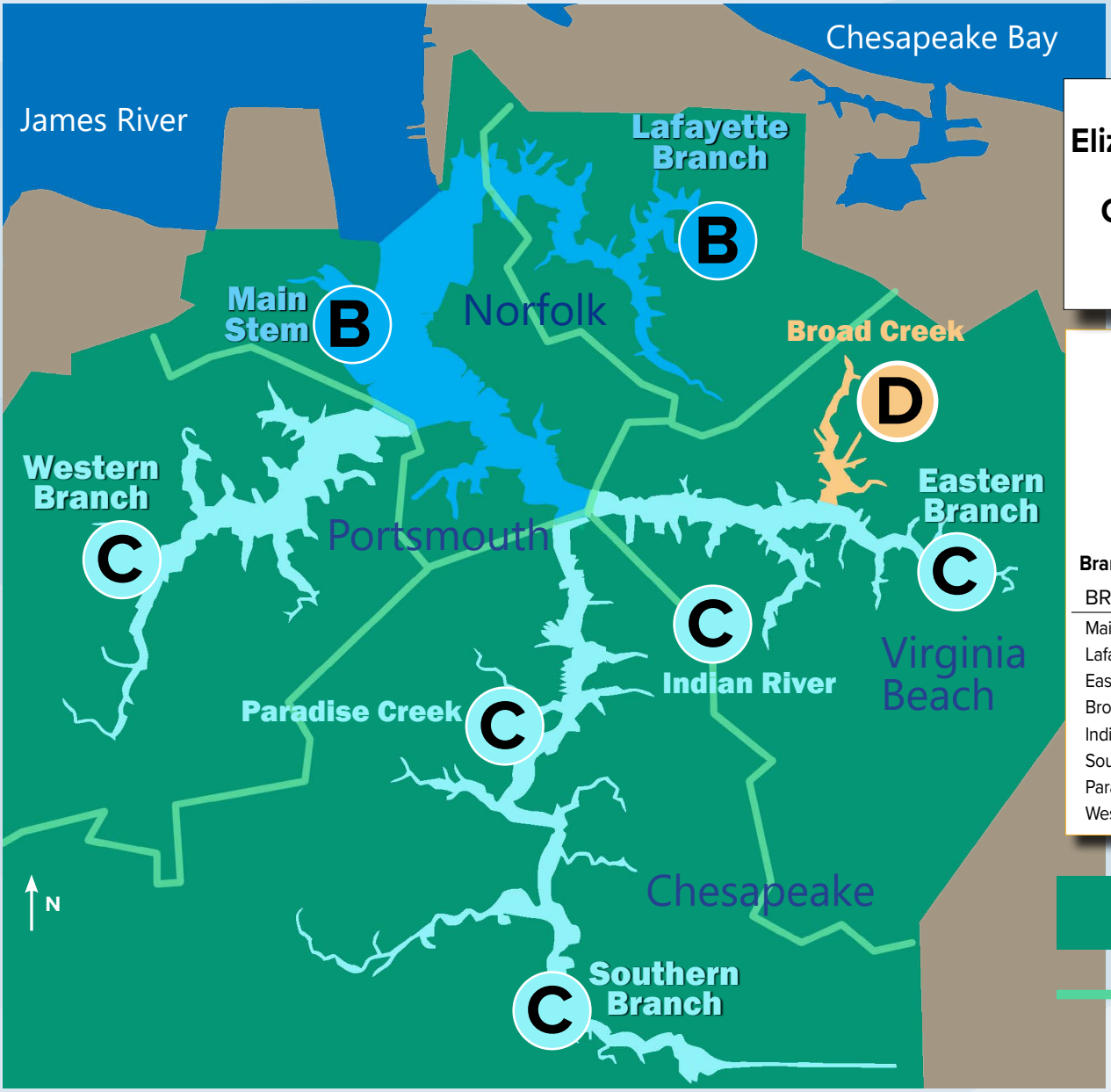
State of the Elizabeth River
SCORECARD 2023

Elizabeth River



Elizabeth River Overall Grade C

River Health Scale

A
B
C
D
F

Branch Grades Then and Now

BRANCH	2020	2023
Main Stem	B	B
Lafayette	C	B
Eastern Branch	C	C
Broad Creek	D	D
Indian River	C	C
Southern Branch	C	C
Paradise Creek	C	C
Western Branch	C	C

Elizabeth River "Watershed" or drainage area

Sub-watersheds delineated by light green lines

Trawl surveys discover rich fish life

For the first time since the Virginia Institute of Marine Science (VIMS) began tracking fish populations throughout the Bay in 1955, trawl surveys have now entered the Elizabeth River – another sign that the health of our urban river is now taken seriously, as recovery milestones are achieved.

