR is working with us on the emergency planning for the Delta due to the recent droughts and floods.

ESTABLISHMENT OF A LONG-TERM TIDAL GAUGE

We established a long-term tidal gauge at Crow's Nest Research Center on Accokeek Creek, a tributary to the Potomac River.

SUPPORTING HIGH RESOLUTION SIMULATIONS OF COMPOUND FLOODING HAZARD FOR JAPAN

We are collaborating with a high tech company to develop a real-time operational system for compound flooding hazards throughout Japan as well as building a long-term simulation database for past events to help local municipal governments in infrastructure development planning. The operational system is being run on the Google cloud.

RICE FOR MODELING STORM TIDE, WIND WAVE INUNDATION & BEACH EROSION

We are working with South Carolina Aquarium to assess the inundation hazards in Charleston and Savannah, GA in a project sponsored by the US Economic Development Administration. Careful assessment is being made on the effectiveness of local infrastructure (storm surge barriers) during compound flooding.

ENHANCING 3D COASTAL MODEL: FROM BASIN TO CREEK – WATER QUALITY MODEL

With funding from the NOAA National Estuarine Research Reserve System, we are demonstrating a novel concept of building a basin-to-creek biogeochemistry model, using the US east coast as a testbed. We will also assist NOAA in transitioning the ecosystem model into operation eventually.

3D COASTAL COMPOUND FLOODING PREDICTION SYSTEM

With funding support from the NOAA National Oceanographic Partnership Program NOAA/NOPP, we are demonstrating a novel concept of building an end-to-end on-demand and on-the-cloud operational system for forecasting flood hazards in US east and Gulf coasts. For example, the Python based system will automatically generate an unstructured mesh based on the hurricane track forecast (with proper refinement along the track and impact areas) using best available DEMs, and set up and execute a SCHISM forecast, and generate standard products (such as maximum elevation, inundation and velocity etc) and display them interactively on the web, all under the cloud platform. This system is expected to be deployed during the 2022 hurricane season.

INCORPORATION OF HYDROLOGIC INPUTS SHORT-RANGE GREAT LAKES FORECAST MODEL

We are exploring model engines and development of 3D capabilities (i.e. stratification) in order to provide an infrastructure that can support coastal and ocean models that extend from the ocean basin (deep ocean waters) through the coastal zone and up to the land watershed network (riverine), and also for the Great Lakes.

LAND USE CHANGE & RECURRENT FLOODING ISSUES IN NORTHERN VIRGINIA (VDOT DISTRICT 8)

We reviewed transportation and development pattern data to determine the amount of development that occurred in recent history in seven localities in District 8 to determine if a link between increased recurrent flooding can be attributed to the increase in impervious surface through intensive run-off.

DECISION SUPPORT MODEL FOR COMPUTING SEDIMENT & NUTRIENT REMOVALS – LIVING SHORELINE RESTORATION JAMES RIVER

We are developing a model for computing restoration benefits, directly accessible to local stakeholders and validated by field measurements. This will inform the future development of a novel tool for stakeholders to select sites for living shoreline restoration that maximizes pollution removal.

DATA PRODUCTS

AREAS SUITABLE FOR LIVING SHORELINES: Ranked for Co-Benefits Provided ([link](#))

COASTAL NATURAL AND NATURE-BASED FEATURES (NNBFs) RANKED: Co-Benefits for Coastal Buildings and Target Areas for the Creation of New or Restoration of NNBFs in Coastal Virginia ([link](#))

GIS DATA: Anne Arundel County, Maryland – Living Shoreline Suitability Model Data 2021 ([link](#))

GIS DATA: Calvert County, Maryland – Living Shoreline Suitability Model Data 2021 ([link](#))

GIS DATA: Dorchester County, Maryland – Living Shoreline Suitability Model Data 2021 ([link](#))

GIS DATA: Talbot County, Maryland – Living Shoreline Suitability Model Data 2021 ([link](#))

