State of the Elizabeth River *Scorecard*

Elizabeth River Project
Making restoration a reality

VIMS | William & Mary
Virginia Institute of Marine Science

Acknowledgements

Project Funders:

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Contributing Partners:

The Elizabeth River Project took the lead to interpret findings for the public with coordination of data collection by Mary Bennett, environmental scientist. Virginia Institute of Marine Sciences managed research funded through a new state allocation for Elizabeth River monitoring, with special thanks to Dr. Michael Unger, chair, scorecard steering committee. Special thanks to Steven Hummel, Virginia Department of Environmental Quality, for key analysis of water quality data, and to the University of Maryland Center for Environmental Science, Integration and Application Network for assistance with data comparison and interpretation. Special thanks to more than a dozen individual scientists who gave generously of their time and expertise to serve on the steering committee.

The Elizabeth River Project is a non-profit with the mission to restore the environmental quality of the Elizabeth River through citizen, business and government partnerships.

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The Elizabeth River Project

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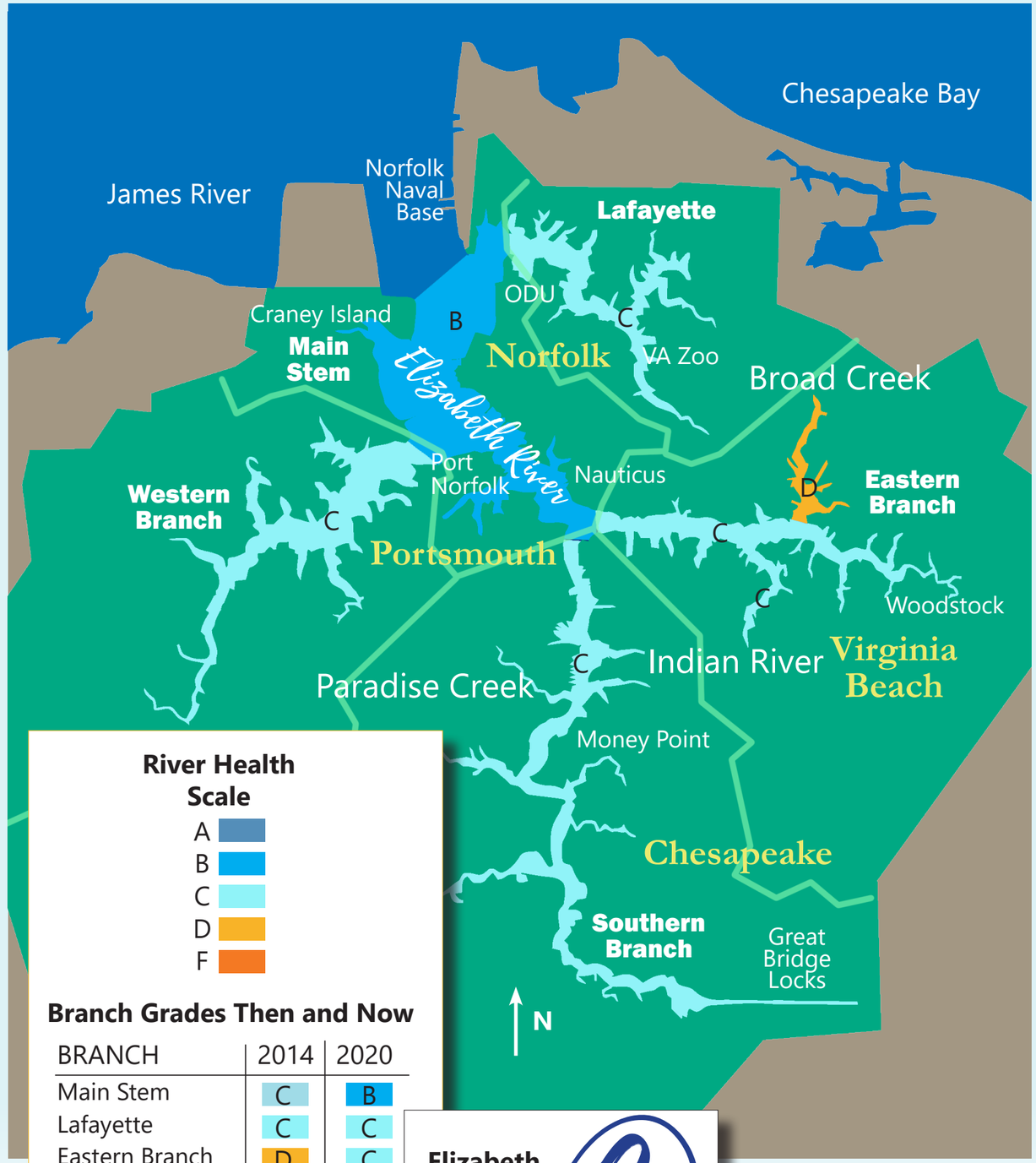
Cover photo of Brown Pelican and other bird photos by David Gibson. Visit his Elizabeth River Bird Blog at www.birdpartner.com.

Contents



What the scorecard measures for this unusual river

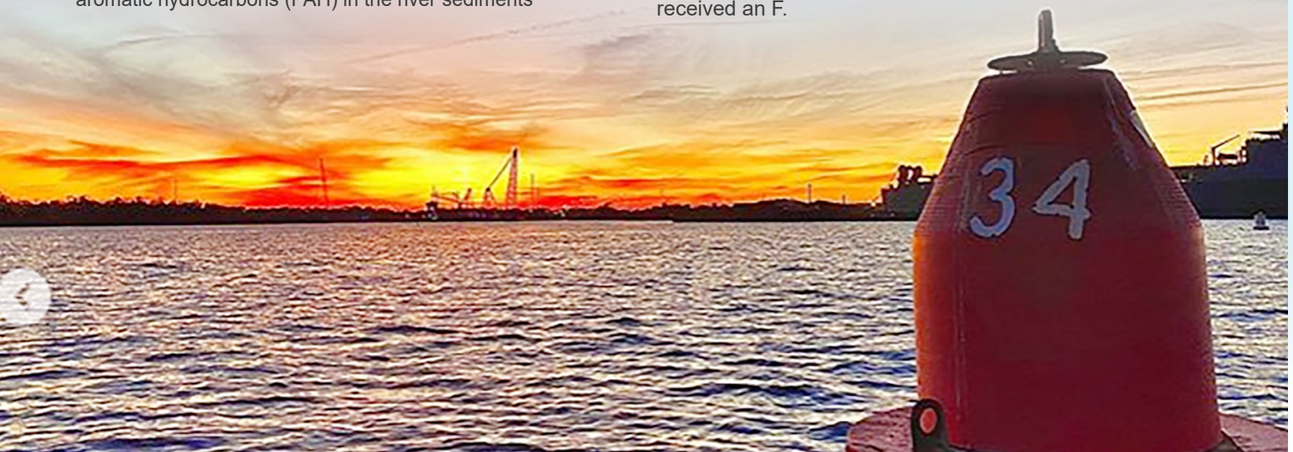
At the southern mouth of the Chesapeake Bay spreads the Elizabeth River, one of the bay's most atypical tributaries. A leading bay nursery for blue crabs, the Elizabeth is also one of the busiest military and commercial ports in the world. The 250-square-mile "watershed," or land area draining to the river, has been developed longer and more densely than most of the bay, with 400 years of filling, deepening and paving to accommodate not only the port but the old port cities of Norfolk and Portsmouth and newer suburbs in Chesapeake and Virginia Beach, VA.

This report evaluates each branch, as well as three of the river's larger creeks, to provide both a short-term, five-year snapshot of river health and also identify long-term trends. The letter grades are for the last five years. Where changes in 10-year trends can be identified, these are indicated separately and reflect 2010–2019. **ALSO SEE THE TECHNICAL APPENDIX AT Elizabethriver.org/SOR2020.**

- **Bacteria (recreation criteria):** Enterococcus bacteria levels in river water, associated with animal and human waste, compared to state criteria for recreational human contact.
- **Bacteria (shellfish criteria):** Fecal coliform bacteria levels in river water, associated with animal and human waste, compared to state criteria for shellfish harvest.
- **Bottom Health:** Measures a number of parameters including abundance and diversity of life on the river bottom (worms, clams etc.)—indicates food availability for many fish. Results are based on Chesapeake Bay Program's Benthic Index of Biotic Integrity.
- **Cancer in Fish:** Prevalence of both precancerous and cancerous lesions found on the liver of the small non migratory fish, the mummichog.
- **Clarity:** Measures the depth that sunlight penetrates through the water column and is important for algae and aquatic vegetation growth.
- **Dissolved Oxygen:** Amount of oxygen dissolved in the water compared to state criteria. Dissolved oxygen is an important factor for healthy marine life.
- **Phosphorus:** An important nutrient for algae growth, the amount is compared to EcoCheck thresholds. Excess phosphorus can lead to algal blooms and fish kills; over-fertilizing is one cause.
- **Nitrogen:** An important nutrient for algae growth, the amount is compared to the University of Maryland's EcoCheck. Excess nitrogen can lead to algal blooms and fish kills; over-fertilizing is one cause.
- **Contaminants on River Bottom:** Levels of polycyclic aromatic hydrocarbons (PAH) in the river sediments compared to levels having negative impacts on river life. In the Elizabeth River, PAHs are correlated with cancer in fish and are often a legacy of former wood treatment facilities.
- **Phytoplankton/Chlorophyll:** Algae, known as phytoplankton, are vital for a productive river. But some types of algae are harmful and in excess can lead to poor water quality with impacts on fish and shellfish. Chlorophyll (the measurable pigment in algae) was compared to EcoCheck thresholds.
- **TBT:** Concentration of Tributyltin (TBT) detected in the water column. TBT has been shown to be highly toxic to marine organisms at very low concentrations and this concern led to regulatory action on the state, federal and international level to reduce its input to the marine environment.

Methodology change affects some scores

To make this scorecard consistent with data evaluations around the Chesapeake Bay, the steering committee for this report for the first time adopted the "EcoCheck" methodology for water quality data as used by the University of Maryland's Center for Environmental Science Integration and Application Network. As a result, improved letter grades in a few cases, notably for dissolved oxygen, are more a reflection of the new methodology than of actual ecosystem improvement. The EcoCheck method grades higher for dissolved oxygen than did the grading method used in the 2014 Elizabeth River scorecard. As a result, Indian River earns a C overall in this report, but would have earned a D under the prior grading method; similarly Broad Creek receives a D and would have received an F.



Dolphins were sighted in all branches of this harbor river in 2020. Photo: Robert Holland.

Summary:

One of America's great harbor rivers again earns a C, defying changing climate conditions to show continued key improvements.

Robert McMillen was sitting on a dock on a still night, watching the moonlight on the Elizabeth River. He heard a faint, unusual sound. Gradually it grew louder. To him it sounded like "poush… poush."

He soon saw glossy backs, lit by the moon. Dolphins were passing by. "It was the sound of their breathing that gave them away," a mesmerized McMillen, of Portsmouth, wrote in a poem about the experience.

When dolphins were sighted in every branch of the urban Elizabeth in the summer of 2020, it delighted the COVID-19 paralyzed community of South Hampton Roads, Virginia. The occurrence also indicated returning health of a harbor river once given up for dead.

Returning dolphins, river otters and bald eagles, all sighted with greater frequency, are here for the returning fish—and in turn, the fish have need of clean water and restored habitat. The health of the water is measured in hard numbers, on the Elizabeth River by more than a dozen area scientists who, since the 1990s, have gathered about every six years to look for trends, progress, and problem areas.

This is the Elizabeth River Scorecard 2020. To grasp the drama, it's necessary to understand something of the past for this harbor river, birthplace of maritime history; and also emerging global influences hard to combat at the local level, including rising seas, warmer water, and increased rainfall.

• **Overall 2020 grade for the Elizabeth River: C**, as in the last scorecard, compiled in 2014. This grade is only remarkable if you realize that when the first group of scientists gathered with the Elizabeth River Project to review the river's health, in 1994, professors vied for whose slides showed the most deformed fish. Holding steady at C is also an accomplishment in the face of abnormally high rainfall each of the five years measured by this scorecard. On urban rivers like this one, every rain brings a heavy deluge of runoff pollution.

• **Most remarkable new grades:** A's and B's, earned river wide for tributyltin (TBT). This is one of the most toxic compounds ever introduced to the marine environment. TBT was added to paint to keep barnacles and algae off the bottom of ships, but proved lethal to fish even in small amounts. Since the Elizabeth River is lined with ship repair facilities, efforts to keep TBT out of the river proved quite a struggle until it was banned internationally. Measuring for TBT in the Elizabeth for the first time in 13 years, Virginia Institute of Marine Science reports it's now below harmful levels everywhere tested. "Really great news," says investigator Michael Unger.

• **Most improved area of the river:** The Southern Branch, earning a C for the first time. This is the most industrialized branch, the infamous stretch where scientists once headed for their deformed fish contests. Cleanup efforts have focused here for decades. The year 2020 saw substantial completion of a milestone, $100 million cleanup by the US Environmental Protection Agency of the Atlantic Wood creosote site on the Southern Branch. Polycyclic aromatic hydrocarbons (PAH), correlated with cancer in the indicator fish, the mummichog, fell from as high as 20,000 parts per million to less than 45 parts per million (ppm), a threshold for effects to marine life.

• **Most hard-won recent progress, with more work needed:** The Eastern Branch, recently dubbed the "lost branch," also lands its first C. The Elizabeth River Project has made this branch its top focus since 2014, partnering with Chesapeake, Norfolk, Virginia Beach, homes, businesses, state and federal governments to carry out an improvement strategy that in 2020 brought Governor Ralph Northam onto the Eastern Branch to declare it fully restored for oyster habitat—only the second bay tributary in Virginia to achieve the status. The Elizabeth River Project met its goals to erase failing scores for Indian River and Broad Creek.