VIMS conducted monthly trawls of the river for the past two years, discovering "a variety of commercially and recreationally important species," 33 species in all, including some surprising ones.

"I had no idea we had blueback herring in the river," said Joe Rieger, Deputy-Director – Restoration, Elizabeth River Project.

"Importantly, we confirmed the use of the Elizabeth River as a nursery habitat for juvenile American shad and blueback herring; these species are under fishing moratoria due to historically low numbers throughout the East Coast of the US," said Dr. Troy Tuckey, VIMS.

See the VIMS Summary of Findings:
tinyurl.com/VIMSER

Virginia Institute of Marine Science captured this lined seahorse near Scott's Creek in Portsmouth in 2022 along with an abundance of marine life.

Elizabeth River Scorecard 2023

Dissolved Oxygen	Key to fish health; improving river-wide. Amount of oxygen present for fish to "breathe."	**A**
Bacteria (enterococci – related to safe recreation)	Promising decrease -Note, no determination of safe or unsafe swimming has been made since there are no public beaches where water quality can be monitored with sufficient frequency. [1]	**A**
Bacteria (fecal coliform – related to safe shellfish consumption)	Western Branch degrading, Lafayette improving. Shellfish beds throughout the river remain closed to harvest based on complex additional factors. Eastern Branch, Southern Branch not monitored.	**B**
Water Clarity	This is how far light can penetrate and is one indicator of suspended pollutants.	**C**
Nitrogen	Excess nitrogen can lead to algae blooms. Improving levels throughout the river, with long term improving trends in Indian River	**B**
Phosphorus	Excess phosphorus can lead to algae blooms. Still failing – Broad Creek, Indian River	**D**
Chlorophyll-A	Pigment in algae; associated with algal blooms	**C**
Bottom "benthic" Life	Life along the bottom of the river forms the foundation of the food chain. Most improved: Southern Branch	**D**
Fish Cancer	Sampling focused on known hotspots – not enough data throughout the river for overall score. Improving where cleanups have occurred.	**N/A**
Sediment Quality	Sampling focused on known hotspots – not enough data throughout the river for overall score. Improving where cleanups have occurred.	**N/A**

Overall River Grade

Holding steady from prior scorecard, 2020. Numerical score improved from 2.7 to 2.9 – just need to get to 3.0 for a B!

C

The non-profit Elizabeth River Project convened a committee of scientists to compile and analyze data and took the lead to interpret data for the public. Data provided by the Virginia Institute of Marine Science, Virginia Department of Environmental Quality, Virginia Department of Health, and Old Dominion University.

Overall score for each parameter as graded by area scientists for data 2018-2022

[1] Regarding recreation safety, be mindful of Vibrio, a naturally occurring, potentially deadly bacteria increasing in many shallow tidal waters with climate change.

Cover photo coutesy of David Gibson

"For one hour we were able to kayak with a mom and baby dolphin...My heart is happy."
- Denise Maples, regarding this photo she took 7/15/2023, Eastern Branch, Elizabeth River.

Are these harmful bacteria in your corner of the river?

Wound infections caused by *Vibrio*, naturally occurring bacteria, can be serious and are increasing with climate change and warming waters. Scientists on the Elizabeth, led by Dr. Corinne Audemard from VIMS, wondered if *Vibrio* are more abundant in oysters at contaminated areas of the river.

For this scorecard, VIMS determined the answer is no – *Vibrio* seem to be no more prevalent in oysters at known hotspots than healthier areas, and *Vibrio* levels in the Elizabeth seem similar to other Virginia locations (though caution is advised in any brackish or salty water, including the ocean.)

Avoid contact with water if you have an open wound and avoid consumption of raw oysters if your immune system is compromised.

For more information on water-related illnesses possible in natural waterways, visit SwimHealthyVA.com.

Dr. Kristen Prossner, VIMS graduate, assisted the study by deploying oyster cages in contaminated areas of the river.