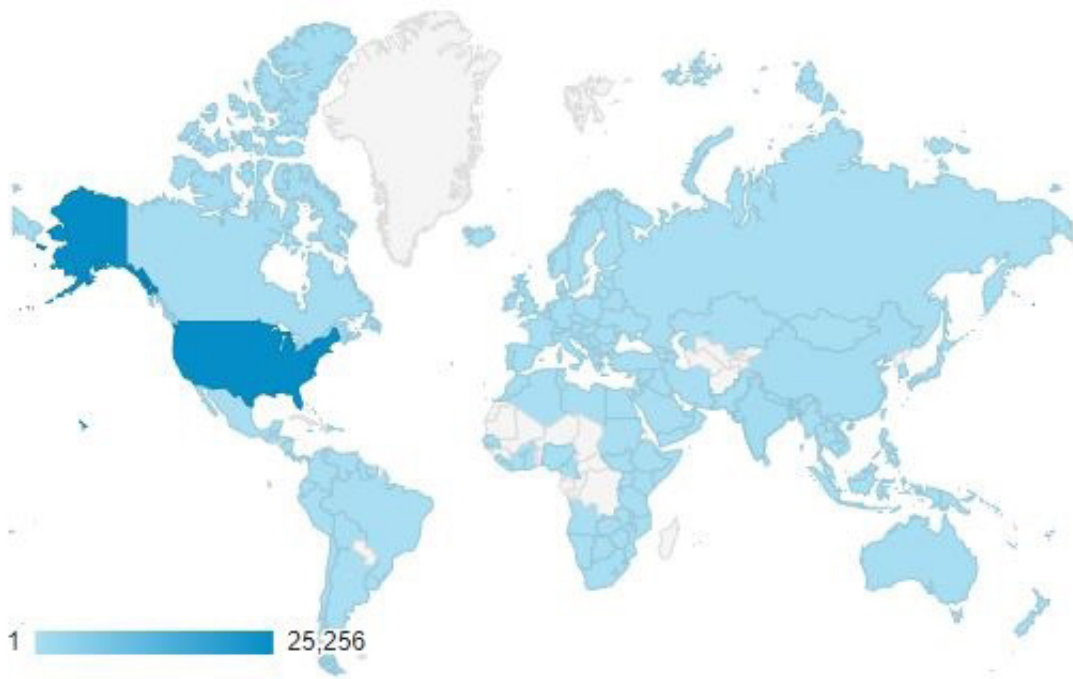
MIGRATION OF THE TIDAL MARSH RANGE UNDER SEA-LEVEL RISE FOR COASTAL VIRGINIA, with LAND COVER DATA ([link](#))

PHYSICAL VULNERABILITY INDEX ([link](#))

ROAD ACCESSIBILITY FROM COUNTY SEAT UNDER FLOODING: Hampton, Newport News, James City, Poquoson, Williamsburg, York, Accomack, Northampton, Alexandria, Fairfax, Gloucester, Mathews, Middlesex ([link](#))

WEBSITES

The Center website (www.vims.edu/ccrm) had 25256 unique visitors worldwide in 2021.



Center personnel also maintain the ADAPTVA.ORG website. It had 28498 unique visitors this year.

NEW ONLINE RESOURCES

LOCALITY ROAD FLOOD TOOL – This new interactive map is for incorporating current and future road flooding into locality planning efforts. This tool shows how road flooding will likely change over time and which areas are inaccessible because some portion of their road network is underwater during flooding. ([webpage](#)) ([tool](#))

NATURE-BASED SOLUTIONS – A web page now serves information about nature-based solutions for tidal flood mitigation, flood insurance services, and water quality benefits. This site includes a series of natural and nature-based feature (NNBF) fact sheets and coastal locality resilience summaries, plus GIS data download links. These products are also served through map layers in the AdaptVA Interactive Map. Natural and Nature-Based Features located on land less than 10 feet in elevation are mapped under Natural Resources. Protection/Restoration Opportunities now include existing coastal NNBFs Ranked according to their benefits. Target Areas along the shoreline where new NNBFs would provide benefits are also displayed. ([link](#))

SUSTAINABILITY IN CHESAPEAKE BAY SHORESCAPES – Using natural and nature-based solutions to protect a shoreline has numerous benefits for the environment and society, yet armoring is still the most common choice of property owners. A new web site describes findings from a study with both natural and social science investigations to examine why this is happening. This study characterized the Shorescape Social-Ecological System to determine what elements have the greatest influence on the future sustainability of shoreline ecosystem services. The new web site contains research finding summaries, shorescape graphics, related peer-reviewed articles, and more. ([link](#))

VIRGINIA OYSTER PRODUCTIVITY INFORMATION TOOL – CCRM collaborated with the VIMS Molluscan Ecology Group to create this tool. It has nine information cards with visual maps, graphics and mini-reports about the oyster aquaculture industry. A map viewer displays most of the data layers discussed in the mini-reports. Studies of oyster productivity and management boundaries helped determine where opportunity for aquaculture expansion exists in Virginia without generating new or added conflict with other users and sensitive habitats. ([webpage](#)) ([tool](#))

PUBLICATIONS

Center publications have a world-wide reach with 16106 downloads through ScholarWorks in 2021.



