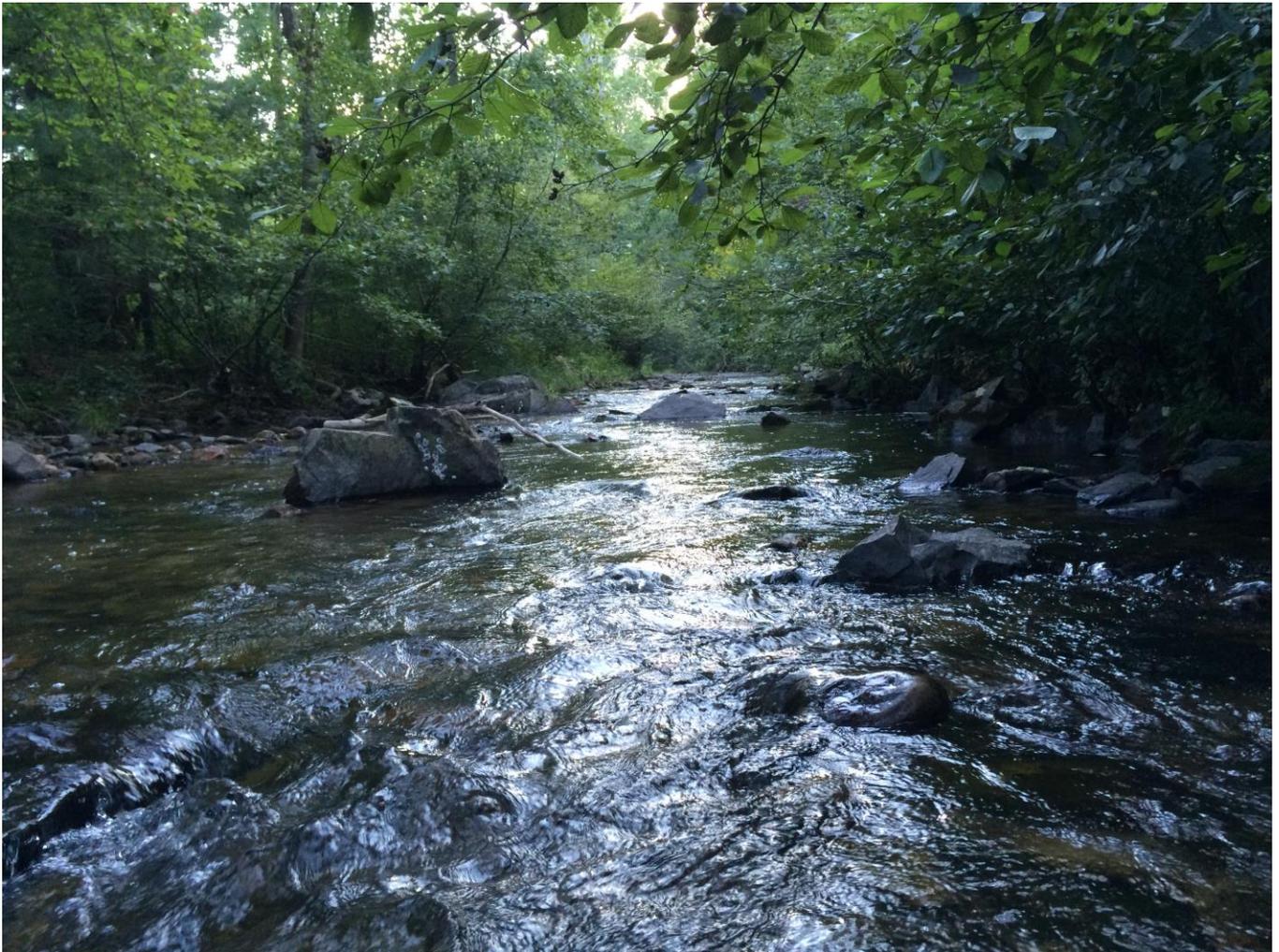


Virginia Water Central Newsletter

Virginia Water Resources Research Center Blacksburg, Virginia August 2016 (No. 66)



Passage Creek along Saint Davids Church Road in Fort Valley, Shenandoah County, Virginia, August 22, 2016.

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S² on H₂O



VWRRRC Supports Next-Generation Training in Water Resources at Virginia Universities and Colleges

By Stephen Schoenholtz

Providing training in the broad field of water resources is an important component of the Water Center's mission and has been a key emphasis of our programming since our founding in 1965. Our efforts to accomplish this goal involve several kinds of opportunities for undergraduate and graduate students:

- **internships** for undergraduates at Virginia Tech and at other Commonwealth universities and colleges, often accomplished in collaboration with our partners at the U.S. Geological Survey;
- **undergraduate research experiences** through independent studies, formal undergraduate research, and honors research projects—all offered for credits at Virginia Tech;
- **opportunities as wage employees** working on our research projects, as funding permits;
- **advising and mentorship of graduate students** in hydrology, biogeochemistry, geography, wetland ecology, and other fields;
- **our competitive seed-grant program**—open to undergraduate and graduate students from any Virginia university or college—providing up to \$5,000 per grant to help supplement a component of a graduate student's thesis or dissertation research project or an undergraduate student's research effort.

But the Water Center's largest focus on next-generation training involves coordination of Virginia Tech's new **undergraduate water degree program**—called "Water: Resources, Policy, and Management" (WRPM)—offered through the Department of Forest Resources and Environmental Conservation. (More information about the degree program is available online at <http://waterdegree.frec.vt.edu/>). The first cohort of students enrolled in this major in fall 2015, and as of the fall 2016 semester there were 36 students in the major. Through the generosity of supporters of this new program, WRPM students can apply for sustainable-water scholarships and research fellowships.

The WRPM program is the first of its kind in the United States at the undergraduate level. It emphasizes an interdisciplinary curriculum, requiring students to choose two specializations, one each from *water science* (aquatic ecosystems; hydrology; water quality; or water treatment and public health) and from *water policy* (watershed management; water planning, policy, and economics; international water management; or water, climate, energy, and global issues). The degree program was recognized at the March 2016 White House Water Summit (<https://www.epa.gov/clusters-program/white-house-water-summit-march-22-2016>) for its innovative approach to train students to help address the many complex water challenges we face. It also was highlighted by the Universities Council on Water Resources (http://ucowr.org/spotlights/va_tech_march) in April 2016. Career and employment options are diverse and exceptional for students with this interdisciplinary training.

Successful initiation of the undergraduate water degree has encouraged us to begin development of an interdisciplinary *graduate* degree program in water resources, offering both M.S. and Ph.D. degree options. Planning for the graduate degree program is underway in coordination with 13 academic departments and five colleges at Virginia Tech.

The Water Center strives to provide well-established and innovative next-generation training opportunities and activities. This issue of our newsletter highlights some recent student activities and accomplishments. As water-resources *challenges* evolve, we aim to continue helping students have relevant training experiences that prepare them to contribute to sustainable water-resources *solutions*.