• **Most heartening water quality indicator:** Dissolved oxygen, graded at A or B for all parts of the river except Broad Creek. This is amazing for an urban river, measuring the amount of oxygen available to river life.

• **Most concerning scores:** Degrading trends for bacteria levels (Lafayette, Western Branch, Mainstem), measured against health standards for safe harvest of oysters; poor water clarity (Western and Lafayette branches); unaddressed contamination hotspots; most ailing score on the river, Broad Creek. Bacteria and water clarity are thought to have been affected by above normal rainfall. Meanwhile, scientists continue to observe elevated fish cancer at remaining PAH hotspots in the river bottom, including offshore of the defunct Republic creosote site on the Southern Branch. Efforts continue by many partners to improve Broad Creek.

So often the Elizabeth River Project thanks the "River Star" homes, businesses, governments, and schools who carry out projects they hope will make a difference. We also thank the donors who make all our work possible. But for this report, the Elizabeth River Project salutes the scientists who tell the community if any of this indeed is working and where to focus next. We salute the grad student at Virginia Institute of Marine Science, Kristen Prossner, who found an inexpensive new way to identify river hotspots with oysters; Steve Hummel at Virginia Department of Environmental Quality who, laid up with an injury, passed the time by making our report more consistent with bay-wide data, and Dr. Wolfang Vogelbein, VIMS, who, undeterred by a pandemic, set up lab in his garage to see how the Elizabeth River's indicator species, the mummichog, is faring.

Our lead scientist on staff at Elizabeth River Project, Joe Rieger, deputy director – restoration, summarized this report's encouraging news this way.

"Out of the eleven parameters evaluated for 10-year river health trends in each branch (55 overall trends analyzed), only three show declining health. All other parameters show improving trends or no change in the trends."

Thank you to all walks of life for the progress that brought dolphins surfing past Robert McMillen this summer. And finally, amazing news about the next scorecard: It's coming out in three years instead of six, thanks to increased state funding for Elizabeth River monitoring.

Emerging challenges:

Abnormally high rainfall, rising sea levels bring deluge of runoff pollution.

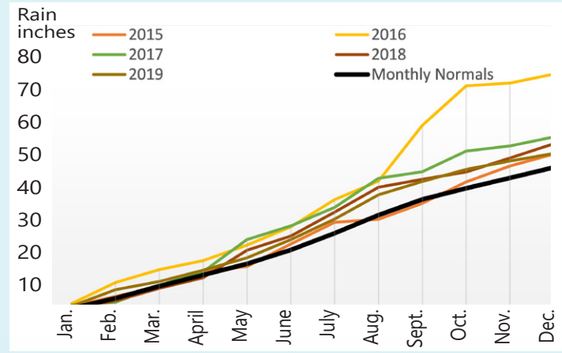
Rain is becoming more frequent and intense along the Elizabeth River, in keeping with global trends. Combined with more flooding from one of the highest rates of sea level rise in the nation, changing climate conditions create extra hurdles for achieving a healthier Elizabeth River.

Since the last Elizabeth River scorecard in 2014, precipitation in the watershed or drainage area was greater in every month compared to the long-term monthly normal, reports Dr. KC Filippino, a Senior Water Resources Planner at Hampton Roads Planning District Commission who analyzed the rainfall data. In fact, 2018 was the wettest year on record here and across the Chesapeake Bay.

Along much of the Elizabeth River, aging underground storm pipes were put in place long before environmental regulations. With each rain, excess lawn fertilizer and sediments wash off yards; oils and grease wash off streets. The toxic mix heads straight through the storm system into the river, typically with no treatment. This can negatively affect many of the parameters measured in this report, from water clarity to dissolved oxygen, nitrogen and phosphorous. Extra rain and a changing climate are also making the water warmer and less salty, further affecting these parameters as well as what species can thrive here.

Kudos to the cities of Chesapeake, Norfolk, Portsmouth and Virginia Beach for massive undertakings to address stormwater pollution.

Meanwhile, pollution loads from the rising tides may prove even more significant. Old Dominion University's Dr. Margie Mulholland, in her Measure the Muck project, found in 2018



Cumulative monthly rainfall from Norfolk International Airport from 2015 to 2019. The black line is the long-term monthly normal average between 1981 and 2010. (Source: NOAA, National Climate Data Center)

The Elizabeth River Project's planned Resilience Lab, coming to the waterfront on North Colley Avenue, will show resilience to rising seas.

Special victory:
Effects of toxic TBT have almost disappeared.

This harbor river was once ground zero for a difficult quest by regulators, scientists and shipyards to reduce a chemical compound that kept barnacles off ships, but was all too harmful for other river life as well. Virginia Department of Environmental Quality sought to limit how much TBT could reach the Elizabeth, while Norfolk's NORSHIPCO, now BAE Ship Repair, led experiments to try to reach permit limits. Eventually, TBT was banned internationally. Not until this scorecard, though, have measurements been taken in recent years to see if TBT still lingers at toxic levels.

"This is really great news," said Dr. Michael Unger, Virginia Institute of Marine Science, reviewing the first testing of TBT in the river in 13 years. Unger led the monitoring with new state funding and for this report gives the Elizabeth only A's and B's for TBT.

Samples were collected in the Elizabeth River semi-monthly (August 2019–September 2020) from 16 stations used in previous monitoring. The results show that TBT concentrations are below 2 ng/L at all stations. Even at extremely low levels, TBT can be lethal to fish and cause females to develop male sex organs.

Location of sampling stations for TBT water column monitoring, 2019, VIMS.

Swimming precautions advised

This report includes a measurement for "recreational contact," gauging how often enterococci bacteria levels exceeded state health standards for human contact with the river. The good news: The Lafayette, Main Stem and Eastern Branches both earn B's in this report for this measurement, with relatively few exceedances, while only two areas of the river received failing grades, Indian River and Broad Creek.

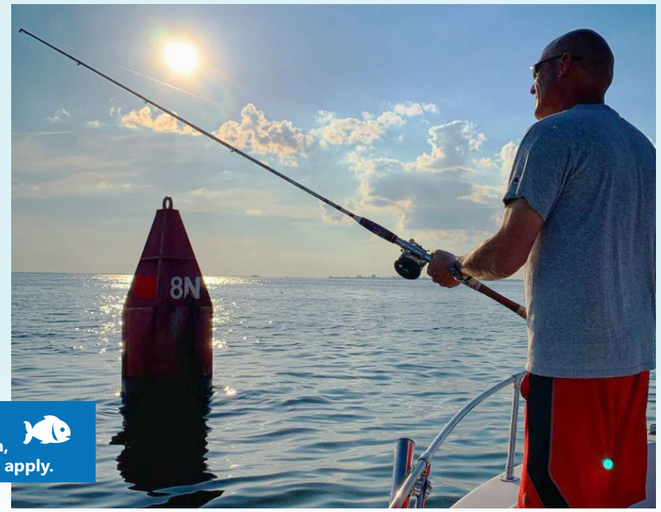
The Virginia Department of Health (VDH) manages beach swimming advisories at public beaches, but there is no state-funded program that routinely monitors other areas on a weekly basis to provide the public with the "current" status of enterococci levels with respect to the level safe for recreational contact. The VDH beach monitoring program does not currently include monitoring sites within the Elizabeth River watershed. Therefore, neither health officials nor Elizabeth River Project make any determination regarding the status of "safe swimming" in the Elizabeth or its tributaries.

Elizabeth River Project nonetheless offers these safety precautions, developed in consultation with VDH:

- As with any urban river, avoid recreational contact for 72 hours after a rain. Elevated bacteria levels are likely after storms due to urban runoff pollution.
- Avoid recreational contact in narrow, shallow creeks. These areas do not flush well and may have excess bacteria even in dry weather.
- Do not make contact with any natural waterway if you have an open cut or burn or if you have liver disease, alcoholism, cancer, diabetes, are a transplant recipient, or have health conditions that compromise your immune system. Potentially serious and fast-acting infections from Vibrio vulnificus, a naturally occurring bacteria, are increasing along the East Coast as waters become warmer and stay warmer year-round. Should you submerge an existing open cut or injure your skin while in natural waterways, clean with warm soapy water and secure with a waterproof bandage as soon as possible. Seek immediate attention if the wound develops unusual redness, swelling or drainage, and inform the doctor of any recent contact with a natural waterway.
- For more information on water-related illnesses possible in natural waterways, visit www.SwimHealthyVA.com.

Fish consumption advisories

The VDH advises against eating more than two meals a month for many species of fish when caught anywhere in the lower James River and its tributaries, including the Elizabeth River and its branches, based on potential PCB contamination. A meal is considered to include an 8 ounce serving of fish. The fish consumption advisory applies to blue catfish or flathead catfish under 32 inches long, channel catfish, white catfish, largemouth bass, bluegill sunfish, American eel, quillback carpsucker, smallmouth bass, creek chub, yellow bullhead catfish, white perch, striped bass, bluefish, croaker, spot, blueback herring, and hickory shad. The advisory goes further to recommend you do not eatblue catfish or flathead catfish 32 inches and longer, gizzard shad, and carp from these areas. In addition, for the Southern Branch of the Elizabeth, the health department has issued a special advisory not to eat the mustard of the blue crab because of potential PCBs and dioxins.



HEADS UP
As throughout southeast Virginia, fish consumption advisories may apply.

Green Heron photo by David Gibson, Elizabeth River Bird Blog (birdpartner.com)

Southern Branch: C

Improved from D

Once infamous industrial branch makes remarkable rebound with mega bottom cleanups.

Remarkably, the Southern Branch of the Elizabeth River, one of the most industrialized stretches of any waterway in America and the birthplace of maritime history, showed the greatest overall improvement of any branch in this scorecard. Once almost a joke among scientists for deformed fish and extreme degradation, this busy stretch of the river leads from some of the world's leading shipyards south along the Intracoastal Waterway to almost bucolic wetlands and forests at the beginning of the Great Dismal Swamp. Today, most shipyards and other industries here are River Star Businesses participating voluntarily with Elizabeth River Project to reduce pollution, while the US Environmental Protection Agency in 2020 substantially completed a $100 million cleanup of some of the worst contamination in America, at Atlantic Wood Industries on the Southern Branch in Portsmouth. Prior Southern Branch cleanups include Elizabeth River Project's removal of contamination and creation of oyster beds and wetlands at Money Point in Chesapeake's South Norfolk, with the Living River Trust and many partners.

Results for the Southern Branch bring the score up from a D in 2014 (hailed as remarkable enough at the time) to a C in 2020. The data shows improving 10-year trends in four key parameters, for Chlorophyll *a*, contaminants on the river bottom, cancer in fish and TBT. Also encouraging, grades for the Southern Branch improved from C to B for both Dissolved Oxygen, essential to fish health, and nitrogen. Excess nitrogen can lead to harmful algal blooms and fish kills.

The goo is going: The Atlantic Wood site is one of a half-dozen wood treatment facilities that formerly operated on the Southern Branch, leaving a legacy of some of the highest known levels of PAH in the world. PAH contamination is associated with cancer in the small indicator fish, the mummichog. At Atlantic Wood, PAH levels in the river bottom sediments were as high as 20,000 parts per million (ppm), with 45 ppm the level above which significant effects are seen on river life. Rates of cancer and pre-cancer lesions in the livers of mummichogs alongside this side at times exceeded 90 percent. Following the EPA cleanup of 35 acres of PAH and other contamination, in the works for nearly three decades, PAH levels at Atlantic Wood are now below 45 ppm and cancer levels in the mummichog have declined dramatically. In addition, Money Point, where more than 36 million pounds of PAH contaminated sediments were removed from 2009–2012, continues to show low levels of both fish cancer and toxics in the sediments.

Underway: The non-profit Living River Trust, www.livingrivertrust.org, is underway with a year-long, nearly $6 million, pioneer project to address PCB contamination in Paradise Creek on the Southern Branch. The project applies pellets of activated carbon to isolate PCB effects while also removing the most severe contamination. Funding represents mitigation for the expansion of the Hampton Roads Bridge Tunnel.

Yet to tackle: A heavily polluted site on the Southern Branch, the defunct Republic Creosote site, remains unaddressed. It is identified for cleanup as part of a mitigation plan for the expansion of the Craney Island dredge management facility, but the expansion and this associated mitigation are on indefinite hold. As well, bacteria levels remain challenging, as throughout much of the river.

Southern Branch ©

Osprey with catch, by David Gibson, Elizabeth River Bird Blog (birdpartner.com)

Southern Branch Grades

Parameter	Description	2014	2020	2020 10Y Trends
Bacteria (recreation)	Human contact criteria for enterococcus.	C	D	
Bacteria (shellfish)	Fecal coliform levels in river water.	-	-	
Bottom Health	Abundance and diversity of river bottom life.	D	D	
Fish Cancer	Cancer and precancerous liver lesions in mummichogs.	-	F	Improving
Clarity	Depth of sunlight penetration.	-	C	
Contaminants	Levels of polycyclic hydrocarbons (PAH) in sediment.	F	F	Improving
Dissolved Oxygen	Amount of oxygen in the water. Important for marine life.	C	B	
Phosphorus	In excess can lead to fish kills and algae blooms.	C	C	
Nitrogen	In excess can lead to fish kills and algae blooms.	C	B	
Chlorophyll	Algae known as Phytoplankton are vital for river production.	B	B	Improving
TBT	Concentration of tributyltin in the water. Highly toxic.	-	B	Improving
Overall Grade		**D**	**C**	

The little fish that's the "canary" of the river bottom

"I don't see grossly visible tumors in the livers anymore"

This tiny brown fish might seem unimportant when you glimpse it darting in schools through the river shallows. But the mummichog (*Fundulus heteroclitus*) is the all-important "canary in the coal mine" for the health of the Elizabeth River.