How good a canary is this fish?

The little mummichog, a spotted, bottom-dwelling fish, has long served as our "canary in the coal mine" for the health of the bottom of the Elizabeth since it doesn't travel far in its lifetime – but how far?

VIMS scientists boated forth to find out, 2021-22. Mary Bennett, Elizabeth River Project environmental scientist, tagged along with the tagging. "The whole process is interesting. They put small radio transponder tags in these tiny fish and send them out in the river and see where they go," she said. After tagging more than 2,400 fish, the answer: The majority of mummichogs stayed in the area where they were tagged but a small portion were found in adjacent areas. "It supports the continued use of the mummichog as an indicator species for successful cleanup," says Joe Rieger, Elizabeth River Project.

See the Mummichog Movement StoryMap: tinyurl.com/Mummimove

Dr. Hamish Small, VIMS, captures mummichogs for this report

State of the Elizabeth River Steering Committee 2023

Funding for this document was made possible by the Virginia Institute of Marine Science through a special allocation of state funds to track the long-term health of the Elizabeth River. Special thanks to the team of scientists and advisors who guided this scorecard.

Mike Unger*	Virginia Institute of Marine Science
Hamish Small*	Virginia Institute of Marine Science
Corinne Audemard	Virginia Institute of Marine Science
Mary Bennett	Elizabeth River Project
Kristie Britt	Virginia Department of Environmental Quality
Dan Dauer	Old Dominion University
Todd Egerton	Virginia Department of Health
Mary Fabrizio	Virginia Institute of Marine Science
KC Filippino	Hampton Roads Planning District Commission
Andrew Garey	Virginia Department of Environmental Quality
Raul Gonzalez	HRSD
Ashley Haines	Norfolk State University
Garry Harris	Elizabeth River Project Board (former)
Grace Holmes	Virginia Department of Environmental Quality

ELIZABETH RIVER PROJECT

DO SOMETHING BEAUTIFUL

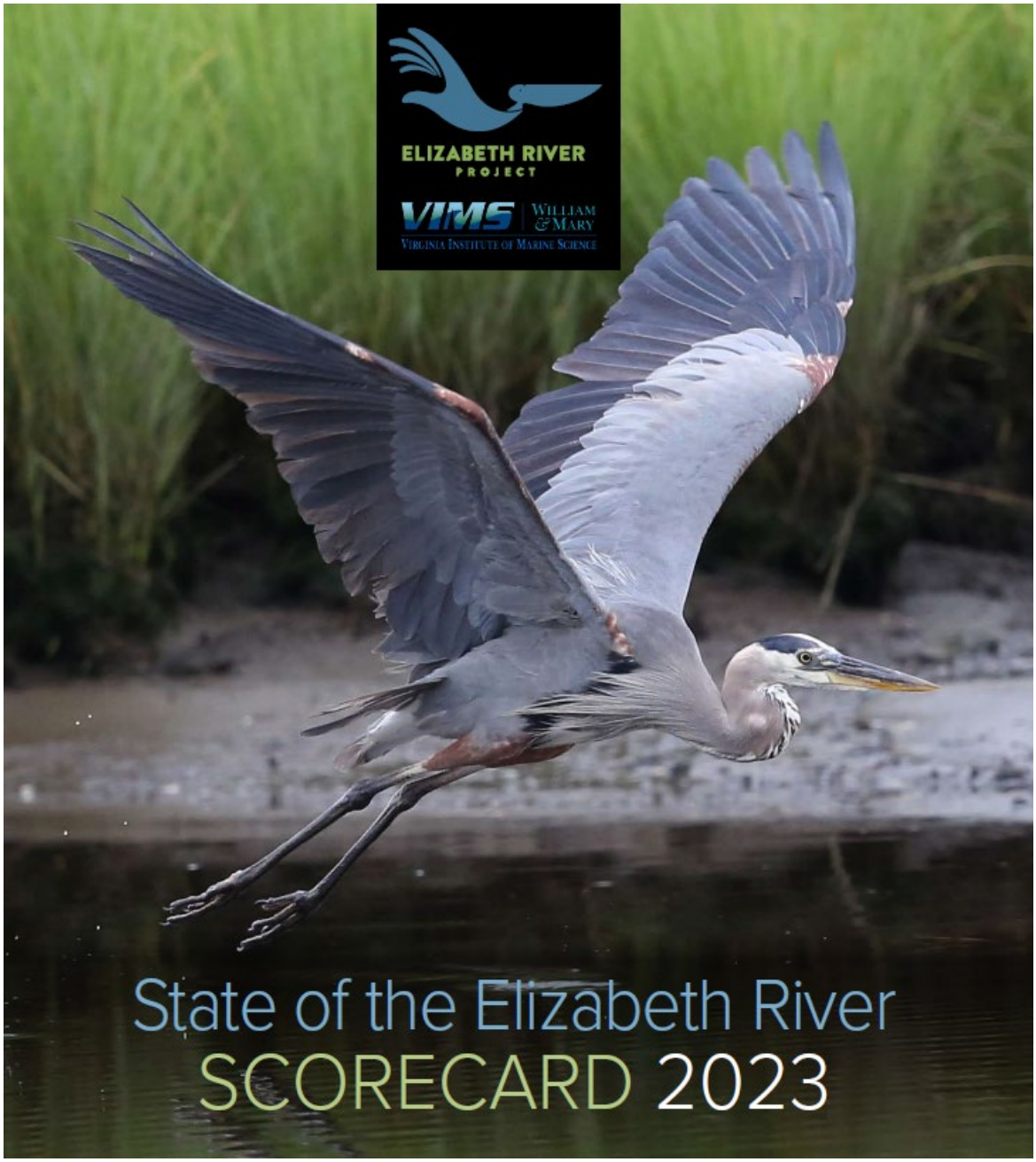
Find your role.