PEER-REVIEWED

A CROSS-SCALE STUDY FOR COMPOUND FLOODING PROCESSES DURING HURRICAN FLORENCE. Ye, Fei; Huang, Wei; Zhang, Yinglong J.; and et al. (2021). *Natural Hazards And Earth System Sciences*, 21, 1703-1719. ([link](#))

ANTICIPATING AND ADAPTING TO THE FUTURE IMPACTS OF CLIMATE CHANGE ON THE HEALTH, SECURITY AND WELFARE OF LOW ELEVATION COASTAL ZONE COMMUNITITES IN SOUTHEASTERN USA. Allen, T.; Behr, J.; (...); Loftis, Jon Derek; (...); Mitchell, Molly; (...); Nunez, Karinna; and et al. (2021). *Journal of Marine Science and Engineering*, 9(11), 1196. ([link](#))

ASTRONOMICAL TIDE AND STORM SURGE SIGNALS OBSERVED IN AN ISOLATED INLAND MAAR LAKE NEAR THE COAST. Li, M.; Li, C.; Xie, L.; Huang, Wei; Zheng, Q.; Tan, K.; and Hong, Y. (2021). *Journal of Marine Science and Engineering*, 9(5), 485. ([link](#))

CHANGES IN PLANT COMMUNITIES OF LOW-SALINITY TIDAL MARSHES IN RESPONSE TO SEA-LEVEL RISE.
Humphreys, Abbey; Gorsky, Adrianna L.; Bilkovic, Donna Marie; and Chambers, Randolph M. (2021). *Ecosphere*, 12(7), e03630. ([link](#))

COASTAL SETTING DETERMINES TIDAL MARSH SUSTAINABILITY WITH ACCELERATING SEA-LEVEL RISE. Nunez, Karinna; Zhang, Yinglong J.; Bilkovic, Donna M.; and Hershner, Carl. (2021). *Ocean & Coastal Management*, 214, 105898. ([link](#))

COMPOUNDING FACTORS FOR EXTREME FLOODING AROUND GALVESTON BAY DURING HURRICANE HARVEY.
Huang, W.; Ye, F.; Zhang, Y.; Park, K.; Du, J.; Moghimi, S.; Myers, E.; Pe’eri, S.; Calzada, J.R.; Yu, H.C.; Nunez, K.; and
Liu, Z. (2021) *Ocean Modelling*, 158, 01735. ([link](#))

EFFECTS OF TIDAL FLOODING ON ESTUARINE BIOGEOCHEMISTRY: QUANTIFYING FLOOD-DRIVEN NITROGEN INPUTS IN AN URBAN LOWER CHESAPEAKE BAY SUB-TRIBUTARY. Macías-Tapia, Alfonso; Mulholland, Margaret R.; Selden, Corday R.; Loftis, Jon Derek; and Bernhardt, Peter W. (2021). *Water Research*, 203(117329). ([link](#))

EVALUATING OPTIMAL REMOVAL OF DERELICT BLUE CRAB POTS IN VIRGINIA, US. Scheld, Andrew M.; Bilkovic, Donna M.; and Havens, Kirk J. (2021). *Ocean & Coastal Management*, 211(105735). ([link](#))

IMPACT ASSESSMENT AND MANAGEMENT CHALLENGES OF KEY RURAL HUMAN HEALTH INFRASTRUCTURE UNDER SEA-LEVEL RISE. Mitchell, Molly; Isdell, Robert; Herman, Julie; and Tombleson, Christine. (2021). *Frontiers in Marine Science*, 8(631757). ([link](#))

LARGE-SCALE VARIATION IN WAVE ATTENUATION OF OYSTER REEF LIVING SHORELINES AND THE INFLUENCE OF INUNDATION DURATION. Morris, Rebecca L.; LaPeyre, Megan K.; Webb, Bret M.; Bilkovic, Donna M.; and et al. (2021). *Ecological Applications*. ([link](#))

LIGHT REGULATION OF PHYTOPLANKTON GROWTH IN SAN FRANCISCO BAY STUDIED USING A 3D SEDIMENT TRANSPORT MODEL. Wang, Zhengui; Chai, Fei; (...); Zhang, Yinglong J.; and et al. (2021). *Frontiers in Marine Science*, 8(633707). ([link](#))