Because the mummichog doesn't migrate, instead living its entire life along the river mud in a span of a few hundred yards, it reflects the condition of its "bottom habitat," considered the foundation of the food chain. Every iteration of the Elizabeth River Project's Watershed Action Plan for the river, beginning with the first plan in 1996, has identified the mummichog as the indicator species to track for river recovery.

The really great news: "I don't see grossly visible tumors in the livers anymore at any of these sites," Dr. Wolfgang Vogelbein told the scorecard steering committee in summer 2020. He had just finished analyzing the latest batch of mummichogs, using a temporary lab he set up in his garage during COVID. Since the 1990s, he and Dr. Michael Unger, both of Virginia Institute of Marine Science, have been measuring cancer and pre-cancerous lesions in mummichogs of the Elizabeth.

The pair have found that areas with the highest concentrations of PAH contamination in the sediment have the highest prevalence of liver lesions and tumors in mummichogs. While some areas of the river still have mummichogs with elevated disease, areas that have undergone sediment clean up, most notably

Dr. Wolfgang Vogelbein, VIMS, converts his garage to a lab during the pandemic to keep going with mummichog studies.

Atlantic Wood, an EPA Superfund site, show dramatic improvements in mummichog health.

The bad news: Signs of cancer and pre-cancer in the little fish are still high for PAH hotspots where no clean up has been conducted, with the defunct Republic Creosote site in Chesapeake and a site at the mouth of the Eastern Branch showing the highest rates of disease (the Southern and Eastern branches both earn F's for sediment contamination). Such findings are why the Elizabeth River Project teaches this slogan to school children and legislators alike: "The goo must go!"

Letter Grades for Sediment Contamination

Stream Name	Parameter	# Sites	Total Samples	%TAF	%TN	Grade	Date Range
MAINSTEM	Fish Cancer	1	60	6.80%	1.70%	C	2018-10-10 - 2018-11-07
LAFAYETTE	Fish Cancer	1	60	3.30%	1.70%	C	2018-10-10 - 2018-11-07
EASTERN	Fish Cancer	1	60	46%	11.90%	F	2018-10-10 - 2018-11-07
WESTERN	Fish Cancer	1	60	0%	0%	A	2018-10-10 - 2018-11-07
SOUTHERN	Fish Cancer	10	600	53%	6.80%	F	2018-10-10 - 2018-11-07

Southern Branch C

Paradise Creek, Southern Branch: C

Improved from D

"One creek at a time" approach still paying off

This creek in Portsmouth was a dumping ground for the Norfolk Naval Shipyard through two world wars, but continues to mend. The shipyard won a White House award with Elizabeth River Project for completing a series of cleanups a few years ago. The Elizabeth River Project created a 40-acre nature park, Paradise Creek Nature Park, with the Port of Virginia and the City of Portsmouth to promote continued stewardship of the two-mile-long creek off the Southern Branch. Along with large-scale improvements at a trash-to-energy plant on the creek, these efforts were part of a "One Creek at a Time" model launched by Elizabeth River Project in 2002 to determine if intensive focus on one area of the river would bring about strong results.

While Elizabeth River Project has since turned its top focus to other areas of the river (the Lafayette beginning in 2009; currently the Eastern Branch), Paradise Creek continues to recover. The creek's overall grade improved from 2014 from a D to a C in this scorecard, with improvements of note for dissolved oxygen and phosphorous and long-term reductions in phosphorus concentrations.

Next up: The cleanup of PCB's in the main body of the creek by the Living River Trust (note, there is no known contamination at the nature park), and expansion of the park's education facilities by the Elizabeth River Project.

Paddlers explore Paradise Creek Nature Park's 11-acre wetland, restored by the Port of Virginia as part of a model focus on this creek.

Paradise Creek Grades

Parameter	Description	2014	2020	2020 10Y Trends
Bacteria (recreation)	Human contact criteria for enterococcus.	B	D	
Bacteria (shellfish)	Fecal coliform levels in river water.	-	-	
Bottom Health	Abundance and diversity of river bottom life.	-	-	
Fish Cancer	Cancer and precancerous liver lesions in mummichogs.	-	-	
Clarity	Depth of sunlight penetration.	-	-	
Contaminants	Levels of polycyclic hydrocarbons (PAH) in sediment.	-	-	
Dissolved Oxygen	Amount of oxygen in the water. Important for marine life.	C	B	
Phosphorus	In excess can lead to fish kills and algae blooms.	F	D	Improving
Nitrogen	In excess can lead to fish kills and algae blooms.	D	D	
Chlorophyll	Algae known as Phytoplankton are vital for river production.	B	B	
TBT	Concentration of tributyltin in the water. Highly toxic.	-	-	
Overall Grade		**D**	**C**	

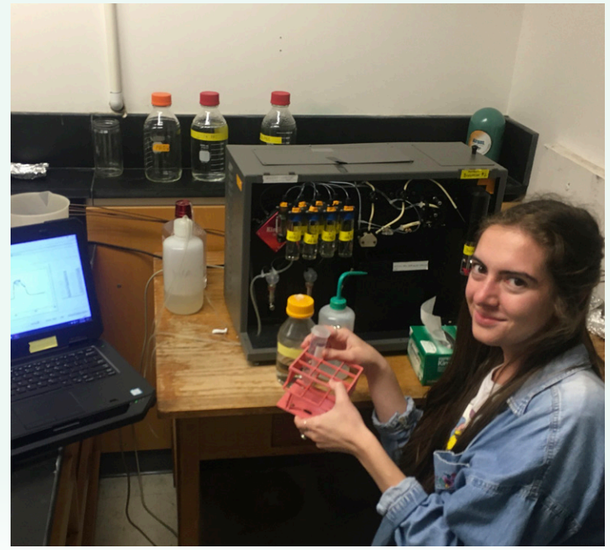
Give her an oyster and 7 minutes

She can say if there's a possible PAH trouble spot

In the past, identifying river hotspots for contamination with PAH—associated with cancer in fish—was a long, arduous and expensive task. Now Kristen Prossner, a Ph.D. student at VIMS, has developed a way to target areas of concern for the contaminant in just 7 minutes, using oysters.

Using biosensor technology, Prossner has shown that the fluid around the oyster mantle ("oyster liquor") can be analyzed for PAHs in a few minutes to predict the tissue concentrations in the whole animal, a task that traditionally takes weeks. She says the novel method should prove an economical way to "help us target areas of concern where remediation should continue," while also tracking the recovery of remediated sites.

Her recent work confirms previously identified PAH hotspots on the Southern Branch, in the vicinity of sites known as Money Point III and Republic Creosote, but also flags potential problems at the mouth of the Western Branch and Eastern Branch of the Elizabeth (see map). Funder: NIEHS-SRP grant RO1ES024245.



Kristen Prossner measures oysters for PAH contamination.

Take sample of oyster mantle fluid. (i.e. oyster liquor)

Mix sample with mouse antibody

Run mixture on biosensor

This will determine PAH concentration in the oyster by how much antibody binds in sample.

“Lost Branch” is now rediscovered; recovery begins.

The Eastern Branch has been the top focus area of the Elizabeth River Project since 2014 when it launched a community-wide plan for the rediscovering the “Lost Branch,” suffering a lack of public awareness.

Milestone gain - In a big sign that both awareness and ecosystem health are improving for the Lost Branch, Virginia Gov. Ralph Northam joined area dignitaries on Nov. 19, 2020 to declare the Eastern Branch of the Elizabeth the second Virginia tributary to achieve the coveted status of fully restored for oyster habitat. The Virginia Marine Resources Commission in 2020 added 21 acres of oyster reef, while Elizabeth River Project and other partners including eight River Star Homes created additional oyster habitat for a total of 24 acres restored. That’s just part of intensive efforts of Elizabeth River Project to carry out the 2014 strategy in partnership with three cities (Chesapeake, Norfolk, Virginia Beach), state and federal governments, River Star Homes, schools, businesses, Wetlands Watch, Friends of Indian River, Norfolk State University. and the University of Virginia, to name a few. Projects range from a pioneer effort by Elizabeth River Project to retrofit ditches to reduce pollution, to new parks created by Chesapeake and Virginia Beach and Norfolk’s $112 million HUD funded project to transform the Eastern Branch shore along Campostella.

In turn, the overall score for the Eastern Branch improves from D to C, with the Eastern Branch showing the best water clarity on the Elizabeth. The branch’s two largest tributaries, Indian River in Chesapeake and Broad Creek in Norfolk, both move off the river’s failing list (note, in part the better grades come from a change in criteria to adopt the more liberal scoring of EcoCheck, used bay-wide).

Top challenge – the goo must go! Despite gains in other areas, this scorecard now flags the Eastern Branch for worst on the river for bottom health (F, severely degraded, with elevated cancer in fish). Additionally, both Indian River and Broad Creek on the Eastern Branch need continued focus for water quality.

“Oyster castles” help stabilize an Eastern Branch shore while providing habitat.

Eastern Branch: C

Improved from D

Eastern Branch Grades

Parameter	Description	2014		2020		2020 10Y Trends
Bacteria (recreation)	Human contact criteria for enterococcus.	B		B		
Bacteria (shellfish)	Fecal coliform levels in river water.		-		-	
Bottom Health	Abundance and diversity of river bottom life.	D		F		
Fish Cancer	Cancer and precancerous liver lesions in mummichogs.	-		F		
Clarity	Depth of sunlight penetration.	-		C		
Contaminants	Levels of polycyclic hydrocarbons (PAH) in sediment.	D		D		Improving
Dissolved Oxygen	Amount of oxygen in the water. Important for marine life.	B		B		
Phosphorus	In excess can lead to fish kills and algae blooms.	D		D		
Nitrogen	In excess can lead to fish kills and algae blooms.	B		C		
Chlorophyll	Algae known as Phytoplankton are vital for river production.	C		C		
TBT	Concentration of tributyltin in the water. Highly toxic.	-		B		Improving
Overall Grade		**D**		**C**		

Eastern Branch C

Broad Creek: D

Improved from F

Norfolk creek needs continued focus for bacteria.

Vast, aging parking lots drain in the vicinity of this creek, along with some of Norfolk's older industrial areas and neighborhoods. Elizabeth River Project, the City of Norfolk, Wetlands Watch, University of Virginia and other partners have focused intensively for the last six years on improving the health of Broad Creek. It appears to be responding, but slowly, with several projects still in the works.

The City of Norfolk completed a major retrofit of Lake Taylor and Elizabeth River Project worked with area businesses and homes to retrofit ditches and restore living shorelines to reduce runoff pollution. Nitrogen parameters are improving but phosphorous still fails. HRSD recently conducted a study to better understand failing bacteria levels in the creek.

Broad Creek Grades

Parameter	Description	2014	2020	2020 10Y Trends
Bacteria (recreation)	Human contact criteria for enterococcus.	F	F	
Bacteria (shellfish)	Fecal coliform levels in river water.	-	-	
Bottom Health	Abundance and diversity of river bottom life.	-	-	
Fish Cancer	Cancer and precancerous liver lesions in mummichogs.	-	-	
Clarity	Depth of sunlight penetration.	-	-	
Contaminants	Levels of polycyclic hydrocarbons (PAH) in sediment.	-	-	
Dissolved Oxygen	Amount of oxygen in the water. Important for marine life.	F	C	
Phosphorus	In excess can lead to fish kills and algae blooms.	D	F	
Nitrogen	In excess can lead to fish kills and algae blooms.	D	D	Improving
Chlorophyll	Algae known as Phytoplankton are vital for river production.	D	D	
TBT	Concentration of tributyltin in the water. Highly toxic.	-	-	
Overall Grade		**F**	**D**	

What you can do: Visit RiverStarHomes.org to commit to 7 simple steps, from reducing excess fertilizers to picking up after pets. Free signature yard flag; rain barrel assistance.

Bald Eagle by David Gibson

Feb 2018 *July 2018* *June 2020*

Before, during, and after creating a "living shoreline" to stem erosion and restore habitat on Indian River. RiverCrest condos hosted the effort with Friends of Indian River, Elizabeth River Project, partners, and volunteers. Photos by Rogard Ross.

Indian River: C

Improved from D

Chesapeake focus area improves, thanks to many

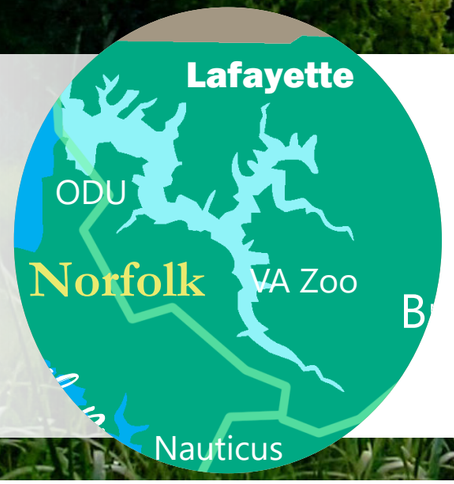
Indian River is this lucky: It has its own non-profit advocacy group, Friends of Indian River. Elizabeth River Project has worked hand-in-hand with the Friends since 2014 with the goal to erase Indian River's failing grade in the last scorecard. Hard-won success: Indian River now merits a C instead of an F, with special thanks to multiple projects with federal, state, and City of Chesapeake help as well as federal funding from the Chesapeake Bay Program's Small Watershed Grants program.

The little river shows improving trends for nitrogen levels in particular. Contiguous homeowners are helping out as River Star Homes, including helping restore oyster habitat, and they report bald eagles and dolphins visiting regularly.

Of concern: Bacteria. Indian River gets a failing grade for the bacteria enterococcus as compared to health standards – in fact the worst score on the Elizabeth. Special thanks to HRSD for bacteria source tracking which may help identify potential contributing factors.