FEATURE ARTICLE

A Student Intern's Discoveries at the Virginia Water Resources Research Center

By Taylor Richmond. In the spring 2016 semester at Virginia Tech, Ms. Richmond served as the first student in a new internship program begun that semester by the Virginia Water Resources Research Center. In May 2016 she graduated with a B.S. degree in Forest Resources and Environmental Conservation.

January 19, 2016. Nervously, I walked up to the glass door leading to the Virginia Water Resources Research Center (the Virginia Water Center, or the Center). It was my first day as the Virginia Water Center's intern. What would I be doing? What would it be like? And what exactly *is* a water center? I was soon put at ease, because one of the first things I learned is that *most* people don't know what the Water Center is or how important it is for water resources. Now that I've had the pleasure of this experience, I hope that by looking through my eyes you will be able to see the Virginia Water Center's role in Virginia water management.

The Water Center

The Virginia Water Resources Research Center resides in the College of Natural Resources and Environment in Cheatham Hall on Virginia Tech's campus in Blacksburg. The *Code of Virginia* states that the Virginia Water Center is "for the purposes of developing, implementing and coordinating water and related land research programs in the Commonwealth and transferring the results of research and new technology to potential users."¹

The Virginia Water Center is a resource for government, citizens, non-profit organizations, industry, and any other stakeholders who may need research or information on water resources. The Virginia Water Center is a way for people to get unbiased information, in order to help them make more educated decisions regarding water resource use and management. Although the Center is located at Virginia Tech, it is also a resource for *all* colleges and universities in the state.

My spring 2016 internship with the Virginia Water Center—the first in a new Center-wide internship program—allowed me to see the three main aspects of its mission: **discovery**, **learning**, and **outreach**. These reflect the three-part mission of Virginia Tech and other land grant universities.² **Discovery** refers to research, and one of the Center's goals is to help aid in the advancement of research through grants, research projects, and facilitating collaborations among scientists. **Learning** refers to helping provide opportunities for students in the field of water resources; specific activities include coordinating the new Water major at Virginia Tech that began in spring 2015; administering the Watershed Management Graduate Certificate; and providing internships, like mine! **Outreach** refers to communicating water information to the public through various media.

One Piece of a Bigger Picture

You might be thinking, "The Virginia Water Center sounds great; there should be water centers in every state." Guess what? Every states does have a water center, and so do the District of Columbia, Guam, Puerto Rico, and the Virgin Islands. Not all of them are called water *centers*; some are referred to as *institutes*.

According to the United States Geological Survey (USGS)³, "Each of the 54 institutes is charged with overseeing competent research that addresses water problems or expands the understanding of water and water-related phenomena. They are also responsible for aiding the entry of new research scientists into

¹ Virginia Legislative Information System. "Code of Virginia, 23-135.7:8". Online at <http://law.lis.virginia.gov/vacode/title23/chapter11/section23-135.7:8/>. Accessed April 22, 2016

² Virginia Tech. "About Virginia Tech." Online at <https://www.vt.edu/about.html>. Accessed April 22, 2016

³ USGS. "USGS Celebrates 50th Anniversary of Water Resources Research Act." Published; July 17, 2014. Online at <https://www.usgs.gov/news/usgs-celebrates-50th-anniversary-water-resources-research-act>. Accessed April 25, 2016.

water resources fields, helping to train future water scientists and engineers, and transferring the results of sponsored research to water managers and the public.”

Despite all of the water centers and institutes having this common mandate, not all of them look quite like the Virginia Water Center. They can range from being a handful of people, like the Virginia Water Center⁴, to dozens of people throughout a university, like the Colorado Water Institute.⁵ Activities can vary too; for example, 14 of the 54 U.S. centers/institutes have water science laboratories.⁶

The 54 centers and institutes create a network of water resource specialists throughout the country, allowing for a collaborative approach to research and dispersion of knowledge. This network is called the National Institutes of Water Resources (NIWR). The current president of NIWR (2016-2017 term), is the Virginia Water Center’s director, Dr. Stephen Schoenholtz. As a part of my internship, I attended the NIWR annual meeting in Washington, D.C., in January 2016, where I was able to observe the interworking of these institutions while assisting with the audio/visual presentations. This showed me an example of how different scientists from different schools and states shared ideas on the future of water resources, and how even scientists are constantly learning and discovering.

While in Washington, I also joined Dr. Schoenholtz and Dr. Kevin McGuire, the Virginia Water Center’s associate director, in meetings on Capitol Hill. There we met with staffers for Virginia’s two U.S. senators, Tim Kaine and Mark Warner, and with U.S. Representative Morgan Griffith (R-9th), who represents the district where Blacksburg is located.⁷ These meetings were to ask for support in the legislation that reauthorizes the Water Resources Research Act⁸, which establishes the centers and institutes and provides funding for efforts at all of the centers and institutes. These meetings gave staffers and the Virginia Water Center a chance to exchange information on water issues happening around the country and specifically in Virginia. They gave me the chance to see an example of how centers/institutes interact with policy makers.

Water Problems In, Research Out

As a research center, how does the Virginia Water Center know *what* to research? I learned about one way during my next experience: at the Virginia General Assembly in Richmond in February. There I sat in on a House committee meeting, attended House and Senate floor sessions, and met with Delegate David Bulova (D-37th) of Fairfax. Delegate Bulova currently serves on three House committees: General Laws; Education; and Agriculture, Chesapeake, and Natural Resources. He also serves on the Statewide Advisory Board to the Virginia Water Center.⁹ Representatives of the Advisory Board are appointed by the Governor, subject to confirmation by the General Assembly. According to the Virginia Water Center¹⁰, “this board includes balanced representation from industries; federal, state, and local agencies; water user groups; and concerned citizens. The Advisory Board recommends policy guidelines for implementing the functions of the Water Center and evaluates programs of the Water Center.” This helps the Center focus its efforts and resources on current problems facing all Virginia water stakeholders.



Above: Taylor Richmond beside the U.S. Capitol, February 10, 2016. *Photo courtesy of Stephen Schoenholtz and Taylor Richmond.*

⁴ Virginia Water Resources Research Center. “Faculty and Staff.” Online at <http://www.vwrcc.vt.edu/faculty-staff/>. Accessed April 22, 2016.

⁵ Colorado Water Institute. “Staff.” Online at <http://www.cwi.colostate.edu/staff.asp>. Accessed April 22, 2016.

⁶ Kim Hachiya. “Twenty-Five Years on the Cutting Edge of University of Nebraska Research.” *Water Current*. Winter 2016.

⁷ U.S. Congressman Morgan Griffith. “9th Congressional District of Virginia.” Online at <http://morgangriffith.house.gov/district/>. Accessed April 25, 2016.

⁸ The Water Resources Research Act as Amended, pages 2437-2445. Online at http://water.usgs.gov/wrri/WRRR_42USC10301_et_seq.pdf. Accessed May 2, 2016.

⁹ Delegate David Bulova. “About David.” Online at <http://www.davidbulova.com/about-david>. Accessed April 22, 2016.

¹⁰ Virginia Water Resources Research Center. “VWRCC Statewide Advisory Board.” Online at <http://www.vwrcc.vt.edu/vwrcc-statewide-advisory-board/>. Accessed April 22, 2016.