David Koubsky	Coastal Virginia Conservancy
Rob Latour	Virginia Institute of Marine Science
Rom Lipcius	Virginia Institute of Marine Science
Zach Martin	United States Army Corps of Engineers
Marjorie Mayfield Jackson	Elizabeth River Project
Edwardo Miles	Virginia Institute of Marine Science
Jamie Mitchell	HRSD
Margie Mulholland	Old Dominion University
Craig Nicol	Virginia Department of Environmental Quality
Joe Rieger	Elizabeth River Project
Bud Rodi	Old Dominion University
Tony Timpano	Virginia Department of Environmental Quality
Troy Tuckey	Virginia Institute of Marine Science
Janet Weyland	Virginia Department of Environmental Quality

*Chairs

For more information including how scores were calculated, contact Mary Bennett, Mbennett@elizabethriver.org, 757-399-7487. Appendix of scores also available.

Printed on post-consumer waste recycled paper with eco-friendly ink.

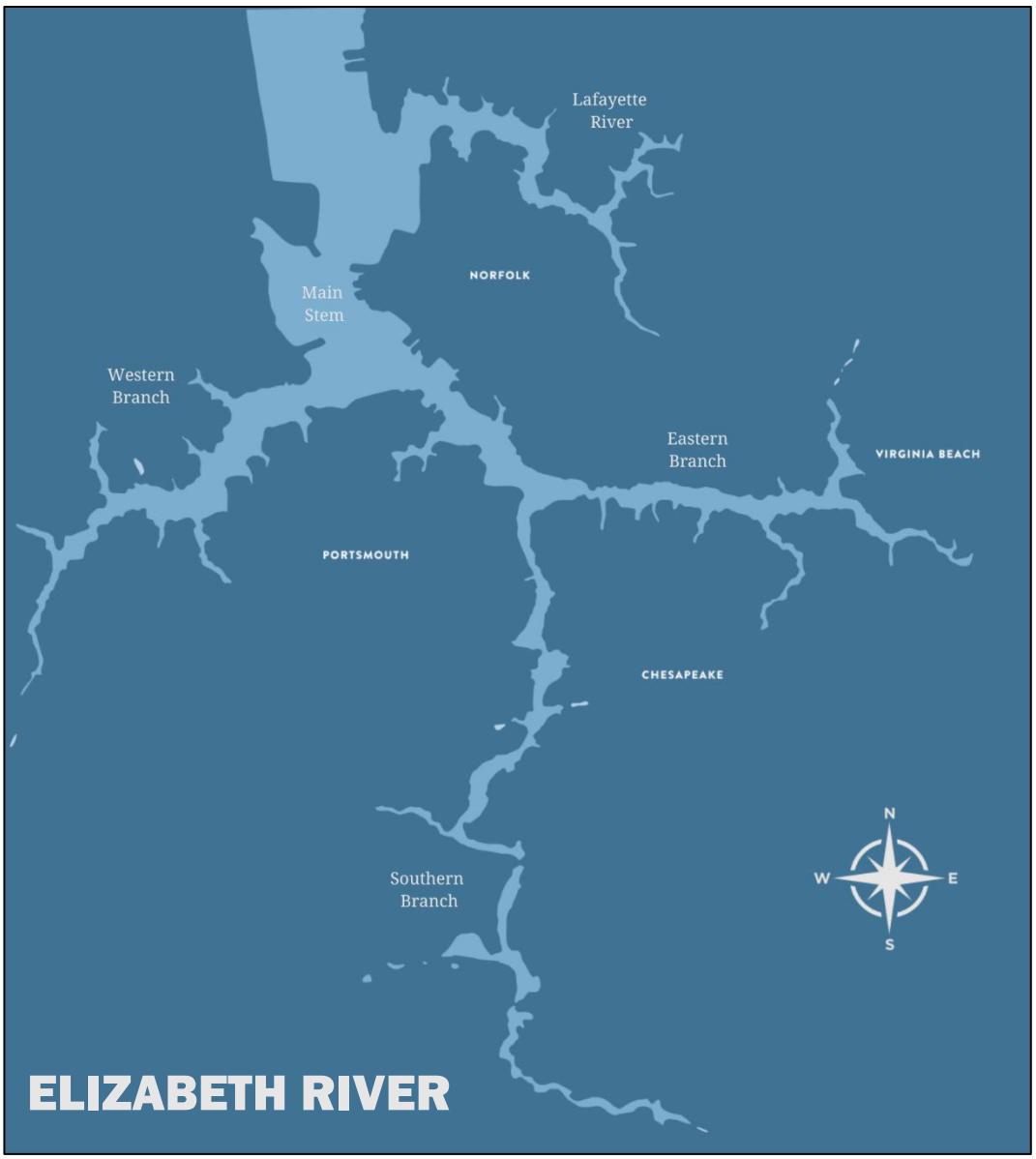


TECHNICAL APPENDIX

Special thanks to the State of the Elizabeth River Steering Committee 2023

The Elizabeth River Project is a non-profit with the mission to restore the Elizabeth River through equitable collaboration with diverse communities, businesses, and governments.

The Elizabeth River Project | 4610 Colley Avenue, Norfolk, VA 23509 | Elizabethriver.org 757-399-7487



Contributing Partners:

The Elizabeth River Project took the lead to interpreting findings for the public with coordination of data collection by Mary Bennett, Environmental Scientist. Virginia Institute of Marine Sciences managed research funded through a state allocation for Elizabeth River monitoring, with special thanks to Dr. Mike Unger and Dr. Hamish Small, chairs, scorecard steering committee. Special thanks for assistance with data comparison and interpretation to the Virginia Department of Environmental Quality for key analysis of water quality data, Virginia Institute of Marine Science for key analysis of fish cancer and sediment contaminations, Old Dominion University for key analysis of the benthos, and Virginia Department of Health for key analysis of bacteria (shellfish). 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 through equitable collaboration with diverse communities, businesses, and governments.

Fall 2023

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ELIZABETH RIVER
PROJECT
DO SOMETHING BEAUTIFUL

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ELIZABETH RIVER PROJECT

DO SOMETHING BEAUTIFUL

1. WHY MONITORING MATTERS

The Elizabeth River Project adopted their first State of the Elizabeth River in 2000 based off data gathered in 1998-1999. Since then, several iterations of the report have been produced. In the last State of the Elizabeht River (2020), a scorecard/ report card method was developed for communicating the ecological monitoring data that is collected for the Elizabeth River. Report cards are an effective decision support tool to communicate aquatic monitoring data because they are easy to understand and are available for the public, scientists, managers, and policy makers (Nature, 2023).

The Elizabeth River is a vital part of our community that adds value to our lives through business, trade, and recreation. It is important to keep track of the health of the river just as it is important to keep track of your personal health. As our doctors monitor aspects of our health like weight and blood pressure or screen for disease and cancer, our local scientists monitor the status of several different variables to make sure the river is happy, healthy, and flowing smoothly. By monitoring various aspects of our river, we can determine long term trends and spot small problems early so that we may make the necessary changes before they turn into larger complications.