Indian River Grades

Parameter	Description	2014	2020	2020 10Y Trends
Bacteria (recreation)	Human contact criteria for enterococcus.	F	F	
Bacteria (shellfish)	Fecal coliform levels in river water.	-	-	
Bottom Health	Abundance and diversity of river bottom life.	-	-	
Fish Cancer	Cancer and precancerous liver lesions in mummichogs.	-	-	
Clarity	Depth of sunlight penetration.	-	-	
Contaminants	Levels of polycyclic hydrocarbons (PAH) in sediment.	-	-	
Dissolved Oxygen	Amount of oxygen in the water. Important for marine life.	B	A	
Phosphorus	In excess can lead to fish kills and algae blooms.	F	F	
Nitrogen	In excess can lead to fish kills and algae blooms.	F	C	Improving
Chlorophyll	Algae known as Phytoplankton are vital for river production.	D	C	
TBT	Concentration of tributyltin in the water. Highly toxic.	-	-	
Overall Grade		**F**	**C**	



Lafayette River: C

Also a C in 2014

"Norway Place in Summer" c. 2020 W. Reed

Lafayette branch holds steady, thanks to prior gains.

The largely residential Lafayette River, considered the northern branch of the Elizabeth River ecosystem, has benefitted from a special focus by multiple partners since Elizabeth River Project and Chesapeake Bay Foundation introduced a community-wide plan for the Lafayette in 2011, with Lafayette Wetlands Partnership leading citizen engagement.

Removed from the state list of impaired waters for bacteria in 2016 and declared the first Virginia tributary to the bay to be fully restored for oyster habitat, in 2018, the Lafayette continues to score well for water quality parameters, overall earning a C, as in 2014. For the key measurement, dissolved oxygen, the Lafayette gets an A. Bacteria levels only occasionally exceed those set by the state for recreation. Trawl surveys have documented 25 species of fish on the Lafeyette's more than 80 acres of restored oyster reefs, including sea horses.

Of concern: Clarity. During most of the summer months, the Lafayette is a milky brown, which could be the result of high densities of algae and suspended sediments. This issue needs further focus, along with degrading bacteria trends relating to shellfish harvest criteria.

Lafayette Branch Grades

Parameter	Description	2014	2020	2020 10Y Trends
Bacteria (recreation)	Human contact criteria for enterococcus.	B	B	
Bacteria (shellfish)	Fecal coliform levels in river water.	B-D	C	Degrading
Bottom Health	Abundance and diversity of river bottom life.	C	D	
Fish Cancer	Cancer and precancerous liver lesions in mummichogs.	-	C	
Clarity	Depth of sunlight penetration.	-	D	
Contaminants	Levels of polycyclic hydrocarbons (PAH) in sediment.	B	B	
Dissolved Oxygen	Amount of oxygen in the water. Important for marine life.	A	A	
Phosphorus	In excess can lead to fish kills and algae blooms.	D	D	
Nitrogen	In excess can lead to fish kills and algae blooms.	B	B	
Chlorophyll	Algae known as Phytoplankton are vital for river production.	C	C	
TBT	Concentration of tributyltin in the water. Highly toxic.	-	A	Improving
Overall Grade		**C**	**C**	

Night heron dominates Lafayette birds.

Population increases rapidly compared to others.

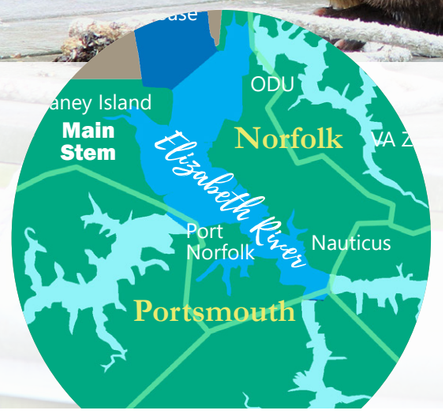
Connie Darden, wife of the late Gov. Colgate Darden, was one of the Elizabeth's earliest ecologists. When she recorded a pair of yellow-crowned night herons nesting near her home, at Flicker Point on the Lafayette branch of the Elizabeth, it was 1947 and they were the first such pair reported in the Mid-Atlantic.

Now the small herons, exotic looking with reddish eyes, bandit-like mask and white plumes in breeding season, are increasing rapidly on the Lafayette, reports Bryan Watts, director of the Center for Conservation Biology at William & Mary. He and Marian Watts observed a proliferation of the birds across lower Tidewater in a 2018 survey, including 138 pairs on the Lafayette and 129 on the larger Elizabeth (total of 267, the most anywhere in Tidewater).

Less encouraging, the Watts found that colonies of great egrets and green herons were declining on the Elizabeth, probably related to loss of habitat. The great egrets prefer 100-year-old stands of loblolly pines. Regarding other bird species, in separate reports, the biology center has recorded returning osprey and peregrine falcon populations along the Elizabeth River system. And bird blogger David Gibson routinely reports some of the earliest and rarest migratory bird sightings in the region at Elizabeth River Project restoration sites, including most recently an Ash-throated Flycatcher in fall 2020 at Money Point in Chesapeake.

Yellow-crowned night herons are the most prevalent heron on the Lafayette. Photo: Bryan Watts

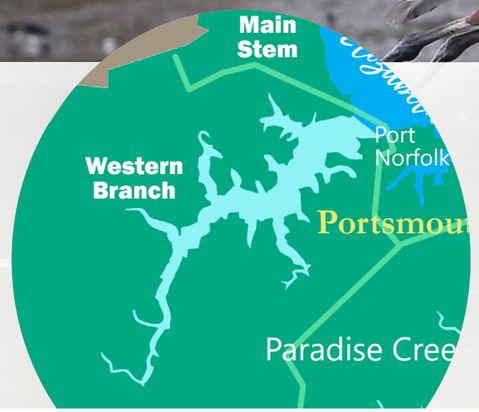
River otters frequent Nauticus docks on the Main Stem.



Main Stem: B

Improved from C

Great Blue Heron by David Gibson, Elizabeth River Bird Blog.



Western Branch: C

Steady from C in 2014

Sediment cleanup adds to continued improvement.

The Main Stem once again earns the highest grade when compared to the other Elizabeth River branches. This wide portion of the river flushes steadily with waters from the James River and Chesapeake Bay and typically exhibits the best health. Nonetheless, the score for the Main Stem further improved in this report, from a C to a B, with improving long-term trends as well.

More goo goes - Reductions in fish cancer and sediment contamination reflect completion of a sediment remediation project by Columbia Gas/NiSource in Crawford Bay, Portsmouth; helping carry out the top priority in the Elizabeth River Project's Watershed Action Plan for the Elizabeth River – "the goo must go." While bacteria levels showed a slightly degrading trend for the Main Stem, it still qualifies for an A for bacteria levels associated with harvest of shellfish.

Main Stem Grades

Parameter	Description	2014	2020	2020 10Y Trends
Bacteria (recreation)	Human contact criteria for enterococcus.	A	B	
Bacteria (shellfish)	Fecal coliform levels in river water.	B-D	A	Degrading
Bottom Health	Abundance and diversity of river bottom life.	C	C	
Fish Cancer	Cancer and precancerous liver lesions in mummichogs.	-	C	Improving
Clarity	Depth of sunlight penetration.	-	C	
Contaminants	Levels of polycyclic hydrocarbons (PAH) in sediment.	D	C	Improving
Dissolved Oxygen	Amount of oxygen in the water. Important for marine life.	B	A	
Phosphorus	In excess can lead to fish kills and algae blooms.	C	C	
Nitrogen	In excess can lead to fish kills and algae blooms.	B	C	
Chlorophyll	Algae known as Phytoplankton are vital for river production.	C	C	
TBT	Concentration of tributyltin in the water. Highly toxic.	-	B	Improving
Overall Grade		**C**	**B**	

Improving trends, healthy dissolved oxygen levels

The finger of the Elizabeth that heads west, through Portsmouth and Chesapeake, receives a C again in this scorecard, but with the most positive score on the river for the key indicator, dissolved oxygen. And while signs of sediment contamination have been found in the Western Branch, monitoring for the 2020 report did not find any signs of cancer in mummichog fish.

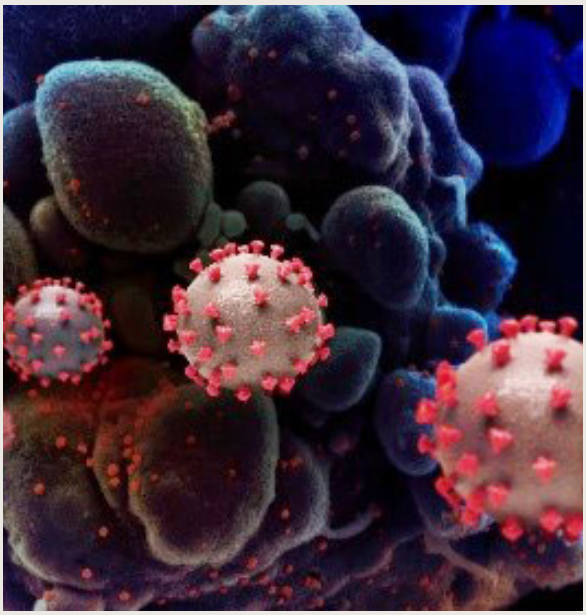
Three parameters did receive D's: bottom health, clarity, and phosphorus. Elevated nutrients and muddy water are likely related to above average rainfall and increasing dry weather flooding.

You can help. Sign up for the free program, River Star Homes, www.elizabethriver.org.

Western Branch Grades

Parameter	Description	2014	2020	2020 10Y Trends
Bacteria (recreation)	Human contact criteria for enterococcus.	B	C	
Bacteria (shellfish)	Fecal coliform levels in river water.	C	B	Degrading
Bottom Health	Abundance and diversity of river bottom life.	C	D	
Fish Cancer	Cancer and precancerous liver lesions in mummichogs.	-	A	
Clarity	Depth of sunlight penetration.	-	D	
Contaminants	Levels of polycyclic hydrocarbons (PAH) in sediment.	-	C	
Dissolved Oxygen	Amount of oxygen in the water. Important for marine life.	A	A	Improving
Phosphorus	In excess can lead to fish kills and algae blooms.	D	D	
Nitrogen	In excess can lead to fish kills and algae blooms.	B	B	
Chlorophyll	Algae known as Phytoplankton are vital for river production.	C	C	
TBT	Concentration of tributyltin in the water. Highly toxic.	-	A	Improving
Overall Grade		**C**	**C**	

2020: Year of the pandemic. Could people catch COVID-19 from the Elizabeth River?



When people are infected with COVID-19, their stools can indicate the presence of genetic material related to the virus. Since the regional wastewater authority, HRSD, discharges treated sewage to the Elizabeth and other waterways, what's the likelihood that contact with this treated water in the Elizabeth could have exposed you to the disease that dominated international news for most of 2020?

Here's the answer from Raul Gonzalez, who manages HRSD programs analyzing its wastewater for molecular pathogens. HRSD added COVID-19 monitoring in March 2020.

"Unlikely," Gonzalez says. "There is currently no evidence of infectious SARS-CoV-2 in wastewater. Only fragments of viral genetic material have been detected. All efforts to culture infectious COVID-19 virus directly from wastewater have failed.

"What's more, only a couple of studies could even culture the infectious virus in stool (well before entering the sewer collection system) but these are poorly described. " Nonetheless, HRSD believes its monitoring for the viral genetic material—not a measure of infectivity—may be useful as a predictor of outbreaks, leading clinical infection data by at least a week.

State of the Elizabeth River Steering Committee 2020

Special thanks to the team of scientists and advisors who guided this scorecard.

Name	Affiliation
Mike Unger (Chair)	Virginia Institute of Marine Science
David Koubsky	Elizabeth River Project
Joe Rieger	Elizabeth River Project
KC Filippino	Hampton Roads Planning District Commission
Kristie Britt	Virginia Department of Environmental Quality
Marjorie Mayfield Jackson	Elizabeth River Project
Mary Bennett (coordinator)	Elizabeth River Project
Raul Gonzalez	HRSD
Danny Barker	HRSD
Steve Hummel	Virginia Department of Environmental Quality
Todd Egerton	Virginia Department of Health
Wolfgang Vogelbein	Virginia Institute of Marine Science
Bryan Watts	William & Mary Center for Conservation Biology
Dan Dauer	Old Dominion University
Anthony Rodi	Old Dominion University
Craig Nicol	Virginia Department of Environmental Quality
Grace Saunders	Elizabeth River Project
Kristen Prossner	Virginia Institute of Marine Science
Wick Harlan	Virginia Department of Environmental Quality
Alexandra Fries	University of Maryland Center for Environmental Science

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State of the
Elizabeth River
December 2020 *Scorecard*

Technical Appendix

Special thanks to the State of the Elizabeth River Steering Committee 2020

Elizabeth River Project
Making restoration a reality

VIMS | William & Mary
Virginia Institute of Marine Science

The Elizabeth River Project is a non-profit with the mission to restore the environmental quality of the Elizabeth River through citizen, business and government partnerships.

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Technical appendix

Table of contents

Methodology for grading the scorecard

Branch grades

Grades for individual branches (Main Stem, Lafayette, Eastern, Western, and Southern) were determined by averaging the grades for all parameters measured for the individual branches. The Main Stem, Lafayette and Western Branch averaged 11 parameters, while the Eastern and Southern Branches only averaged 10 parameters as data for bacteria in shellfish was not collected in these two branches. Grades for sub-tributaries (Broad Creek, Indian River, and Paradise Creek) were determined by averaging the grades for recreational bacteria, dissolved oxygen, phosphorus, nitrogen, and chlorophyll as data for the other variables were not collected.

Grading scales vary between some of the parameters and are based on the consensus of partners that collaborated throughout this process. Letter grade percentages are relative to each parameter. The grade scales used for each parameter and the rationale for letter grade derivation is summarized under each parameter section (Pages 5-18).