I've Made a Discovery!

The Virginia Water Center promotes research in several ways. Sometimes the Center funds researchers, other times it helps find scientists to solve a problem, and still other times Center scientists lead projects. I experienced an example of the latter by working with the Center's post-doctoral research associate Ross Vander Vorste. He is working on a U.S. Office of Surface Mining and Reclamation project to study the process of leaf litter decomposition, a key ecosystem function, in headwater streams affected by coal-mining activities in the Appalachian region. His work will use decomposition rates as well as macroinvertebrate and microbial diversity to help assess impacts of coal mining on stream biology. My participation with this research project helped me develop an understanding of the connection between research and water management practice in Virginia.

Dispersing Information

As stated earlier, outreach refers to dispersing information to the public, using various means to reach different audiences. At the Virginia Water Center (and at many other state water centers/institutes), this can be through the traditional media of general publications, reports in scientific journals and conferences. Evolving in the age of technology, the Virginia Water Center now also uses blogs and podcasts. I had the opportunity to work on the Center's versions of these newer media. For the Virginia Water Central News Grouper blog, I wrote an article about declining mercury emissions in the United States.¹¹ In the podcast medium, I had the chance to contribute to three episodes of Virginia Water Radio¹². This podcast uses sounds and music to open up a topic for discussion, ranging from amphibians to water recreation. Generally about four minutes long, the episodes give listeners an idea about a water topic and then provide links to sources of more information. I found Virginia Water Radio to be a fun and unique way of synthesizing information that can be targeted to different audiences; it's particularly suited to people on the go who want to learn something new about water.

Many Topics Out Of Reach

Although the Virginia Water Center works on many water issues, there is no way they can be involved in every water problem in Virginia. While I learned that many Virginians do not know what the Virginia Water Center does exactly, I also learned that citizens often call the Center when they have a problem with water in their area, even if the Center is not involved. This requires that the Center to be aware up of many issues affecting water resources (even if they can't be "experts" on all of the issues), so that they are prepared to answer citizens' questions. In this vein, I attended a local Total Maximum Daily Load (TMDL) meeting on PCB's in the New River. The Center is not directly involved in this local TDML process or with PCB's specifically, but the information I brought back helped generate an item for the News Grouper blog.

A Small Center in a Big Water World

May 2, 2016. As I confidently left the Virginia Water Center, I could proudly say, "I know what the Virginia Water Center does!" They are working hard to advance our understanding of water resources through **discovery**, while creating a new generation of well-informed scientists through **learning**. As well, they are working to give citizens a better understanding of water resources through **outreach**. Although the Center is a small organization, they have a large ambition to stay up-to-date on current technologies, issues, and research in order to serve the eight million Commonwealth citizens.

Learning about the Center's specific missions, however, was only part of *my* mission as an intern. I also gained an understanding of the larger world of water resources all over the United States. The interwoven network of policy makers, scientist, and stakeholders is much more intricate than I had ever thought. The Virginia Water Center is one door to this complex system of water issues, research, and management.

So if you should ever find yourself walking up to that glass door of 210 Cheatham Hall at Virginia Tech, I hope you will have a better understanding of the wide water world waiting on the other side.

¹¹ Virginia Water Central News Grouper. "Mercury Emissions from Human Sources Declined 30 Percent from 1990-2010" (posted 1/25/16). Online at <https://vawatercentralnewsgrouper.wordpress.com/>. Accessed May 2, 2016.

¹² Virginia Water Radio Episodes 301 (2-1-16), 313 (4-25-16), and 314 (5-2-16), all available online at <http://www.virginiawaterradio.org>.

AT THE WATER CENTER

To reach the Virginia Water Resources Research Center: phone (540) 231-5624; FAX (540) 231-6673; e-mail water@vt.edu; Web site www.vwrrc.vt.edu.

Walker Award Winner for 2016-17

Established to honor the late William Walker, the founding director of the Virginia Water Resources Research Center, this award has been given since 1999 to recognize and support graduate students in water resources who are pursuing work in a field different from their undergraduate study, or who have returned to school following a period of professional work.

The Walker Award winner for 2016-17 is Travis Spangler. Travis is pursuing a master's degree in Biological Systems Engineering at Virginia Tech. Prior to enrolling in graduate school, he completed his bachelor's degree in Mechanical Engineering at Virginia Tech and worked in industry for several years. He is currently investigating floating treatment wetlands as potential nutrient removal technologies for stormwater runoff.

The application period for the Walker Award typically runs from March to May. More information about this program is available online at <http://www.vwrrc.vt.edu/walker-award/>.



Travis Spangler, winner of the 2016-17 Walker Award from the Virginia Water Center. *Photo courtesy of Travis Spangler.*

Report from 2015-16 Walker Award Winner

Analysis of Mechanical Meters Inaccuracies and the Effect of Meter Replacement on Reported Water Use

By Carlos F. Mantilla-Pena

May 16, 2016

[*Ed. note:* This report has been edited slightly by *Virginia Water Central Newsletter* for space or format].

In collaboration with Pulaski County [Virginia] Public Service Authority (PC PSA), and in response to their interest in developing a meter replacement program, an analysis of their residential metering infrastructure conditions and the effect of meter replacement on reported (actual minus non-measured volume) water use was performed. This was accomplished by testing 564 mechanical meters (six different models), selected from 1,430 meters that had been previously replaced with ultrasonic meters. Random

stratified sampling by throughput was applied to the most frequent model in the system, with a total of 310 “Model 1” meters tested, with throughput ranging from 11,000—4,000,000 gallons. Accuracy tests were performed following the American Water Works Association (AWWA) standards for the 0.25, 2, and 15 gallons per minute (gpm) flow rates, and additionally at 0.5, 1, and 5 gpm.

Using GIS [geographic information system] tools, it was possible to determine that the geospatial location of the meter did not have a significant impact on the accuracy level at the different flow rates. The analysis of the test results indicated that all the meter models presented the lowest level of accuracy at 0.25 gpm with median values of 98 percent, 87 percent, 0 percent, 78 percent, 80.5 percent, and 89.8 percent for models 1 through 6, respectively. Although the sample size was different for each of the models, it was possible to conclude that Model 1 was the most reliable, and that Models 2, 3, and 4 should be replaced at the earliest convenience. Specifically, it was found that Model 1 meters started to drop their accuracy level at 0.25 gpm, after the meters had been in service for approximately 30 years and had a throughput above 1.6 million gallons.

Residential water meter readings from June 2012 through October 2013 and from June 2014 through October 2015 were analyzed to evaluate the effect of meter replacement on reported water use. A computer program was written (using R statistical software) to remove the service locations that presented inconsistent meter readings and/or had a change in customer. Data were analyzed from a total of 589 service locations (residential households) from the original 1,430 that had meter change.

It was found that in the months prior to meter replacement, the total monthly reported water use (589 customers) had a non-linear downward trend, with a reduction in the general slope after meter replacement. The same tendency was observed for the residential locations still having an old mechanical meter (1,528). The latter suggests that meter replacement did not have a significant impact on overall reported water use.