LIVING SHORELINES ACHIEVE FUNCTIONAL EQUIVALENCE TO NATURAL FRINGE MARSHES ACROSS MULTIPLE ECOLOGICAL METRICS. Isdell, Robert; Bilkovic, Donna Marie; Guthrie, Amanda; Mitchell, Molly; Chambers, Randolph M.; Leu, Matthias; and Hershner, Carl. (2021). *PeerJ*, 9(e11815). ([link](#))

NURSERY HABITAT USE BY JUVENILE BLUE CRABS IN CREATED AND NATURAL FRINGING MARSHES. Bilkovic D.M., R.E. Isdell, D. Stanhope, K.T. Angstadt, K.J. Havens, and R.M. Chambers. (2021). *Ecological Engineering* 170:10633 ([link](#))

PREFERENCES FOR DERELICT GEAR MITIGATION STRATEGIES BY COMMERCIAL FISHERS. DelBene, J.A., A.M. Scheld, and D.M. Bilkovic. (2021). *Marine Policy* 132: 104662. ([link](#))

RIBBED MUSSEL GEUKENSIA DEMISSA POPULATION RESPONSE TO LIVING SHORELINE DESIGN AND ECOSYSTEM DEVELOPMENT. Bilkovic, Donna Marie; Isdell, Robert; Guthrie, Amanda G.; Mitchell, Molly; and Chambers, Randolph M. (2021). *Ecosphere*, 12(3), e03402. ([link](#))

SEASONAL VARIATIONS AND DRIVING FACTORS OF THE EASTERN MAINE COASTAL CURRENT. Li, Denghui; Wang, Zhengui; Xue, Huijie; and et al, (2021). *JGR Oceans*, 126(e2021JC017665). ([link](#))

REPORTS

EXPANDING THE USE OF NATURAL AND NATURE-BASED INFRASTRUCTURE TO ENHANCE COASTAL RESILIENCY. Berman, M., Mason, P., Hendricks, J., & Rudnick, T. (2021). Virginia Institute of Marine Science, William & Mary. ([link](#))

LAND USE CHANGE AND RECURRENT FLOODING ISSUES IN NORTHERN VIRGINIA. Nunez, K., Loftis, D., and D. Schatt. (2021). Final Report for the Virginia Transportation Research Council. Center for Coastal Resources Management. Virginia Institute of Marine Science, William & Mary, Gloucester Point, Virginia.

NATURE-BASED SOLUTIONS FOR COASTAL RESILIENCE. Center for Coastal Resources Management. (2021). *Rivers & Coast*, Summer 2021, Vol. 16. Virginia Institute of Marine Science, William & Mary. ([link](#))

OUTREACH

The Center for Coastal Resources Management (CCRM) staff produced materials for outreach education, and communicated relevant information through talks, workshops, e-newsletters, our website, and social media posts; all supporting actionable science.



TRAINING & PRESENTATIONS

In 2021, Center staff provided training and gave talks at more than 69 events in which we reached more than 3000 people. Some were small training classes or skyping with a scientist while others were large multi-stakeholder conferences. These events were mostly virtual this year due to travel restrictions related to Covid-19 plus some field training in person at VIMS. CCRM presented on a wide range of topics including everything from climate change, sea-level rise and flooding risk management to marine debris, living shorelines, and coastal management tools. Audiences varied and included the general public; local, state and federal government; other scientists and students of all ages.

COMMUNITY ENGAGEMENTS

CCRM's annual **Tidal Wetlands Workshop** was held virtually due to Covid-19 as two Shoreline Management Webinars. Each event focused on a different topic that included presentations and live interaction with tidal wetland scientists and regulatory agency staff: Aug 11 – Tidal Marsh Ecology featuring recent studies of tidal marshes and living shorelines, and Aug 25 – Integrated Shoreline Management featuring shoreline guidelines and regulations that incorporate sea-level rise and climate change. There were 278 webinar participants representing a broad range of coastal stakeholders. ([link](#))

The 5th annual **Catch the King Tide** volunteer mapping effort took place November 6-7 to 'catch' the highest tide of the year throughout coastal Virginia. More than 100 volunteers collected over 5,000 data marks and more than 150 photographs through the Sea Level Rise app downloaded on smartphones and tablets. This app is currently undergoing some updates with a new version expected to be released in early 2022. ([link](#))

E - NEWSLETTERS

CCRM distributes a quarterly e-newsletter which summarizes and communicates current issues that support integrated management of coastal zone resources; announces pertinent publications, programs and events; and points the reader to more detailed information on our website (and others).