Each letter grade was first translated into a midpoint number as seen in Tables 1 and 2 and then averaged to determine the overall branch score from 0-5.

Table 1: Multiple threshold scales used throughout the State of the Elizabeth River Report Card.

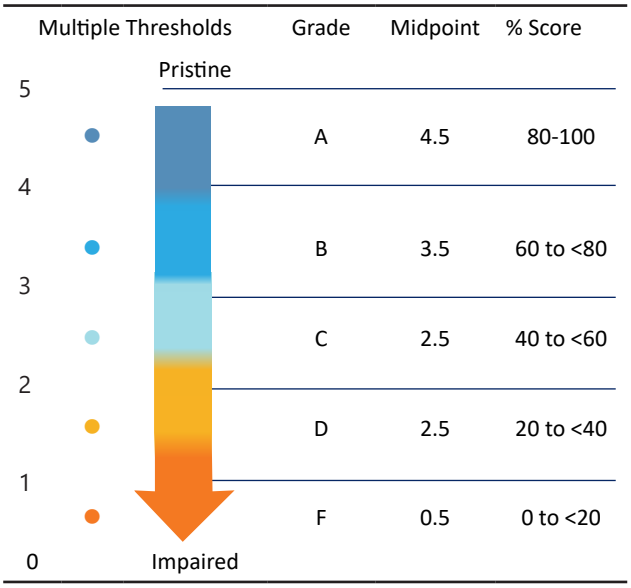


Table 2: Letter grades associated with each parameter measured throughout the Elizabeth River.

Branch of Elizabeth River	Bacteria (Rec)	Bacteria (shellfish)	Bottom Health	Fish Cancer	Clarity	Contaminant	DO	Phosphorus	Nitrogen	Chlorophyll	TBT	Branch Score	Branch Grade
Main Stem	B	A	C	C	C	C	A	C	C	C	B	3.05	B
Lafayette	B	C	D	C	D	B	A	D	B	C	A	2.86	C
Eastern Branch	B	–	F	F	C	D	B	D	C	C	B	2.20	C
Broad Creek	F	–	–	–	–	–	C	F	D	D	–	1.30	D
Indian River	F	–	–	–	–	–	A	F	C	C	–	2.10	C
Southern Branch	D	–	D	F	C	F	B	C	B	B	B	2.30	C
Paradise Creek	D	–	–	–	–	–	B	D	D	B	–	2.30	C
Western Branch	C	B	D	A	D	C	A	D	C	C	A	2.95	C

River-wide grade - C

The overall grade for the Elizabeth River was determined by calculating a weighted average of the five main branches (Mainstem, Eastern, Lafayette, Southern, Western). Weights were determined based on surface area (see page 10, Table 2). To fully represent the river system, water quality data collected in the sub-tributaries were added back into their respective branches. Modified grades and weighted averages for each of the branches are in Tables 3 and 4. Weights were determined by using surface area.

Table 3: Parameter grades for the five main branches of the Elizabeth River.

Branch	Bacteria (Rec)	Bacteria (shellfish)	Bottom Health	Fish Cancer	Clarity	Contaminant	Dissolved Oxygen	Phosphorus	Nitrogen	Chlorophyll	TBT
Main Stem	B	A	C	C	C	C	A	C	C	C	B
Lafayette	B	C	D	C	D	B	A	D	B	C	A
Eastern Branch	F		F	F	C	D	B	D	C	C	B
Southern Branch	D		D	F	C	F	B	D	C	B	B
Western Branch	C	B	D	A	D	C	A	D	B	C	A

Table 4: The Elizabeth River received an overall grade of C.

Name	Average	Average Grade	W	Weighted Average	Overall Grade
Main Stem	3.05	B	0.44	1.35	
Lafayette	2.86	C	0.12	0.35	
Eastern Branch	1.90	D	0.12	0.23	
Southern Branch	2.10	C	0.16	0.34	
Western Branch	2.95	C	0.15	0.44	
			1	2.72	C

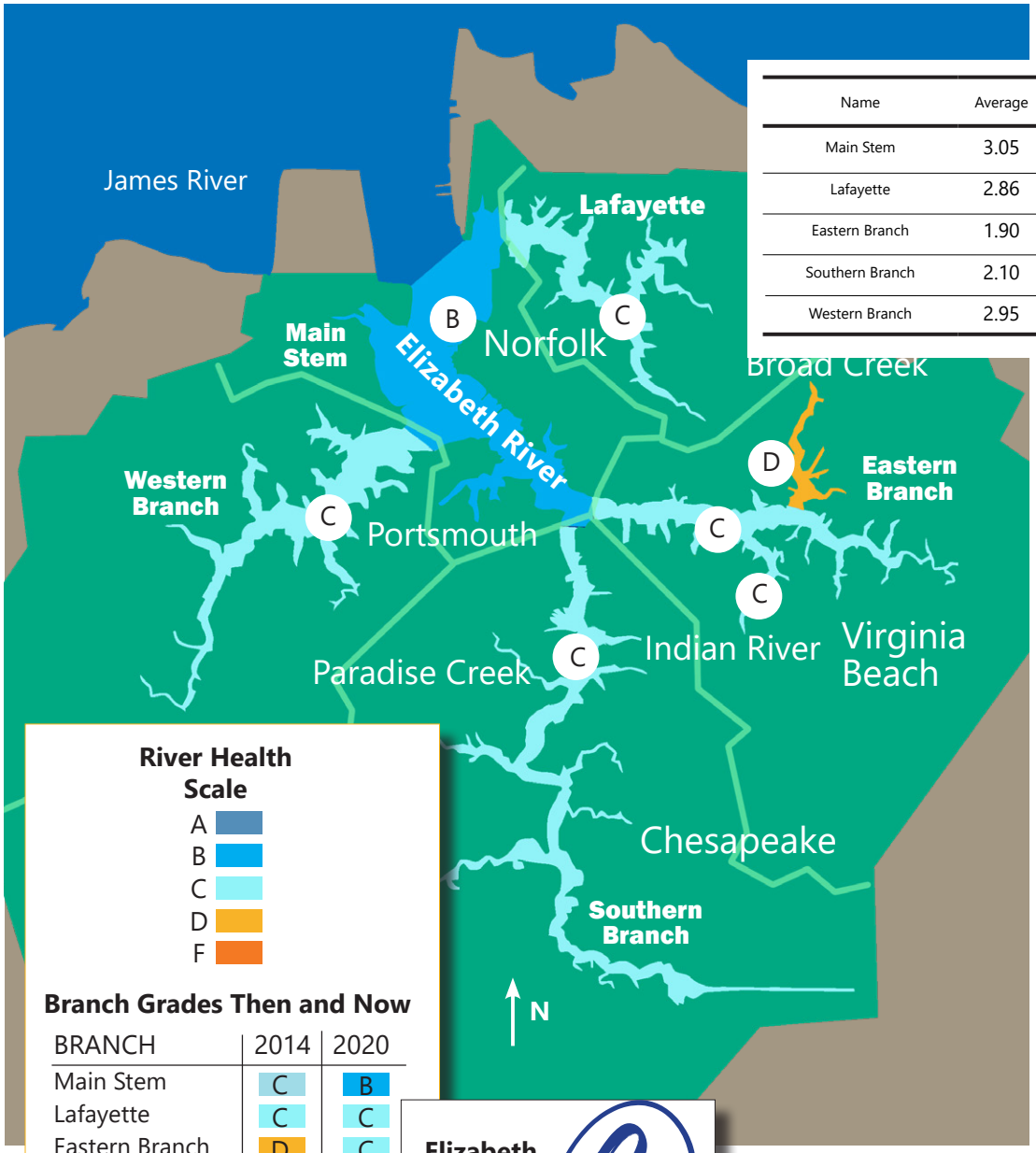


Figure 1: The Elizabeth River is a tidal river that is connected to the Chesapeake Bay. There are five main branches to the Elizabeth River- the Main Stem, the Lafayette River, the Eastern Branch, the Western Branch and the Southern Branch. The river flows through the cities of Norfolk, Portsmouth, Chesapeake, and Virginia Beach. The entire watershed, the area that drains into the river after it rains, is approximately 9,600 acres and is composed of five smaller sub-watersheds.

Fecal coliform bacteria & shellfish sanitation standards

Researchers:

Todd Egerton (Virginia Department of Health) and Steven Hummel (Virginia Department of Environmental Quality)

Virginia Department of Health (VDH)'s Division of Shellfish Safety and Waterborne Hazards Control routine monitoring data were used for the analysis of bacteria in the Elizabeth River as it relates to shellfish sanitation standards. VDH collects water samples and conducts fecal coliform analyses from 13 stations in the Elizabeth River (Figure 1) on a monthly basis as part of its shellfish growing area classification program. VDH and the National Shellfish Sanitation Program (NSSP) calculate the geometric mean and the 90th percentile of the most recent 30 fecal coliform data points to determine the status of the waterbody in its classification. The NSSP criteria for approved growing areas is for a geometric mean of $\leq$ 14 fecal coliform colony forming units (cfu) per 100 mL and an 90th percentile of $\leq$ 31 cfu/100mL.

For this analysis, a modified approach of the UMCES EcoCheck was utilized to calculate scores following the method used by UMCES and GDNR for the Coastal Georgia Report Card (2015). For each station, each sample is compared to the 31 CFU threshold. Samples <31 receive a passing score (100) and a failing score (0) if they exceed 31. These monthly scores (100s and 0s) are averaged for each station for each year (2010-2019) to produce an annual station score. The Station Grade is based on the average of the scores the last 5 years (2015-2019). Segment Grades are based on the average of all stations within the river segment.

Table 5: Grading criteria

Grade	Criteria
A	>90% of samples $\leq$31 cfu
B	80-90% of samples $\leq$31 cfu
C	70-80% of samples $\leq$31 cfu
D	60-70% of samples $\leq$31 cfu
F	<60% of samples $\leq$31 cfu

This scale is based on best professional judgement and is comparable to similar scorecards for other waterbodies.

Letter grades

Stream Name	Samples	Percent	Grade	Date Range
Mainstem	N=6	90.90%	A	2010-2019
Lafayette River	N=5	70.30%	C	2010-2019
Western Branch	N=2	83.10%	B	2010-2019
Entire Elizabeth River	N=13	83.50%	B	2010-2019

Trends were calculated from regression analysis of the fecal coliform data from 2010-2019 using annual averages from each station and segment (using average of all stations within segment). Trends were considered significant if the p-value was less than 0.05. Increasing concentrations of fecal coliforms were considered a declining trend. Significant increases in fecal coliforms (declining trend) were identified in 6/13 stations, with long term declining trends in each segment.

Trend – Bacteria & shellfish sanitation standards

Name	Samples	Date Range	p.value	estimate	Trend	Status
MAIN STEM	60	2010 - 2019	0.0801	8.508	Significant 0.1	Declining
LAFAYETTE	50	2010 - 2019	0.0631	8.506	Significant 0.1	Declining
WESTERN	20	2010 - 2019	0.0548	3.732	Significant 0.1	Declining

River bottom health

Researcher: Dr. Daniel M. Dauer (Old Dominion University)

The status of benthic communities is classified for the Chesapeake Bay Program as follows: (1) values less than or equal to 2 are classified as Severely Degraded; (2) values greater than 2.0 to 2.6 as Degraded; (3) values greater than 2.6 but less than 3.0 as Marginal; and (4) values of 3.0 or more are classified as Meeting Goals or similar to reference conditions. For this report the proposed grading system using the BIBI score is: A: 4.0 – 5.0, B: 3.0 – 3.9, C: 2.6 – 2.9, D: 2.1 – 2.5, F: ≤ 2.0.

Grade	Status	B-IBI Score
A	Meeting Goals	4.0-5.0
B	Meeting Goals	3.0-3.9
C	Marginal	2.6-2.9
D	Degraded	2.1-2.5
F	Severly Degraded	≤ 2.0

Regular sampling of the benthos of the Elizabeth River is presently limited to two fixed-point stations in the Southern Branch (SBE2 and SB5) that have been sampled since 1989. In 2019, the watershed was sampled intensively with 25 random sites sampled in each of the five branches (125 total sites). The 2019 benthic was compared to a previous intensive sampling in 1999 of 25 random sites in each of the branches.

Comparing 1999 data with 2019 data the best benthic community condition was in the Mainstem of the river. The Mainstem had the highest average B-IBI value in both 1999 and 2019; the B-IBI value did not change (B-IBI = 2.8). The area of degraded benthic community condition declined from 52% (1999) to 44% (2019). The Southern Branch was the only stratum to show a significant improvement in benthic community condition compared to the 1999 data. The 1999 average B-IBI value of 2.0 significantly increased to 2.5 in 2019. This B-IBI value is near the marginal category for the Chesapeake Bay of 2.6 – 2.9. In addition, the area of degraded benthic community condition declined from 96% (1999) to 64% (2019). The Lafayette River average B-IBI declined significantly from 2.6 (1999) to 2.1 (2019) and the area of degraded benthic community condition increased from 72% (1999) to 92% (2019). The Eastern Branch average B-IBI declined significantly from 2.3 (1999) to 1.8 (2019) and the area of degraded benthic community condition increased from 80% (1999) to 100% (2019). The Western Branch average B-IBI declined slightly from 2.3 (1999) to 2.2 (2019) and the area of degraded benthic community condition decreased slightly from 84% (1999) to 80% (2019).

In summary, the increased benthic community degradation seen in the 2019 data also occurred outside of the Elizabeth River watershed. Clearly larger scale drivers of ecosystem condition affected the patterns observed in the Elizabeth River watershed comparing 1999 and 2019. Further analyses of large-scale and long-term patterns in water column parameters (e.g. bottom dissolved oxygen, salinity, temperature, suspended solids, and nutrients) are required.