Water Center Competitive Grants Program – Awards for 2016-17

Under the **Competitive Grants Program**, the Water Center awards grants of up to \$5000 to support research by students at Virginia colleges or universities. The application period for the Competitive Grants Program typically runs from January to March. More information about this program is available online at <http://www.vwrrc.vt.edu/grant-opportunities/competitive-grants/>.

In May 2016, the Water Center awarded Competitive Grants for the period June 1, 2016, to May 31, 2017, to the following students and projects:

Joanna Adadevoh, Ph.D. student, Department of Chemical Engineering University of Virginia: “Exploiting Bacterial Chemotaxis to Enhance Degradation of NAPL Sources in Contaminated Groundwater Systems.”

Carrie Jensen, Ph.D. student, Geospatial and Environmental Analysis Program, Virginia Tech: “Headwater Stream Length Dynamics during Storm Events in the Valley and Ridge Province.”

Amanda Laverty, Ph.D. student, Department of Ocean, Earth & Atmospheric Sciences, Old Dominion University: “Microplastics as Vectors for Bacteria and Human Pathogens in Coastal Environments.”

Water Center Competitive Grants Program – Summary Reports for 2015-16

Following are **summary reports for the four grants awarded in 2015**, for work done between June 2015 and May 2016. The reports were written by the respective student principal investigators, with editing in some places by the *Water Central Newsletter* editor for space or format, including adding bolding and italics.

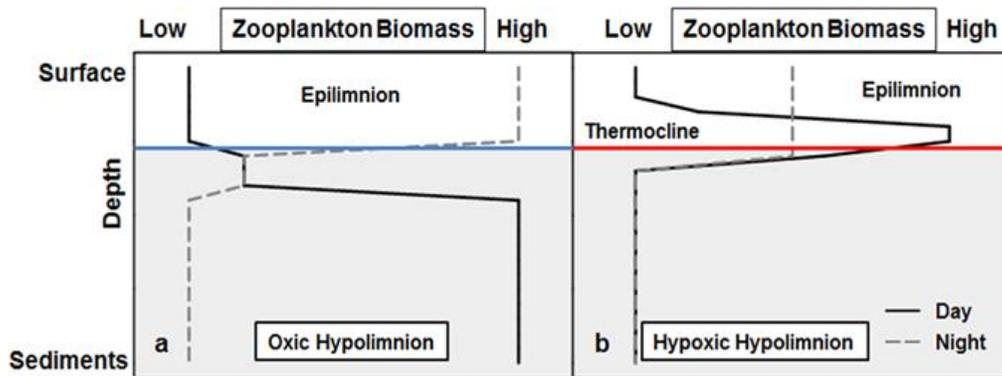
2015-16 Report 1. Hypoxia Induces Trade-offs on Zooplankton Behavior and Community Structure in Lakes and Reservoirs.

Student Principal Investigator: Jonathan P. Doubek; Faculty Co-Principal Investigator: Cayelan C. Carey; Department of Biological Sciences, Virginia Tech, Blacksburg, Va.

In many regions worldwide, land use and climate change are resulting in the depletion of dissolved oxygen in the bottom waters of lakes and reservoirs, a phenomenon known as **hypolimnetic hypoxia**. [*Ed. note: Hypolimnion* refers to the lower part of a water body in which the temperature, dissolved gases, and other conditions differ from top to bottom. **Hypoxia** refers to dissolved oxygen conditions that are lower than needed to support most aquatic life.]

Hypolimnetic hypoxia has severe consequences for water quality and aquatic food webs, because it can have major effects on aquatic organisms that need oxygen to survive. For example, hypoxia may fundamentally alter **zooplankton** behavior and ecology. [*Ed. note: Zooplankton* are small, often microscopic animals that typically float in a water column and can swim only weakly, if at all.] Zooplankton

play a critical role in freshwater lakes and reservoirs by their position in the food web, being the dominant grazers of algae, and in turn, being preyed upon by fish. Typically, zooplankton migrate to the deeper and dark bottom waters during the day to escape fish predation in the well-lit surface waters. Under the physiologically stressful conditions of hypoxia in the deeper waters, however, many zooplankton may remain in surface waters during daylight, trading the stress of low dissolved oxygen, called **oxic stress**, for increased predation risk [see Report 1/Figure 1, below, for a conceptual model of zooplankton location in response to oxygen conditions]. Hypoxia, therefore, has the capacity to change the vertical position of zooplankton in the water column during the daytime, which may result in lower zooplankton biomass and have possible ramifications for lake and reservoir water quality and food webs.



Report 1/Figure 1. Conceptual illustration of changes of zooplankton biomass in the water column during a) oxic hypolimnetic conditions (left, blue line) and b) hypoxic hypolimnetic conditions (right, red line).

We sampled five reservoirs weekly to biweekly in southwestern Virginia in 2014 and 2015 to examine how hypolimnetic oxygen concentrations impact the vertical distribution, density, biomass, and community composition of zooplankton. Four reservoirs are under the jurisdiction of the Western Virginia Water Authority and supply drinking water to Roanoke (Carvins Cove, Spring Hollow, Falling Creek, and Beaverdam), and Gatewood Reservoir supplies drinking water to Pulaski. These reservoirs varied on a gradient of hypolimnetic oxygen concentrations, from hypoxic to oxic during most of the thermally-stratified period. We also conducted a 24-hour sampling campaign on a reservoir with a hypoxic hypolimnion to examine how zooplankton were vertically distributed over an entire day.

We found that under hypoxic conditions, zooplankton were predominately found in the surface waters, did not exhibit their characteristic vertical migration, and had overall lower densities and biomass than in more oxic hypolimnetic conditions. Zooplankton in hypoxic reservoirs were typically also smaller than zooplankton in oxic reservoirs and there were only a few zooplankton taxa predominately found in hypoxic waters. [Ed. note: **Taxa** refers to species or other groups of organisms sharing characteristics in a scientific classification, or **taxonomy**.]

Altogether, our results suggest that hypolimnetic hypoxia may alter zooplankton vertical distribution, densities, and community characteristics. Looking ahead, our next major research goal is to determine how hypoxia may indirectly alter **phytoplankton** [floating plant-like organisms] and nutrient cycling through altering zooplankton communities.

2015-16 Report 2. Controls on Water Clarity: The Role of Organic Matter versus Inorganic Sediment.