- JANUARY 2021 ([link](#))
- MAY 2021 ([link](#))
- JULY 2021 ([link](#))
- SEPTEMBER 2021 ([link](#))

SOCIAL MEDIA

CCRM increased our social media effort as another approach to inform the public about coastal issues in Virginia with the ultimate goal of building relationships within our local community. You can follow us on [Facebook](#), [LinkedIn](#), [YouTube](#), and [Instagram](#).

INSTITUTIONAL PARTNERS

GOVERNMENT AGENCIES

ACCOMACK-NORTHAMPTON PLANNING DISTRICT COMMISSION
 ALABAMA GEOLOGICAL SURVEY
 CALIFORNIA DEPARTMENT OF WATER RESOURCES
 CENTRAL WEATHER BUREAU - TAIWAN
 COLONIAL SOIL AND WATER CONSERVATION DISTRICT
 COMMONWEALTH OF VIRGINIA
 DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL
 FEDERAL EMERGENCY MANAGEMENT AGENCY
 FEDERAL HIGHWAYS ADMINISTRATION
 FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION
 HAMPTON ROADS PLANNING DISTRICT COMMISSION
 JAMES CITY COUNTY
 MARYLAND DEPARTMENT OF THE ENVIRONMENT
 MARYLAND DEPARTMENT OF NATURAL RESOURCES
 MIDDLE PENINSULA PLANNING DISTRICT COMMISSION
 NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
 NATIONAL FISH AND WILDLIFE FOUNDATION
 NOAA – CHESAPEAKE BAY OFFICE
 NOAA – FISHERIES AUKE BAY LABORATORIES
 NOAA – MARINE DEBRIS PROGRAM
 NOAA – MIDATLANTIC REGIONAL INTEGRATED SCIENCES AND ASSESSMENTS
 NOAA – NATIONAL ESTUARINE RESEARCH RESERVE SYSTEM
 NOAA – NATIONAL OCEAN SERVICE BEAUFORT LAB
 NOAA – NATIONAL WATER CENTER
 NOAA – OFFICE OF COAST SURVEY
 NOAA – OFFICE FOR COASTAL MANAGEMENT
 NOAA – RESTORE SCIENCE PROGRAM
 NOAA – SEA GRANT
 NATIONAL SCIENCE FOUNDATION
 NATIONAL WILDLIFE FEDERATION
 NATURAL RESOURCES CONSERVATION SERVICE
 NORTH CAROLINA DEPARTMENT OF ENVIRONMENTAL QUALITY
 NORTH CAROLINA NATIONAL ESTUARINE RESEARCH RESERVE
 NORTH CAROLINA OFFICE OF RECOVERY AND RESILIENCE
 NORTHERN NECK PLANNING DISTRICT COMMISSION
 MARYLAND DEPARTMENT OF ENVIRONMENT
 SOIL AND WATER CONSERVATION DISTRICT
 US ARMY CORPS OF ENGINEERS - RESEARCH AND DEVELOPMENT CENTER
 US ARMY CORPS OF ENGINEERS - INSTITUTE FOR WATER RESOURCES
 US DEPARTMENT OF DEFENSE
 US ENVIRONMENTAL PROTECTION AGENCY
 US FISH AND WILDLIFE SERVICE
 US GEOLOGICAL SURVEY
 VIRGINIA COASTAL ZONE MANAGEMENT PROGRAM

VIRGINIA DEPARTMENT OF CONSERVATION AND RECREATION
 VIRGINIA DEPARTMENT OF EDUCATION
 VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY
 VIRGINIA DEPARTMENT OF HEALTH
 VIRGINIA DEPARTMENT OF TRANSPORTATION
 VIRGINIA DEPARTMENT OF WILDLIFE RESOURCES
 VIRGINIA GEOGRAPHIC INFORMATION NETWORK
 VIRGINIA MARINE RESOURCES COMMISSION
 VIRGINIA SECRETARY OF NATURAL AND HISTORIC RESOURCES
 VIRGINIA SPECIAL ASSISTANT TO THE GOVERNOR ON COASTAL RESILIENCE