Letter grades

Stream Name	1999			2019		
	B-IBI	Status	Grade	B-IBI	Status	Grade
Mainstem	2.8	Marginal	C	2.8	Marginal	C
Southern	2.0	Severely Degraded	F	2.5	Degraded	D
Lafayette	2.6	Marginal	C	2.1	Degraded	D
Western	2.3	Degraded	D	2.2	Degraded	D
Eastern	2.3	Degraded	D	1.8	Severely Degraded	F
Elizabeth River	2.4	Degraded	D	2.4	Degraded	D

Contaminants on the river bottom

Researchers: Dr. Michael A. Unger (Virginia Institute of Marine Science) and Dave Koubsky (Elizabeth River Project)

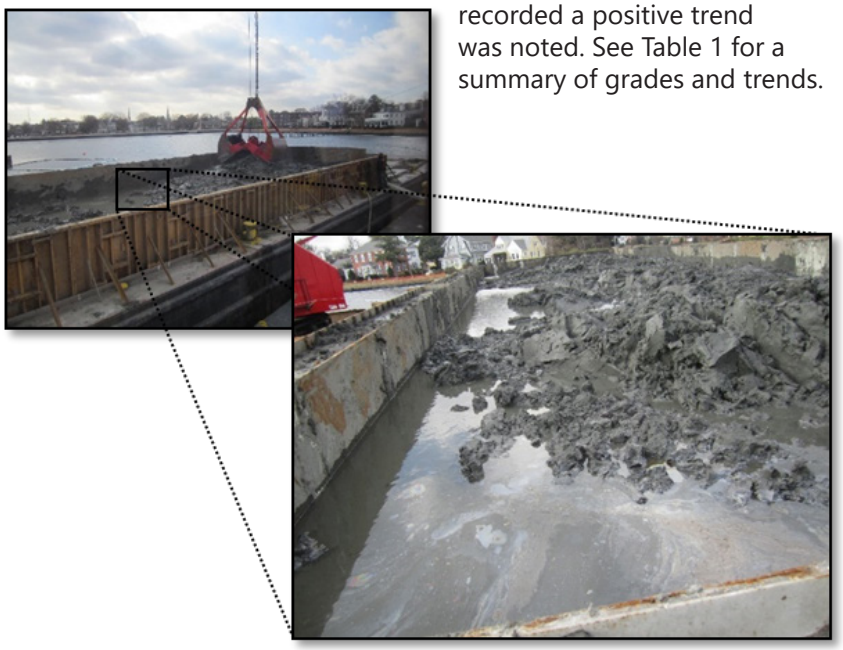
Sediment contamination throughout the river was evaluated for polycyclic aromatic hydrocarbons (PAH) because the river is known to have high levels from defunct wood treatment facilities and urban stormwater runoff. Multiple databases were reviewed and are listed at the end of this section.

Sediment PAH data for the river was evaluated against Sediment Quality Guidelines (SQG) developed by Long et al, 1995 (NOAA EMAP). The SQG is based on toxicity data from numerous field and laboratory studies (Long et al. 1998). The SQG used in the report was the Effects Range Low (ERL) value which was the lowest concentration that produced adverse effects in 10% and the Effects Range Median (ERM) value, a concentration at which 50% of the studies reported harmful effects. The ERL used for total PAHs was 4 parts per million and the ERM value was 45 parts per million (for a total of 19 summed compounds).

Insufficient monitoring data from fixed sediment sampling stations prevented an analysis of a comprehensive trend to establish long-term changes in sediment contamination levels. However, where direct evidence of clean-up leading to reduction in sediment contamination levels was recorded a positive trend was noted. See Table 1 for a summary of grades and trends.

DATA USED FOR EVALUATION
NOAA Query Manager (Version 2.96)
2020 – Peck Iron and Metal Remedial Invest. (SB)
2019 – VIMS Mummichog Study (multiple branches)
2019 – ODU B-IBI Study (EB)
2018 Atlantic Creosote Remedial Investigation Studies
2016 – Swimming Point Remedial Action
2015 to 2019 Money Pont Long-term Monitoring Studies
2012 to 2018 Atlantic Wood Remedial Action Studies
2012 and 2019 VIMS NIEHS Study-Grant RO1ESO20949
2011 USACE Evaluation of Dredged Material Southern Branch of the Elizabeth River
2009 to 2020 DEQ – TRO sampling
2000 ARML VADEQ Monitoring
1999 ARML VADEQ Monitoring
1998 AMRL VADEQ Monitoring
1990 to1998 VA SWCB (KY, MD, NC, TN, VA, WV)

Grade	Criteria
A	Total PAH < 1ppm
B	Total PAH < 4ppm in all samples
C	Total PAH > 4ppm but all samples < 45ppm
D	Total PAH any site > 45 ppm
F	Total PAH more than one site > 45 ppm



Toxic PAH's under removal at Money Point in Chesapeake, VA.

Letter grades

	Parameter	Grade	Trends
MAINSTEM	Contaminants	C	Improving
LAFAYETTE	Contaminants	B	-
EASTERN	Contaminants	D	Improving
WESTERN	Contaminants	C	-
SOUTHERN	Contaminants	F	Improving

Cancer in the mummichog indicator fish

Researchers: Dr. Wolfgang Vogelbein and Dr. Michal Unger (Virginia Institute of Marine Science)

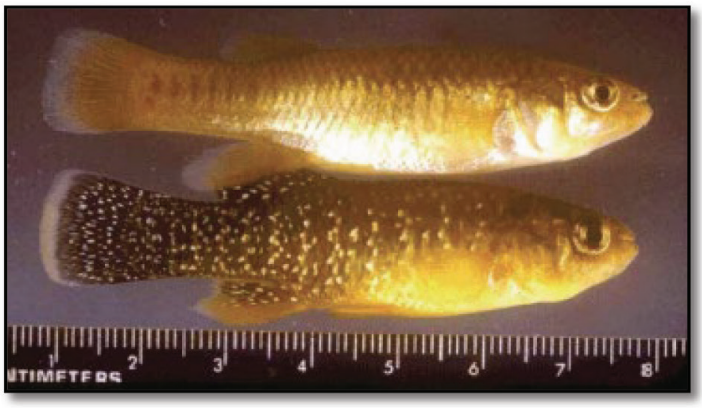
The health of a small non-migratory fish called the mummichog (*Fundulus heteroclitus*) reflects the quality of the habitat where it lives. Mummichog live among the marsh grasses along the edge of the river and because they are non-migratory, they spend their entire lives in a small area. Mummichogs when exposed to elevated concentrations of carcinogens in the river bottom, such as polycyclic aromatic hydrocarbons (PAHs), will develop lesions and cancer in their livers. Because the mummichog reflects the condition of the habitat where it lives, each iteration of the Elizabeth River Watershed Action Plan since the first version in 1996 has adopted the mummichog as the indicator species to track the progress in cleaning up contaminated river bottom.

Grade	Criteria	
	%TAF	%TN
A	≤ 2%	0%
B	≤ 5%	0%
C	>5-10%	≤ 2%
D	variable but up to 25%	≤5%
F	variable but > 10%	> 5%

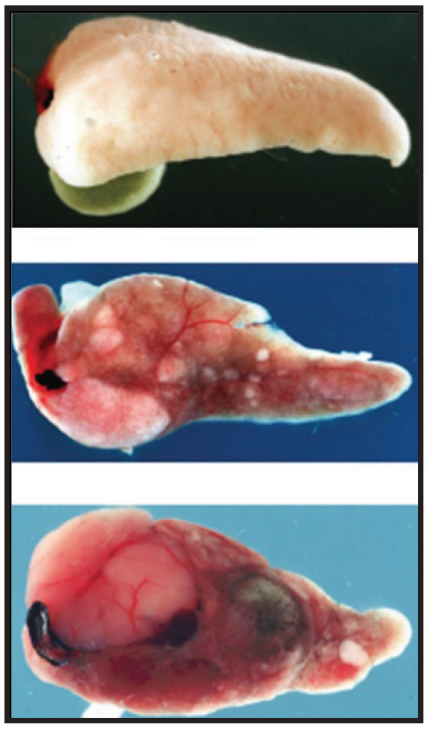
Fish collections for the 2020 Scorecard: Approximately 60 adult mummichogs, *Fundulus heteroclitus*, were collected within the Elizabeth River system at each of 14 Study Sites (~840 fish total). Fish were collected during the period from 10 Oct through 7 Nov. 2018 necropsied and livers were stored in fixative to expedite completion of ER Report Card by the summer of 2020. The 840 mummichog livers were processed for routine paraffin histology by Dr. Vogelbein and prevalence of fish with precancerous lesions (Hepatic Altered Foci; TAF) and liver cancers (Neoplasms; TN) were recorded.

Letter grades

Stream Name	Parameter	# Sites	Total Samples	%TAF	%TN	Grade	Date Range
MAINSTEM	Fish Cancer	1	60	6.80%	1.70%	C	2018-10-10 - 2018-11-07
LAFAYETTE	Fish Cancer	1	60	3.30%	1.70%	C	2018-10-10 - 2018-11-07
EASTERN	Fish Cancer	1	60	46%	11.90%	F	2018-10-10 - 2018-11-07
WESTERN	Fish Cancer	1	60	0%	0%	A	2018-10-10 - 2018-11-07
SOUTHERN	Fish Cancer	10	600	53%	6.80%	F	2018-10-10 - 2018-11-07



Mummichog and comparison of healthy liver samples to coanerous and precancerous liver samples.

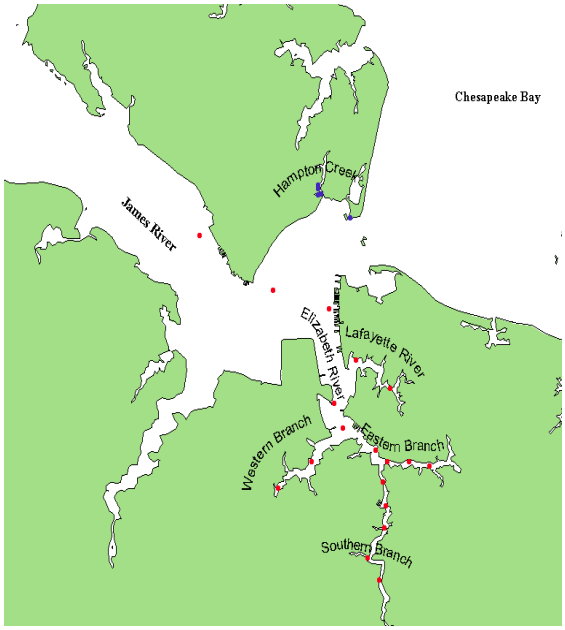


Tributyltin (TBT)

Researchers: Dr. Michal Unger (Virginia Institute of Marine Science)

Tributyltin (TBT): Tributyltin is a biocide additive to antifoulant paints that was used on the bottom of boats and ships. TBT has been shown to be highly toxic to marine organisms at very low concentrations (ng/L) and this concern led to regulatory action on the state, federal, and international level to reduce its input to the marine environment. Regulations in the 1980s restricted its use and TBT was finally banned by the International Maritime Organization (IMO), an agency of the United Nations, in the mid 2000s. Monitoring in the Elizabeth River from 1999-2006 showed that regulations were working to reduce TBT in the Elizabeth River but recent studies have shown that TBT was increasing again in some countries due to illegal use. TBT monitoring was initiated in 2019-2020 to monitor the current conditions in the Elizabeth River to assess the long-term effectiveness of the TBT regulations.

Grade	Criteria
A	Concentrations not detected at 1 ng/L in any of the samples
B	Concentrations at or >1 ng/L in some samples but average < 1 pptr
C	Average concentrations > 1 ng/L but less than 2 ng/L
D	Average concentrations > 2 ng/L but less than 10 ng/L
F	Average concentrations > 10 ng/L or multiple observations > 20 ng/L



Tributyltin (TBT) Water Column Monitoring in 2019-2020:

VIMS was awarded funding via a VA State Initiative to conduct TBT monitoring in the Elizabeth River in support of the Elizabeth River Project's development of an Elizabeth River Score card in 2020. As part of this effort, Dr. Unger's group collected and analyzed water samples for TBT to assess the current trends and compare the results to previous monitoring efforts. Samples were collected in the Elizabeth River semi-monthly (August 2019 – September 2020) from 16 stations used in a previous VADEQ monitoring program (Unger, 2007). This allowed a direct comparison to previous monitoring results from 1999-2006 in the Elizabeth River watershed. Some delays in the sampling and analyses occurred due to COVID-19 shutdowns but samples from August 2019 through July 2020 have been analyzed. The results show that TBT concentrations are below 1 ng/L in the Lafayette and Western Branches. The Main Stem, Eastern, and Southern branches detected low levels of TBT. All branches showed significant reduction in TBT in the Hampton Roads region from previous monitoring. Results demonstrate that regulations have been successful at reducing TBT inputs to the region and that TBT is consistently below the level of concern and the Elizabeth River receives an "A" or "B" grade throughout the watershed. This is a great success story for the aquatic health of the Elizabeth River.