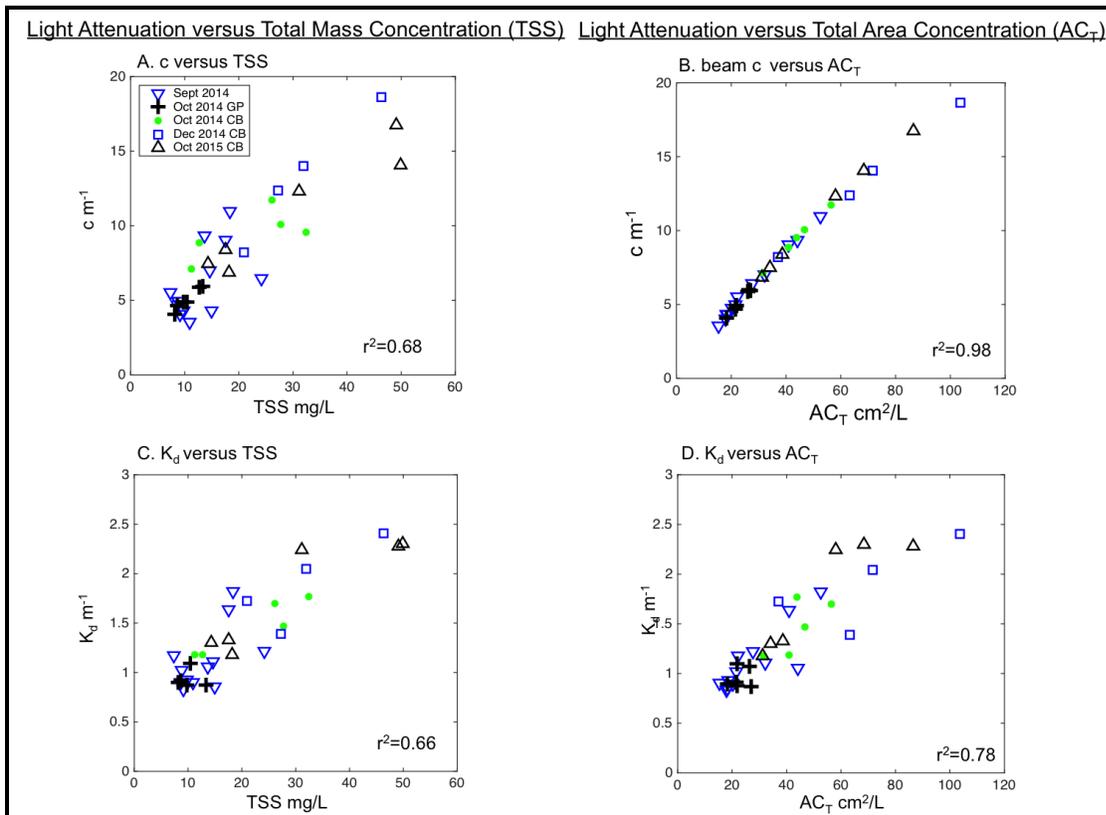
Student Principal Investigator: Kelsey A. Fall; Faculty Co-Principal Investigator: Carl T. Friedrichs; Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Va.

Degraded water clarity associated with suspended particulate matter is a major water-quality management issue in estuaries. Typical estuarine suspended particles are not single solid particles, but rather are clusters of inorganic and organic particles and water, called **flocs**. [Ed. note: **Organic** refers to substances containing carbon and typically referring to material that has been part of a living organism. **Inorganic** refers to material that does not contain carbon and may or may not have been part of a living organism.] Due to their fragile nature, flocs are difficult to observe in place, so their influence on **light propagation** [that is, the passage of light through the water] is not well defined.

This project used a combination of sophisticated acoustic and optical instrumentation and advanced irradiance meters to measure important floc properties, investigate the influence of organic matter on those

properties, and evaluate the influence of suspended flocs on light propagation. Observations were collected along the York River estuary in southeastern Virginia.

Results from this study suggest that floc properties and overall water clarity are related to the relative concentrations of organic matter versus inorganic matter in suspension. Preliminary analysis of our results indicates that light **attenuation** [that is, the reduction in the amount of light passing through water over distance] is better correlated to particle concentration as measured by particle *area* rather than particle *mass*, and that the majority of particle area concentration is attributed to small particles ($\leq \sim 10$ micrometers, μm , or millionths of a meter) [see Report 2/Figure 1, below]. Observations suggest that particle size, in turn, is strongly related to the relative concentrations of inorganic versus organic solids in suspension. In general, an increase in the relative fraction of organic matter is associated with a decrease in particle size as well as a decrease in particle settling velocity. Particle settling velocity is an important property to consider because it controls how long and how high in the water column particles stay in suspension.



Report 2/Figure 1. In this study, two independent measurements of light attenuation were collected: beam attenuation (c) and vertical diffuse light attenuation (K_d). Both c and K_d have units of 1/meters and increase as light attenuation increases. The figures above show observed relationships between these measures of light attenuation and suspended particle concentration in surface waters of the York River estuary. As indicated by explained variance (r^2), both measurements of attenuation were better explained by particle area concentration (AC_T with units of square centimeters per liter) than by particle mass concentration (TSS with units of milligrams per liter). [Ed note: The statistical quantity **variance**, or r^2 , indicates that amount of variation in a quantity of interest (in this case, light attenuation) that is explained by a given factor (in this case, the two factors of interest are particle area and particle mass). A higher r^2 indicates a larger amount of the variation is explained by the factor of interest.]

Estuarine *circulation* further segregates organic and inorganic solids along the length of the York. Smaller, organic rich, slowly settling particles tend to make up a larger fraction of the suspended material in the surface waters of the lower estuary, while particles in the upper estuary are predominantly inorganic and tend to be larger with larger settling velocities.

This project emphasizes the importance of smaller particles on light attenuation and suggests that the relative concentration of organic matter influences the concentration of these smaller, continually suspended particles. Further analysis is needed to refine these trends. Current velocities and turbulence from current meters still need to be analyzed, and the influence of *colored* dissolved organic matter needs to be investigated. It is expected that in response to estuarine eutrophication (i.e., an increase in the rate of supply of organic matter), particle properties will evolve differently in distinct sections of partially mixed estuaries, highlighting the need for localized management strategies as well as system-based strategies.

More details on this project are available at the following links (to PDFs):

http://www.vims.edu/~cfried/presentations/2015/Fall_Sep2015_INTERCOH_abstract.pdf; and
http://www.vims.edu/~cfried/presentations/2016/Fall_Oct2016_PiE_abstract.pdf.

2015-16 Report 3. Relative Roles of Biogeochemical Cycling and Hydrologic Transport on Nutrient Export at a Forested Hillslope.

Student Principal Investigator: Raymond Mark Lee; Faculty Co-Principal Investigator: Brian Strahm; Department of Forest Resources and Environmental Conservation, Virginia Tech, Blacksburg, Va.

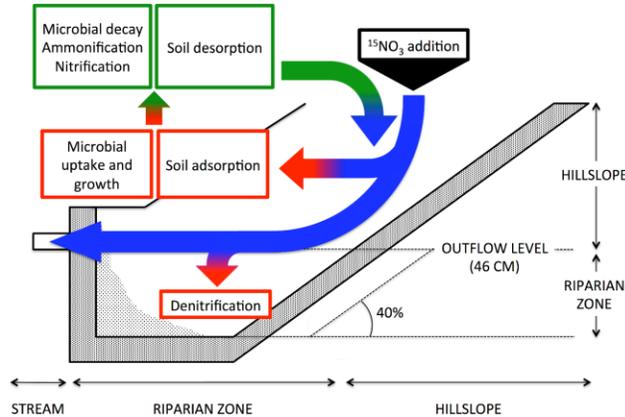
Forest ecosystems collectively process nearly two-thirds of the freshwater supply in the United States, and nutrient dynamics in these systems can impact drinking water quality downstream. Air pollution is a significant source of anthropogenic [human-generated] loading of nitrate (NO₃) over time, and soils can subsequently leach excess NO₃ to streams. It remains unclear exactly how NO₃ is processed and exported by a forest ecosystem, and to what extent under different environmental conditions. This research seeks to parse out the impacts of hydrological transport (precipitation; subsurface flow) and biogeochemical retention (interactions with soil) of NO₃ within a broader context of global change.