UNIVERSITIES / INSTITUTES

CHESAPEAKE BAY NATIONAL ESTUARINE RESEARCH RESERVE
 COASTAL STUDIES INSTITUTE (ECU/UNC)
 DAUPHIN ISLAND SEA LAB
 DUKE UNIVERSITY
 EAST CAROLINA STATE
 GEORGE MASON UNIVERSITY
 GORDON COLLEGE
 HAMPTON UNIVERSITY
 LOUISIANA STATE UNIVERSITY AGRICULTURAL CENTER
 LOUISIANA STATE UNIVERSITY COLLEGE OF COAST & ENVIRONMENT
 MISSISSIPPI STATE UNIVERSITY
 NATIONAL CHENG KUNG UNIVERSITY - TAIWAN
 OLD DOMINION UNIVERSITY
 PENNSYLVANIA STATE UNIVERSITY
 RUTGERS UNIVERSITY
 SMITHSONIAN ENVIRONMENTAL RESEARCH CENTER
 TROY UNIVERSITY
 UNIVERSITY OF CENTRAL FLORIDA
 UNIVERSITY OF DELAWARE
 UNIVERSITY OF FLORIDA
 UNIVERSITY OF GEORGIA
 UNIVERSITY OF HAWAII - NATIONAL DISASTER PREPAREDNESS TRAINING CENTER
 UNIVERSITY OF MAINE
 UNIVERSITY OF MELBOURNE - AUSTRALIA
 UNIVERSITY OF NEW ORLEANS
 UNIVERSITY OF SOUTH ALABAMA
 UNIVERSITY OF QUEENSLAND - AUSTRALIA
 UNIVERSITY OF TASMANIA - AUSTRALIA
 UNIVERSITY OF VIRGINIA
 UNIVERSITY OF WASHINGTON
 VIRGINIA SEA GRANT
 VIRGINIA TECH
 WAGENINGEN UNIVERSITY AND RESEARCH - THE NETHERLANDS
 WATER INSTITUTE OF THE GULF
 WILLIAM & MARY - CENTER FOR CONSERVATION BIOLOGY

WILLIAM & MARY - CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS
 WILLIAM & MARY - KECK ENVIRONMENTAL FIELD LABORATORY
 WILLIAM & MARY - VIRGINIA COASTAL POLICY CENTER

NON-GOVERNMENT ORGANIZATIONS

ALBEMARLE-PAMLICO NATIONAL ESTUARY PARTNERSHIP
 AMERICAN SHORE AND BEACH PRESERVATION ASSOCIATION
 CHESAPEAKE BAY FOUNDATION
 CHESAPEAKE BAY PROGRAM
 CHESAPEAKE BAY TRUST
 CHESAPEAKE RESEARCH CONSORTIUM
 FRIENDS OF THE RAPPAHANNOCK
 GALVESTON BAY FOUNDATION
 GARDEN CLUB OF AMERICA
 HELMHOLTZ-ZENTRUM GEESTHACHT - GERMANY
 HONDA FOUNDATION
 JAMES RIVER ASSOCIATION
 KENAH CONSULTING
 MORRIS ANIMAL FOUNDATION
 NATIONAL FISH & WILDLIFE FOUNDATION
 NATIONAL WILDLIFE FEDERATION
 NATURAL RESOURCES CONSULTANTS, INC
 NORTH CAROLINA COASTAL FEDERATION
 OYSTER RESTORATION PARTNERSHIP
 PARTNERSHIP FOR DELAWARE ESTUARY
 PONTCHARTRAIN CONSERVANCY
 RAND CORPORATION
 RAPPAHANNOCK RIVER BASIN COMMISSION
 SITKA SOUND SCIENCE CENTER
 THE CONSERVATION FUND
 THE NATURE CONSERVANCY
 THE ELIZABETH RIVER PROJECT
 VIRGINIA EXTENSION MASTER GARDENERS - JAMES CITY COUNTY - WILLIAMSBURG
 VIRGINIA EXTENSION MASTER GARDENERS - NORTHERN NECK
 VIRGINIA EXTENSION MASTER GARDENERS - YORK/POQUOSON
 VIRGINIA MASTER NATURALISTS - HISTORIC RIVERS
 VIRGINIA MASTER NATURALISTS - MIDDLE PENINSULA
 VIRGINIA MASTER NATURALISTS - NORTHERN NECK
 VIRGINIA MASTER NATURALISTS - PENINSULA
 VIRGINIA MASTER NATURALISTS - TIDEWATER
 WETLANDS WATCH
 WILLIAMSBURG BOTANICAL GARDEN
 YORK RIVER AND SMALL COASTAL BASIN ROUNDTABLE