Letter grades

	Parameter	# Sites	Concentration	Grade	Date Range
MAINSTEM	TBT	4	Detected	B	August 2019 – September 2020
LAFAYETTE	TBT	2	Not Detected	A	August 2019 – September 2020
EASTERN	TBT	3	Detected	B	August 2019 – September 2020
WESTERN	TBT	2	Not Detected	A	August 2019 – September 2020
SOUTHERN	TBT	5	Detected	B	August 2019 – September 2020

Water quality analysis

(Clarity, Nitrogen, Phosphorous, Chlorophyll-*a*, Bacteria compared to Recreational Health Standards, Dissolved Oxygen)

Researcher: Steven Hummel (Virginia Department of Environmental Quality)

Summary of approach

Letter grades were calculated for each parameter and monitoring station using 5 years of data collected 2015 through 2019. If a branch or tributary contained more than one monitoring station those station grades were averaged together. Grading scales vary between some of the parameters and are based on the consensus of partners that collaborated throughout this process. Letter grade percentages are relative to each parameter. The grade scales used for each parameter and the rationale for letter grade derivation is summarized under each parameter section. Letter grade percentages were calculated by using either the percent violations method, or mean score method. Scoring thresholds were based on tables provided in EcoCheck 2011 protocol. Water Clarity for example scores each sample 1-5 following thresholds in (**Table 1)** and averages scores for each station. Recreational Bacteria was calculated differently, using the 104 cfu threshold value as in the equations below.

$$Percent\ Violations = \frac{\sum Exceedances\ of\ threshold\ value}{\sum Samples} \times 100$$

$$Percent\ Score = \frac{\bar{x}\ score}{Maximum\ possible\ score} \times 100$$

Table 1 *Example of thresholds for calculating scores for water clarity based on secchi disc depth readings and salnity regime. This table was taken directly from EcoCheck 2011 Table 7.1*

Table 7.1. Multiple thresholds based on salinity regime for water clarity calculations.

Score	Tidal Fresh	Oligohaline	Mesohaline	Polyhaline
5	≥1.3	≥0.9	≥1.8	≥2.1
4	≥0.9–<1.3	≥0.7–<0.9	≥1.6–<1.8	≥2.0–<2.1
3	≥0.6–<0.9	≥0.5–<0.7	≥1.0–<1.6	≥1.1–<2.0
2	≥0.4–<0.6	≥0.3–<0.5	≥0.6–<1.0	≥0.8–<1.1
1	≥0.2–<0.4	≥0.2–<0.3	≥0.3–<0.6	≥0.5–<0.8
0	<0.2	<0.2	<0.3	<0.5

Weighted grades

To account for the size differences of each branch, an overall weighted grade was developed using both surface area and volume (See equation below and Table 1). Weighted grades are only included as a comparison for the 5 main branches. Samples from Indian River and Paradise Creek were merged with the Eastern Branch and Paradise Creek was merged with the Southern Branch. Larger branches carry more weight than smaller branches. The Mainstem Elizabeth River accounts for >68% of the total water by volume and >42% of the surface area.

$$Weighted\ by\ volume = \sum_{all\ streams} \frac{(Letter\ Grade\ percentage\ stream_i) * (Volume\ of\ stream_i)}{100}$$

Table 2 *the volume and surface area for each major branch of the Elizabeth River watershed.*

Branch	Volume m^3	Volume %	Surface Area m^2	Surface Area %
Mainstem	135,831,272	65.85	20,326,587	42.83
Lafayette River	9,418,585	4.57	6,180,999	13.02
Eastern Branch	11,723,010	5.68	5,890,000	12.41
Southern Branch	37,409,865	18.14	8,870,308	18.69
Western Branch	11,902,230	5.77	6,193,352	13.05

Trend analysis

Linear regression was used to predict outcome variable *Y* (Letter Grade percent) values using the input predictor variable *X (Year)*. Models were created for each parameter and monitoring station using 10 years of data from 2010-2019. If a branch or tributary contained more than one monitoring station, those station grades were averaged together so that each year contained one letter grade percentage. Consistently increasing positive slopes over time (i.e. higher grade percentages each year) can generally indicate an improvement in water quality. Positive slopes with significance at $p<0.05$ were labeled as "Improving" and $p<0.1$ as "Possibly Improving". Likewise negative slopes (i.e. decreasing grade percentages each year) with significance resulted in "Declining" or "Possibly Declining" determinations.

β_1 intercept
β_2 slope
ϵ *Error*

$$Y = \beta 1 + \beta 2X + \epsilon$$

Salinity

Score determinations for Nitrogen, Phosphorus, Chlorophyll-*a*, and Water Clarity parameters account for water salinity during the analysis. Each monitoring station was assigned a fixed salinity regime based on Chesapeake Bay Program designated salinity segments Table 3 and figure 1. It's important to note that the DEQ stations and Chesapeake Bay Program stations provided in Table 3 are essentially the exact same station with different catalogue names (e.g. Western Branch 2-WBE002.11 is WBE1). Paradise Creek, Indian River, and Broad Creek stations are only monitored through other DEQ programs and therefore do not have matching Chesapeake Bay Program codes. For completeness, a 5 year average salinity was calculated for smaller tributaries and found to produce a salinity regime (i.e. Mesohaline) consistent with Chesapeake Bay Program salinity regime polygons. Mainstem Elizabeth River is the only stream segment with the Polyhaline salinity regime.

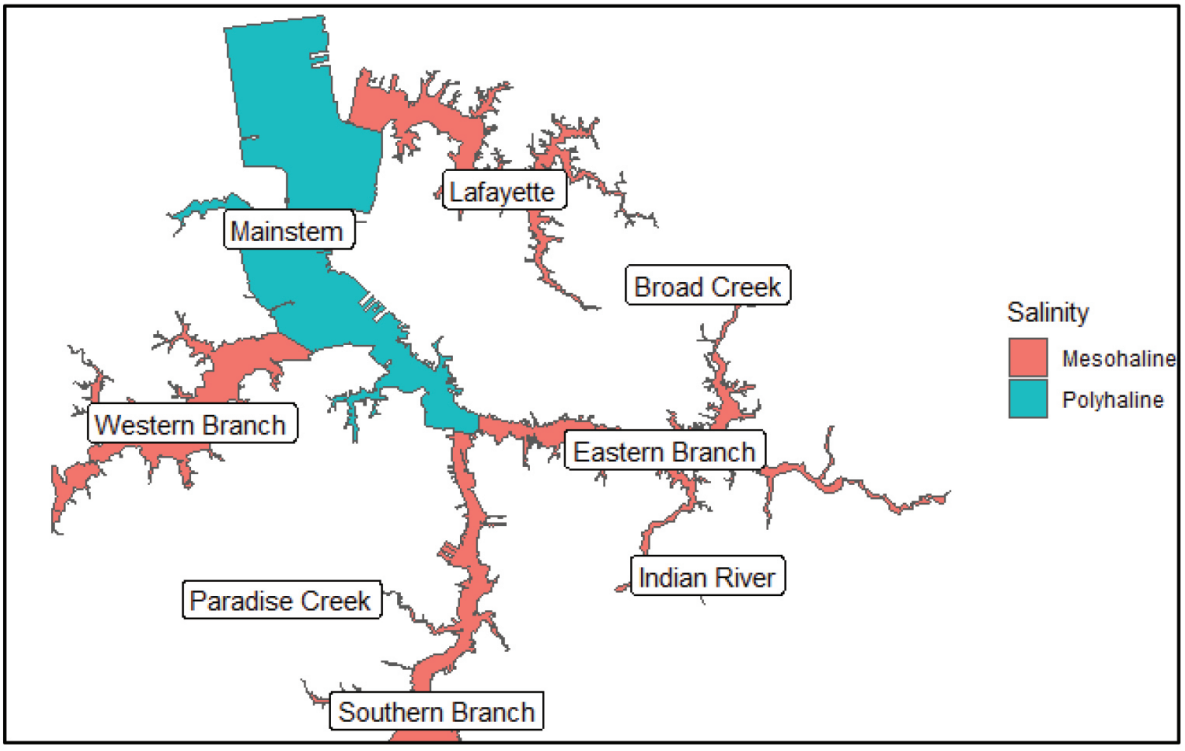
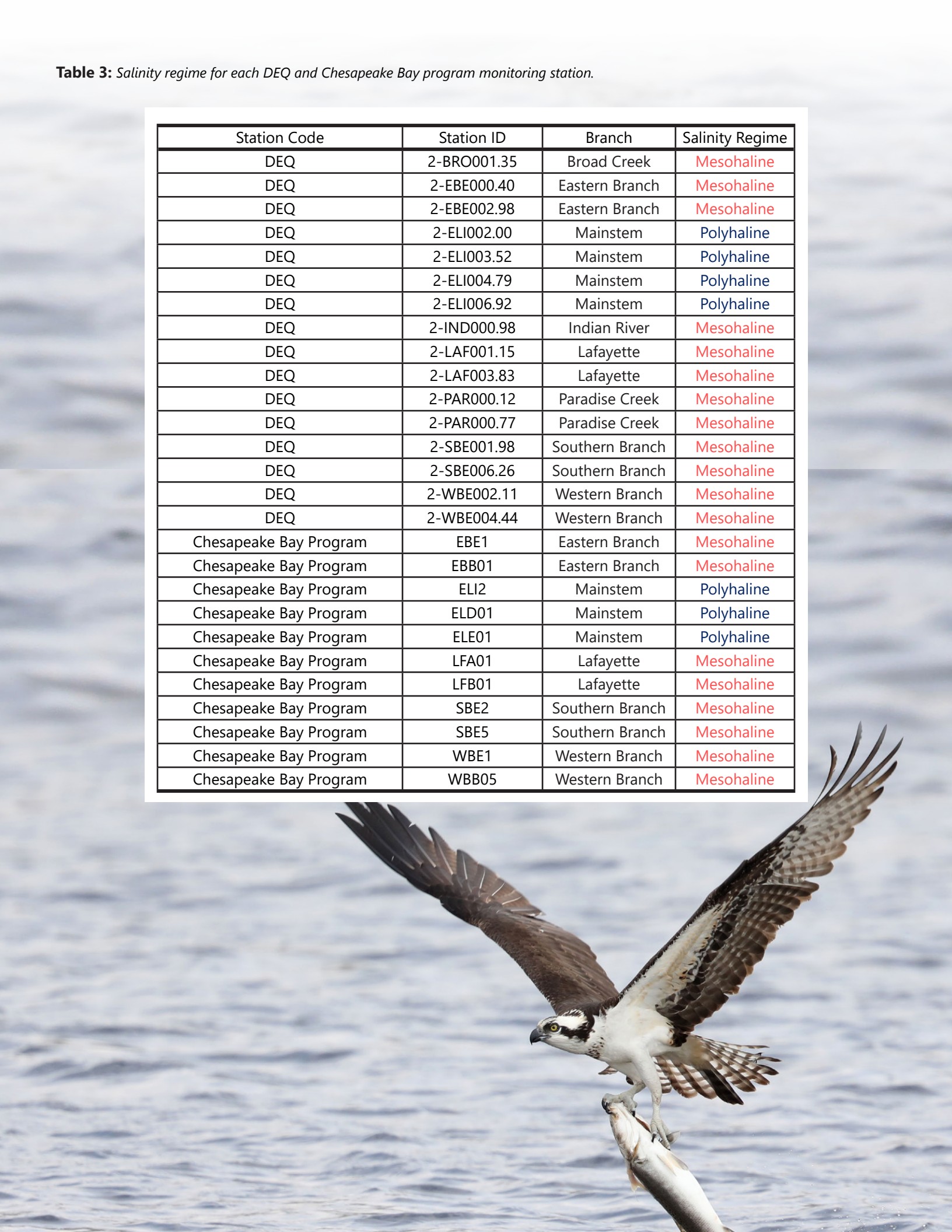


Figure 1: *The Mainstem of the Elizabeth River is classified by the Polyhaline salinity regime. All other branches fall into the Mesohaline regime.*

Table 3: *Salinity regime for each DEQ and Chesapeake Bay program monitoring station.*

Station Code	Station ID	Branch	Salinity Regime
DEQ	2-BRO001.35	Broad Creek	Mesohaline
DEQ	2-EBE000.40	Eastern Branch	Mesohaline
DEQ	2-EBE002.98	Eastern Branch	Mesohaline
DEQ	2-ELI002.00	Mainstem	Polyhaline
DEQ	2-ELI003.52	Mainstem	Polyhaline
DEQ	2-ELI004.79	Mainstem	Polyhaline
DEQ	2-ELI006.92	Mainstem	Polyhaline
DEQ	2-IND000.98	Indian River	Mesohaline
DEQ	2-LAF001.15	Lafayette	Mesohaline
DEQ	2-LAF003.83	Lafayette	Mesohaline
DEQ	2-PAR000.12	Paradise Creek	Mesohaline
DEQ	2-PAR000.77	Paradise Creek	Mesohaline
DEQ	2-SBE001.98	Southern Branch	Mesohaline
DEQ	2-SBE006.26	Southern Branch	Mesohaline
DEQ	2-WBE002.11	Western Branch	Mesohaline
DEQ	2-WBE004.44	Western Branch	Mesohaline
Chesapeake Bay Program	EBE1	Eastern Branch	Mesohaline
Chesapeake Bay Program	EBB01	Eastern Branch	Mesohaline
Chesapeake Bay Program	ELI2	Mainstem	Polyhaline
Chesapeake Bay Program	ELD01	Mainstem	Polyhaline
Chesapeake Bay Program	ELE01	Mainstem	Polyhaline
Chesapeake Bay Program	LFA01	Lafayette	Mesohaline
Chesapeake Bay Program	LFB01	Lafayette	Mesohaline
Chesapeake Bay Program	SBE2	Southern Branch	Mesohaline
Chesapeake Bay Program	SBE5	Southern Branch	Mesohaline
Chesapeake Bay Program	WBE1	Western Branch	Mesohaline
Chesapeake Bay Program	WBB05	Western Branch	Mesohaline



Water clarity

Water Clarity measurements were taken by lowering a secchi disc off the shaded side of a boat and recording the depth in meters where the disc becomes invisible. Scores for each monitoring station were generated following the EcoCheck thresholds found in Table 7.1 of the protocol and Table 1 in this section of this document. If salinity is designated as Tidal Fresh, Oligohaline, or Mesohaline, only water clarity samples taken April-October were used in the scorecard. Scores for stations with Polyhaline or Marine salinities included samples collected March-November (EcoCheck, 2011). Trend analysis is not part of the EcoCheck protocol, however scores and letter grade percentages used were derived from the same salinity-based sample collection periods. Broad Creek and Paradise Creek were excluded from the Water Clarity grade and trend analyses due to a lack of secchi disc readings.