The research involves conducting a **tracer** experiment in a physical soil model that was built on a forested hillslope to represent a full continuum of hydrological processes from the hillslope, to a hypothetical riparian zone, to a stream. Report 3/Figure 1 (next page) is a conceptual diagram of the processes involved, while Report 3/Figure 2 shows the physical soil model. The physical soil model is located at U.S. Forest Service's Coweeta Hydrologic Laboratory in western North Carolina, within the Southern Appalachian region. The model was built approximately 50 years ago for an experiment that researchers used to develop a conceptual subsurface flow model that is still well-cited today.

The tracer in this research is labeled isotopes of NO₃ in water at levels that represent future conditions of high NO₃ loading. The physical model is irrigated until the labeled NO₃ and water are recovered at the outflow, with soil water and retention of NO₃ measured at several points past the tracer addition site to determine the travel time of NO₃ relative to water. Calculation of a water balance is done by applying controlled rates of irrigation along with measuring soil moisture in the model, estimating evapotranspiration with local meteorological data, and measuring the outflow to the hypothetical stream.

Along with measurements from the physical model, the research involves use of a computer model, HYDRUS, which simulates flow of water and solutes through variably saturated, porous media, such as soil. HYDRUS can be customized for specific parameters of interest in a given situation, such as Southern Appalachian forested hillslopes. Measurements of flow and moisture distribution in the physical model, along with sensitivity analyses, are being used to calibrate HYDRUS so that it fits the observed data; the Virginia Water Center grant provided the support to soil moisture and temperature probes being used in these measurements. Once that is accomplished, HYDRUS can be used to simulate responses to conditions that aren't possible in the physical model, such as predicted increased precipitation and nitrogen deposition resulting from climate change.

As of summer 2016, the customized HYDRUS model was in the final stages of calibration against current observed data and had been used in planning for the tracer experiments, which were moving forward as planned.



Report 3/Figure 1 (above). Conceptual illustration of the fate of the nitrate-tracer addition to a physical soil model. The black box is the addition, red boxes are possible sinks, green boxes are possible sources, and the blue arrow shows hydrological transport out of the system.



Report 3/Figure 2 (above). The physical soil model after installation of all the physical infrastructure (greenhouse shelter; plumbing, irrigation, and electrical lines) and instruments (soil moisture and temperature probes; input and output tipping buckets; lysimeters; and meteorological station). *Photo courtesy of Ray Lee.*

2015-16 Report 4. A Mass Balance Approach to Investigate Arsenic in a Petroleum Hydrocarbon Plume.

Student Principal Investigator: Brady Ziegler; Faculty Co-Principal Investigator: Madeline Schreiber; Department of Geosciences, Virginia Tech, Blacksburg, Va.

Arsenic is a known human toxin and carcinogen that is related to development of skin, lung, and bladder cancers. Arsenic exposure in humans is primarily through arsenic-contaminated drinking water sources. Alluvial aquifers are particularly vulnerable to having elevated concentrations of arsenic in groundwater, with notable examples in Southeast Asia and in the Midwestern United States. In these aquifers, naturally occurring arsenic can exist in aquifer sediments, most commonly adsorbed to ferric-iron hydroxides (FeIII). Under conditions where oxygen is adequate (called “oxidizing” or “oxic” conditions), the hydroxide is stable,

and arsenic remains adsorbed to the sediment mineral surface and is not found in groundwater. Under conditions of lower oxygen—called “reducing” conditions—stimulated by the presence of bioavailable organic matter, however, the solid ferric-iron hydroxide can be microbially reduced to *dissolved ferrous* iron (FeII). After dissolution of iron, arsenic that was adsorbed to the mineral is also released into groundwater.

There is abundant scientific literature documenting the mobilization of arsenic during biodegradation of organic matter coupled with reduction of ferric-iron minerals, but these studies traditionally focus on biodegradation stimulated by natural levels of organic matter. Under natural conditions, biodegradable organic matter in an aquifer is typically limited or distributed unevenly, so arsenic-related geochemical reactions can be slow and intermittent in the aquifer. In contrast, under conditions where organic matter is plentiful and widespread—such as after a significant oil spill—a (near) infinite source of human-generated organic matter serves as a constant driver of the reducing conditions that promote the continual release of arsenic from sediment to groundwater. That situation allows study in much shorter time frames of reactions that might take several decades when the reactant is organic matter at natural levels.

For this study, we used a 30+-year-old oil spill site to assess long-term arsenic cycling in the aquifer where biodegradation coupled with reduction of ferric-iron hydroxide to ferrous iron has been well-established and arsenic mobilization has been observed. Using a two-dimensional mass balance approach, this has addressed (or will soon address) the following:

1. Is the majority of arsenic in the hydrocarbon plume contained in sediment or groundwater?
2. Does partitioning of arsenic between sediment and groundwater change within the plume where different oxidizing/reducing (or “redox”) conditions prevail?

Funding from the Virginia Water Resources Research Center supported travel to the field site in Bemidji, Minnesota, to collect additional groundwater samples within the dissolved hydrocarbon plume, along with collection of three additional sediment cores from the aquifer within the hydrocarbon plume. In combination with groundwater and sediment data collected in 2011-2014, data from these samples were incorporated into a computer model to assess the distribution of arsenic mass between aquifer sediments and groundwater.

Preliminary results suggest that the distribution of arsenic mass closely follows that of iron. Most of the arsenic mass (>99%) exists in aquifer sediments; less than one percent of arsenic in the system is in groundwater. Results also suggest that long-term biodegradation at the Bemidji site has created different redox zones that have different implications for arsenic cycling. Depending on redox conditions, sediments can act as a source, sink, or both a source and a sink for dissolved arsenic. Results from this study will be used to evaluate the capacity for the aquifer to naturally attenuate arsenic and assess arsenic mobilization under current and future geochemical conditions. The results will be presented in one or more publications in peer-reviewed journals.

TEACHING WATER

Especially for Virginia’s K-12 teachers

This Issue of *Water Central* and the Virginia Standards of Learning

Below are suggested Virginia Standards of Learning (SOLs) that may be supported by items in this issue. The SOLs listed are from Virginia’s 2010 Science SOLs and 2008 Social Studies SOLs. Abbreviations: BIO = biology; CE = civics and economics; CH = chemistry; ES = earth science; GOV = Va. and U.S. government; LS = life science; PH = physics; WG = world geography.