Grade Rubric: EcoCheck 2011

≥ 80	A
60-79	B
40-59	C
20-39	D
< 20	F

Letter grades

Name	Percent	Grade	Samples	Date Range
EASTERN	53.5	C	52	2015-05-20 - 2019-06-06
MAINSTEM	48.8	C	91	*2015-03-17 - 2019-06-06
LAFAYETTE	35.7	D	46	2015-05-19 - 2019-06-05
SOUTHERN	49.2	C	52	2015-05-20 - 2019-06-06
WESTERN	28.3	D	46	2015-05-19 - 2019-06-05

*Note the earlier sample collection month for the Mainstem due to salinity being polyhaline.

Weighted grades

Weighted Volume	Weighted Surface area	Volume Grade	Surface area grade
47.35870689	45.07688498	C	C

Trend

Name	Samples	Date_Range	p.value	estimate	Trend	Status
MAINSTEM	119	2010 - 2019	0.3017	0.524	No Trend	—
ELIZABETH	215	2010 - 2019	0.5589	-0.491	No Trend	—
LAFAYETTE	115	2010 - 2019	0.4357	0.37	No Trend	—
SOUTHERN	122	2010 - 2019	0.3206	-0.645	No Trend	—
WESTERN	114	2010 - 2019	0.8924	-0.086	No Trend	—

Total nitrogen

Samples were collected at 0.5 meters below the surface and 0.5 meters above maximum depth at each monitoring station. The bottom and surface measurements were averaged for each station so that each station had one Total Phosphorus (TP) and one Total Nitrogen (TN) value to score for each sample collection day. Station data were acquired using the publicly available Chesapeake Bay Program data downloader for all branches except for Broad Creek, Paradise Creek, and Indian River which were gathered from DEQ's internal database. Paradise Creek samples did not have TN analyzed by the lab and values were summed manually using TN= Kjeldahl + Nitrite + Nitrate. Per EcoCheck Protocol only samples collected April to October were used in the analysis. Refer to Table 8.1 in the EcoCheck manual for score determinations. Broad Creek and Indian River showed improving trends ($p < 0.05$) for Nitrogen.

Grade Rubric: EcoCheck 2011

≥ 80	A
60-79	B
40-59	C
20-39	D
< 20	F

Letter grades

Name	Parameter	Samples	Percent	Grade	Date Range
BROAD	TN	19	31.6	D	2015-04-16 - 2019-10-02
EASTERN	TN	22	59.1	C	2015-05-20 - 2019-06-06
MAINSTEM	TN	25	48	C	2015-05-19 - 2019-06-05
INDIAN	TN	15	48	C	2015-05-07 - 2019-09-11
LAFAYETTE	TN	35	69.7	B	2015-05-19 - 2019-06-05
PARADISE	TN	32	33.1	D	2015-05-20 - 2019-10-30
SOUTHERN	TN	15	66.7	B	2015-05-20 - 2019-06-06
WESTERN	TN	39	61.5	B	2015-05-19 - 2019-06-05

Weighted grades

Parameter	Weighted Volume	Weighted Surface area	Volume Grade	Surface area grade
TN	48.9	51.7	C	C

Trend

Name	Samples	Date Range	p.value	estimate	Trend	Status
BROAD	39	2010 - 2019	0.0377	2.203	**Significant 0.05**	**Improving**
EASTERN	70	2010 - 2019	0.3768	-1.088	No Trend	—
MAINSTEM	93	2010 - 2019	0.5825	-0.753	No Trend	—
INDIAN	30	2010 - 2019	0.0237	2.185	**Significant 0.05**	**Improving**
LAFAYETTE	90	2010 - 2019	0.7891	0.273	No Trend	—
PARADISE	85	2010 - 2019	0.2256	1.121	No Trend	—
SOUTHERN	55	2010 - 2019	0.807	-0.321	No Trend	—
WESTERN	93	2010 - 2019	0.354	1.145	No Trend	—

Total phosphorus

Samples were collected at 0.5 meters below the surface and 0.5 meters above maximum depth at each monitoring station. The bottom and surface measurements were averaged for each station so that each station had one Total Phosphorus (TP) and one Total Nitrogen (TN) value to score for each sample collection day. Station data were acquired using the publicly available Chesapeake Bay Program data downloader for all branches except for Broad Creek, Paradise Creek and Indian River which were gathered from DEQ's internal database. Paradise Creek samples did not have TN analyzed by the lab and values were summed manually using TN= Kjeldahl + Nitrite + Nitrate. Per EcoCheck Protocol only samples collected April to October were used in the analysis. Refer to Table 8.1 in the EcoCheck manual for score determinations. Broad Creek and Indian River showed improving trends ($p < 0.05$) for Nitrogen. Paradise Creek is possibly starting to show a trend for reductions in Phosphorus pollution with significance at $p < 0.1$.

Grade Rubric: EcoCheck 2011

≥ 80	A
60-79	B
40-59	C
20-39	D
< 20	F

Letter grades

Stream Name	Samples	Percent	Grade	Date Range
BROAD	9	26.7	D	2015-04-16 - 2019-08-07
EASTERN	51	57.6	C	2015-03-19 - 2019-09-18
MAINSTEM	93	48.2	C	2015-03-17 - 2019-09-18
INDIAN	20	43	C	2015-03-03 - 2019-09-11
LAFAYETTE	47	49.8	C	2015-03-17 - 2019-09-17
PARADISE	27	63.7	B	2015-03-19 - 2019-09-18
SOUTHERN	48	74.2	B	2015-03-19 - 2019-09-18
WESTERN	46	43	C	2015-03-19 - 2019-09-17

Weighted grades

Weighted Vol	Weighted Surface area	Volume Grade	Surface area grade
51.4	50.9	C	C

Trend

Stream Name	Samples	Date Range	p.value	estimate	Trend	Status
BROAD	19	2010 - 2019	0.572	-1.09	No Trend	—
EASTERN	112	2010 - 2019	0.501	0.582	No Trend	—
MAINSTEM	205	2010 - 2019	0.333	0.979	No Trend	—
INDIAN	39	2010 - 2019	0.652	0.364	No Trend	—
LAFAYETTE RIVER	107	2010 - 2019	0.749	0.343	No Trend	—
PARADISE	73	2010 - 2019	0.8	0.285	No Trend	—
SOUTHERN	112	2010 - 2019	0.0534	1.17	Significant 0.1	Possibly Improving
WESTERN	105	2010 - 2019	0.577	0.739	No Trend	—

Chlorophyll-*a*

Grab samples were collected by boat 0.5 meters below the surface and filtered through a Whatman GF/F 0.7µm filter. In the lab the spectrophotometric method was used to measure the absorbances at different wavelengths (e.g. chlorophyll-*a*, b, and c, and pheophytin-a) and to determine an estimate of phytoplankton biomass. Only samples collected March–May or July– September were used in this scorecard per EcoCheck protocol. June is excluded from analysis due to observations with high variability. Scores were produced for each station by comparing measurements to multiple ecologically important thresholds based on salinity and season (EcoCheck, 2011 Table 6.1a). The Southern Branch showed significance at $p<0.1$ for the trend analysis barely exceeding $p<0.05$ and therefore is likely improving.

Grade Rubric: EcoCheck 2011

≥ 80	A
60-79	B
40-59	C
20-39	D
< 20	F

Letter grades

Stream Name	Samples	Percent	Grade	Date Range
BROAD	9	26.7	D	2015-04-16 - 2019-08-07
EASTERN	51	57.6	C	2015-03-19 - 2019-09-18
MAINSTEM	93	48.2	C	2015-03-17 - 2019-09-18
INDIAN	20	43	C	2015-03-03 - 2019-09-11
LAFAYETTE	47	49.8	C	2015-03-17 - 2019-09-17
PARADISE	27	63.7	B	2015-03-19 - 2019-09-18
SOUTHERN	48	74.2	B	2015-03-19 - 2019-09-18
WESTERN	46	43	C	2015-03-19 - 2019-09-17

Weighted grades

Weighted Vol	Weighted Surface area	Volume Grade	Surface area grade
51.4	50.9	C	C

Trend

Stream Name	Samples	Date Range	p.value	estimate	Trend	Status
BROAD	19	2010 - 2019	0.572	-1.09	No Trend	—
EASTERN	112	2010 - 2019	0.501	0.582	No Trend	—
MAINSTEM	205	2010 - 2019	0.333	0.979	No Trend	—
INDIAN	39	2010 - 2019	0.652	0.364	No Trend	—
LAFAYETTE RIVER	107	2010 - 2019	0.749	0.343	No Trend	—
PARADISE	73	2010 - 2019	0.8	0.285	No Trend	—
SOUTHERN	112	2010 - 2019	0.0534	1.17	Significant 0.1	Possibly Improving
WESTERN	105	2010 - 2019	0.577	0.739	No Trend	—

Enterococci bacteria & recreational health standards

Presence of Enterococci bacteria can be an indication that potentially harmful pathogens are present. DEQ ambient monitoring data was used for the analysis of bacteria in the Elizabeth River. Grab samples were collected by boat at the surface and shipped to the lab within 24 hours of sample collection. Growth media are inoculated with sample water and colony forming units (cfu) of bacteria per 100mL are reported. Values were compared against Virginia's Water Quality Standard threshold value of 104 cfu/100mL for estuarine waters. Exceedances of the standard can result in beach closures by Virginia Department of Health.

Grade Rubric: EcoCheck 2011

≥ 80	A
60-79	B
40-59	C
20-39	D
< 20	F

Letter Grades

Stream Name	% Exceedances	Letter Grade	Samples	Exceedances	Date Range
BROAD	74.1	F	27	20	2015-02-03 - 2019-12-04
EASTERN	8	B	100	8	2015-03-19 - 2019-12-12
MAINSTEM	5.1	B	137	7	2015-01-21 - 2019-12-12
INDIAN	79.3	F	29	23	2015-01-13 - 2019-11-12
LAFAYETTE	5.6	B	89	5	2015-01-21 - 2019-11-21
PARADISE	19.2	D	52	10	2015-03-19 - 2019-12-12
SOUTHERN	16.8	D	101	17	2015-03-19 - 2019-12-12
WESTERN	14	C	86	12	2015-03-19 - 2019-11-21

Weighted grades

Weighted Vol	Weighted Surface area	Volume Grade	Surface area grade
9.47	12.1	B	C

Trend:

Stream Name	Samples	Date Range	p.value	estimate	Trend	Status
BROAD	55	2010 - 2019	0.921	-0.196	No Trend	—
EASTERN	210	2010 - 2019	0.907	0.093	No Trend	—
MAINSTEM	290	2010 - 2019	0.76	-0.176	No Trend	—
INDIAN	55	2010 - 2019	0.189	-2.3	No Trend	—
LAFAYETTE RIVER	201	2010 - 2019	0.6	0.401	No Trend	—
PARADISE	134	2010 - 2019	0.445	0.75	No Trend	—
SOUTHERN	216	2010 - 2019	0.768	-0.305	No Trend	—
WESTERN	193	2010 - 2019	0.343	-1.04	No Trend	—

Dissolved oxygen

Vertical profiles of depth, pH, temperature, dissolved oxygen, and salinity were taken every 0.5 meters from the surface to approximately 0.5 meters above the bottom using a YSI or Hydrolab sonde. Dissolved oxygen was evaluated against the threshold of 5mg/L at each measurement down the depth profile at each station. Each measurement was assigned a "≥ 5mg/L pass" or "< 5mg/L fail" grade then averaged into a percentage for each monitoring station. All stations were evaluated as "Open Water" and presence or absence of pycnoclines was not determined. Using the 5mg/L threshold for all stations is a conservative evaluation as presence of pycnoclines reduces the threshold values to 3mg/L or 1 mg/L i.e. making it easier to "pass". The Western Branch showed significance at p<0.1 indicating that dissolved oxygen has probably improved from 2010-2019.

Grade Rubric: EcoCheck 2011

≥ 80	A
60-79	B
40-59	C
20-39	D
< 20	F

Letter grades

Stream Name	Samples	Exceedances	Percent	Grade	Date Range
BROAD	28	12	57.1	C	2015-02-03 - 2019-12-04
EASTERN	192	48	75	B	2015-03-19 - 2019-12-12
MAINSTEM	276	40	85.5	A	2015-01-21 - 2019-12-12
INDIAN	30	6	80	A	2015-01-13 - 2019-11-12
LAFAYETTE RIVER	180	16	91.1	A	2015-01-21 - 2019-11-21
PARADISE	53	11	79.2	B	2015-03-19 - 2019-12-12
SOUTHERN	192	53	72.4	B	2015-03-19 - 2019-12-12
WESTERN	175	12	93.1	A	2015-03-19 - 2019-11-21

Weighted grades

Weighted Volume	Weighted Surface area	Volume Grade	Surface area grade
83.4	83.6	A	A

Trend

Stream Name	Samples	Date Range	p.value	estimate	Trend	Status
BROAD	58	2010 - 2019	0.724	0.424	No Trend	—
EASTERN	405	2010 - 2019	0.722	-0.447	No Trend	—
MAINSTEM	583	2010 - 2019	0.998	-0.001	No Trend	—
INDIAN	58	2010 - 2019	0.307	1.92	No Trend	—
LAFAYETTE RIVER	401	2010 - 2019	0.837	0.129	No Trend	—
PARADISE	142	2010 - 2019	0.876	0.288	No Trend	—
SOUTHERN	415	2010 - 2019	0.707	0.365	No Trend	—
WESTERN	392	2010 - 2019	0.0604	1.35	Significant	0.1 Possibly Improving

State of the Elizabeth River Steering Committee 2020

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