Newsletter Section	Science SOLs	Social Studies SOLs
Feature: Water Center Intern’s Discoveries	6.7, 6.9, LS.11, ES.6, ES.10	CE.1, CE.7, CE.9, WG.7, GOV.1, GOV.8, GOV.9, GOV.16
At the Water Center/Competitive Grants Program Summary Reports Report 1: Hypoxia and Zooplankton Report 2: Water Clarity and Sediments Report 3: Stream Nitrogen Cycling Report 4: Aquifers, Arsenic, and Hydrocarbons	Report 1: ES.8, BIO.8 Report 2: ES.8, ES.10, BIO.8, PH.4, PH.8 Report 3: ES.8, BIO.1, BIO.8 Report 4: ES.6, ES.8, BIO.8, CH.1, CH.6	All reports: WG.2

N O T I C E S

If you would like to receive **regular e-mail notifications** about meetings, reports, and other items related to water quality and water monitoring, you may do so by joining the **Virginia Water Monitoring Council**; contact Jane Walker at (540) 231-4159 or janewalk@vt.edu.

For an online list of Virginia water-related **government meetings** (updated weekly), please see the Virginia Water Central News Grouper posts at <https://vawatercentralnewsgrouper.wordpress.com/?s=Virginia+Water-related+Government+Meetings>.

For an online list of Virginia water-related **conferences and other events** (updated at least monthly), please see the Virginia Water Central News Grouper's "Quick Guide to Virginia Water Events," at <http://vawatercentralnewsgrouper.wordpress.com/?s=Quick+Guide>.

For an online list of water-related **conferences and meetings outside of Virginia** (updated quarterly), please see the Virginia Water Central News Grouper's "Water Conference Sampler from around the United States and Elsewhere," at <http://vawatercentralnewsgrouper.wordpress.com/?s=Water+Conference+Sampler>.

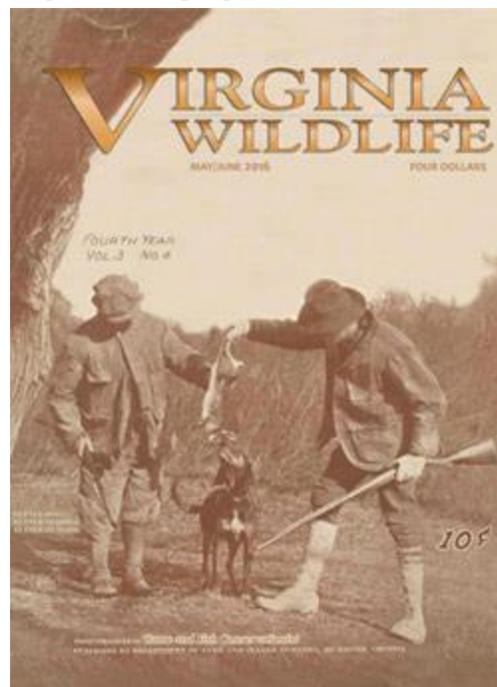
All Web sites listed in this section were functional as of 9/6/16.

Happy 100th Anniversary to the Virginia Department of Game and Inland Fisheries

On June 17, 2016, the Virginia Department of Game and Inland Fisheries, or VDGIF, celebrated its 100th anniversary. According to the VDGIF's first annual report (September 29, 1917), the department started out in 1916 in "the cloak room of the Senate Chamber in the Capitol," and proceeded to appoint game wardens "as fast as the boards of supervisors of the different counties and the councils of the different cities furnished lists of ten suitable persons from which the law required the Commissioner to select the wardens." From that modest beginning, VDGIF has grown into today's agency with its central office in Richmond; regional offices in Charles City, Fredericksburg, Forest, Marion, and Verona; district offices in Blacksburg, Chesapeake, and Farmville; and nine fish hatcheries across the Commonwealth. The department is overseen by the Board of Game and Inland Fisheries, currently with 11 members. Boating, fishing, hunting, wildlife management (both game and non-game), conservation policing, and education are the department's main areas of work. According to the department's Web site (<http://www.dgif.virginia.gov/>), VDGIF's mission is the following: "to manage Virginia's wildlife and inland fish to maintain optimum populations of all species to serve the needs of the Commonwealth; to provide opportunity for all to enjoy wildlife, inland fish, boating, and related outdoor recreation and to work diligently to safeguard the rights of the people to hunt, fish and harvest game as provided for in the Constitution of Virginia; to promote safety for persons and property in connection with boating, hunting and fishing; [and] to provide educational outreach programs and materials that foster an awareness of and appreciation for Virginia's fish and wildlife resources, their habitats, and hunting, fishing, and boating opportunities." The VDGIF Web site on the anniversary is

<http://www.dgif.virginia.gov/100/>, and a special 100th anniversary edition of the department's magazine, *Virginia Wildlife*, is available online at <http://www.dgif.virginia.gov/virginia-wildlife/>. You can contact the department's main office at P.O. Box 90778, Henrico, VA 23228-0778; phone (804) 367-1000. The regional offices, district offices, and fish hatcheries are all listed at this Web site: <http://www.dgif.virginia.gov/about/offices/>. For a news media account of the department's first 100 years, see "Virginia wildlife agency turns 100," by Bill Cochran in *The Roanoke Times*, 6/12/16, online at http://www.roanoke.com/sports/outdoors/bill-cochran-wildlife-agency-celebrates-years-of-success/article_30599d02-d671-5cea-9b29-e763592c22dd.html.

At right: The cover of the 100th anniversary issue of *Virginia Wildlife*, the magazine of the Virginia Department of Game and Inland Fisheries. Image accessed at <http://www.dgif.virginia.gov/100/>, 6/22/16.



Sea-level Rise Adaptation and Mitigation in Norfolk the Focus of July 2016 PRI Feature

“How One Virginia City is Re-framing Sea-level Rise as an Opportunity,” by Carolyn Beeler, is a 5 min./35 sec. audio on efforts by businesses, local government, and universities in the Norfolk, Va., region to find and offer ways for homeowners and other property owners to mitigate or adapt to the impacts of current and predicted sea-level rises. Aired on June 27, 2016, by PRI (Public Radio International), the piece is available online at <http://www.pri.org/stories/2016-06-27/how-one-virginia-city-re-framing-sea-level-rise-opportunity>.

Geology of Virginia Published in July 2016

On July 25, 2016, Virginia Gov. Terry McAuliffe announced the release of *The Geology of Virginia* by the Virginia Museum of Natural History. According to James Beard, the Museum’s curator of earth sciences, the new publication is the first comprehensive review of Virginia geology in over 100 years, covering regional, historical, economic, and hazards geology, along with fossil life. The book is available for purchase at the Museum, 21 Starling Avenue, Martinsville, VA 24112; phone (276) 634-4141; or online at the Museum’s Web site, <http://www.vmnh.net/>. **Source:** [Governor McAuliffe Announces Publication of Geology of Virginia](#), Virginia Governor’s Office News Release, 7/25/16.

Chesapeake Bay Urban Stormwater BMPs Factsheets

In April 2016, the Chesapeake Stormwater Network (<http://chesapeakestormwater.net/>) released the sixth in a series of factsheets on urban stormwater best management practices (BMPs). The factsheets are designed to make more accessible the information generated in a parallel series of reports by the Chesapeake Bay Program’s Urban BMP Expert Workgroup. The first seven reports/factsheets cover the following topics: Stormwater Retrofits (June 2015); Practices for New and Redevelopment Projects (June 2015); Residential Stewardship Practices (June 2015); Stream Restoration (June 2015); Nutrient Management (August 2015); and Enhanced Erosion and Sediment Control (May 2016). Another set of factsheets is expected to be ready later in 2016. For more information and to access the factsheets, visit <http://chesapeakestormwater.net/2015/06/urban-bmp-fact-sheets/>. Contact the Network at 8030 Main Street, Ellicott City, MD 21043; phone (410) 750-7635; e-mail: Tom Schueler, watershedguy@hotmail.com; or Cecilia Lane, watershedgal@hotmail.com.

Rex Springston’s December 2015 Retirement Marked 22 Years of Virginia Environmental Reporting

On November 30, 2015, reporter Rex Springston retired from the *Richmond Times-Dispatch*, after 24 years at that newspaper—including environmental reporting for 22 years—and 41 years altogether in journalism. On January 21, 2016, the Virginia departments of Forestry; Game and Inland Fisheries; Conservation and Recreation; and Environmental Quality jointly presented Mr. Springston with a Lifetime Achievement Award (“State agencies honor Springston for environmental reporting,” *Richmond Times-Dispatch*, 1/21/16; online at http://www.richmond.com/news/virginia/government-politics/article_db28a47f-2bd5-58f0-b761-e82c4446e4a6.html). Just prior to his retirement, Mr. Springston compiled a list of some of his favorite articles, covering subjects from sturgeon in the James River, to Canebrake Rattlesnakes in southeastern Virginia swamps, to Hellbender salamanders in southwestern Virginia streams: “Advice of long years of reporting: Love bats, avoid ticks,” *Richmond Times-Dispatch*, 11/30/15, is available online at http://www.richmond.com/outdoors/article_69bf28b6-4252-5b10-bcc8-91580664e27f.html. You can reach the newspaper at 300 E. Franklin Street, Richmond, VA 23219; phone (804) 649-6000.

A Summer 2016 Look Back at Virginia’s Recent Development of Oyster Aquaculture and Its Connection to France

“Vive l’huitre! Chesapeake oyster aquaculture has roots in France,” by Rona Kobell in the July-August 2016 issue of *Bay Journal*, looks back at some key events in the development of Virginia’s oyster aquaculture industry since the early 2000s. The article describes the role of J. Carter Fox—a seasonal resident of Reedville, Va. (Northumberland County) and former member of the Virginia Marine Resources Commission—in helping Virginia watermen, marine resource professionals, and politicians learn about oyster aquaculture in France, and how those lessons and connections helped Virginia develop its now robust oyster aquaculture industry. The article is available online at

http://www.bayjournal.com/article/vive_la_oyster_chesapeake_oyster_aquaculture_has_roots_in_france, or contact Bay Journal at (717) 428-2819; e-mail: bayjournal@earthlink.net.

Potable Reuse of Water Examined in Arizona Water Center Publication in May 2016

“Potable Reuse of Water,” published in the 2016 edition of *The Arroyo*, from the University of Arizona Water Resources Research Center, provides a detailed introduction to the technology and issues of using treated wastewater as potable water. The publication is focused on issues of concern in Arizona, but the article provides much information applicable to potable water use in other states, including descriptions of reuse systems in Arizona, California, Georgia, New Mexico, and Texas. The publication is available online at <https://wrrc.arizona.edu/publications/arroyo>; or contact the Arizona center at (520) 621-9591, or e-mail: wrrc@cals.arizona.edu. For information on water reclamation and reuse in Virginia, see the Virginia Department of Environmental Quality Web site at <http://www.deq.virginia.gov/Programs/Water/LandApplicationBeneficialReuse/WaterReclamationReuse.aspx>.

A Closer Look at Jellyfish

Jellyfish are the focus of “In the Increasingly Damaged Sea, One Animal is Thriving,” broadcast on August 3, 2016, on the PBS NewsHour. The 6 min./52 second video, available online at <http://www.pbs.org/newshour/bb/increasingly-damaged-sea-one-animal-thriving/>, examines how populations of jellyfish are increasing, possibly as a result of fishing harvests that remove feeding competitors and of jellyfish’ capacity for tolerating pollution. The report includes a visit to jellyfish research facilities at the New England Aquarium in Boston. For more information on jellyfish, see the Smithsonian National Museum of Natural History, “Jellyfish and Comb Jellies,” online at <http://ocean.si.edu/jellyfish-and-comb-jellies>.

An Ambitious Effort to Clean the Oceans of Plastic

Boyan Slat of the Netherlands is leading a project called “The Ocean Cleanup,” aiming to employ passive barriers to collect plastic moving with the world’s ocean currents. An estimated nine million tons of plastic reach the oceans annually. Mr. Slat’s ambitious project is described in a PBS NewsHour segment, “Can this project clean up millions of tons of ocean plastic?” (8 min./29 sec.) aired on August 14, 2016, and available online at <http://www.pbs.org/newshour/bb/can-project-clean-millions-tons-ocean-plastic/>. The segment also gives background information on the problem of plastics in the oceans and how currents move and concentrate the debris into patches, such as the so-called “Great Pacific Garbage Patch” (or “Pacific trash vortex”) in the North Pacific Ocean. For more information on ocean debris, see the Smithsonian National Museum of Natural History, “Ocean Trash Plaguing Our Sea,” online at <http://ocean.si.edu/ocean-news/ocean-trash-plaguing-our-sea>; or the National Geographic Society, “Great Pacific Garbage Patch,” online at <http://nationalgeographic.org/encyclopedia/great-pacific-garbage-patch/>.

Energy and Climate Notices

- The **U.S. Climate Resilience Toolkit** is a joint effort of several federal agencies to provide scientific tools, information, and expertise to help people manage climate-related risks and opportunities, and improve their resilience to extreme events. The main Web page for the Toolkit is <http://toolkit.climate.gov/>. At that site, the “Topics” tab (<http://toolkit.climate.gov/#topics>) provides access to sources of information on how climate change can impact particular regions or sectors of the United States; the current topic areas (as of 9/7/16) are the following: Arctic, Built Environment, Coasts, Ecosystems, Energy, Food, Health, Marine, Transportation, Tribal Nations, and Water.

- In January 2015, the U.S. Geological Survey (USGS) released a report and accompanying data set on the **location and methods used in hydraulic fracturing gas and oil wells** across the United States from 1947 to 2010. The 15-page report, “Trends in Hydraulic Fracturing Distributions and Treatment Fluids, Additives, Proppants, and Water Volumes Applied to Wells Drilled in the United States from 1947 through 2010—Data Analysis and Comparison to the Literature” (U.S. Geological Survey Scientific Investigations Report 2014–5131), is available online at <http://pubs.usgs.gov/sir/2014/5131/>. For more information, contact Heidi Koontz, phone (303) 202-4763, or e-mail: hkoontz@usgs.gov; or the USGS Office of Communications and Publishing, 12201 Sunrise Valley Drive, MS 119, Reston, VA 20192, phone (703) 648-4460.

Virginia Water Central Newsletter

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