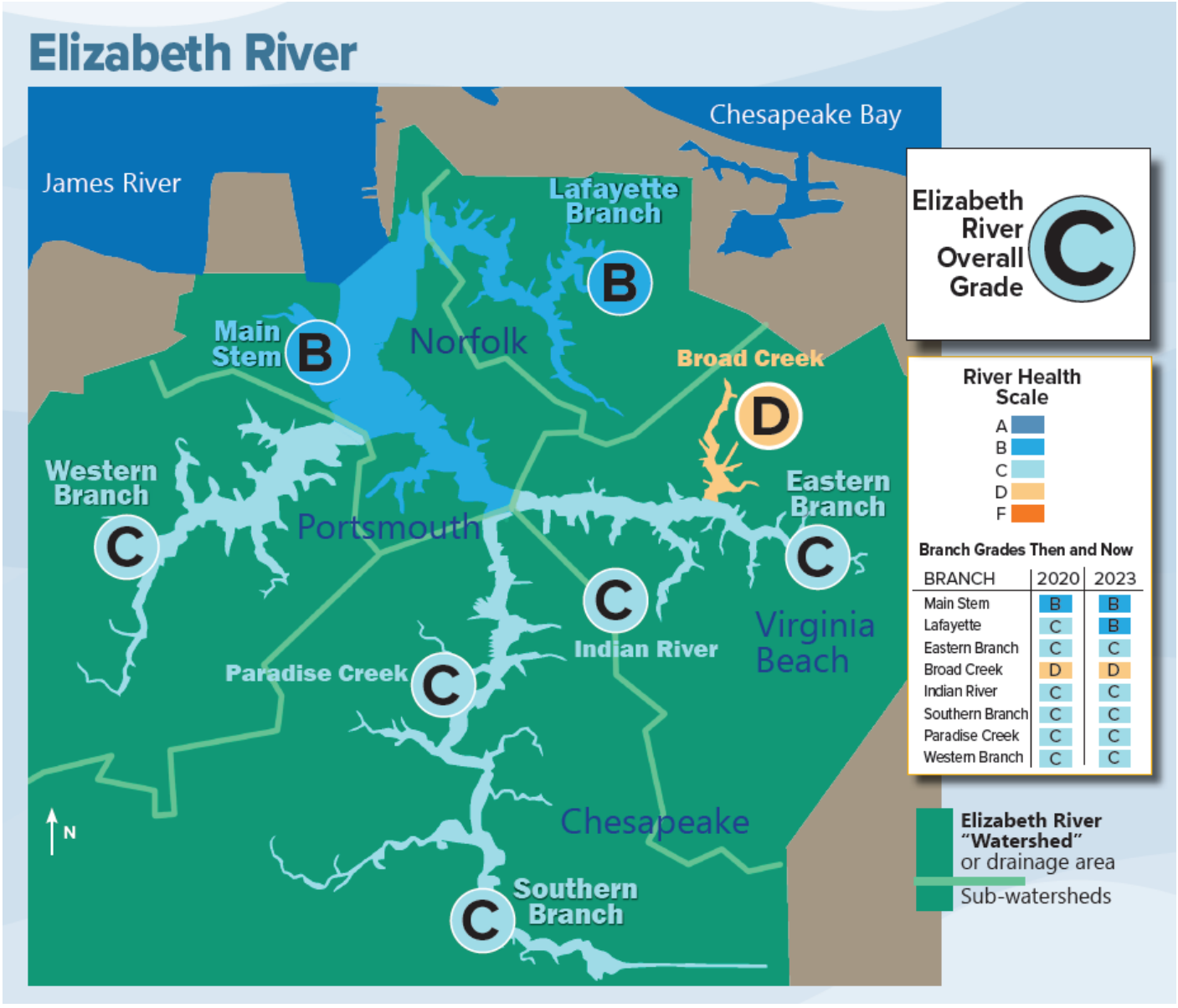

Figure 1: The Elizabeth River is a tidal river that is connected to the Chesapeake Bay. There are five main branches to the Elizabeth River- the Main Stem, the Lafayette River, the Eastern Branch, the Western Branch, and the Southern Branch. The river flows through the cities of Norfolk, Portsmouth, 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 subwatersheds. In 2023, the Main Stem and Lafayette Branches scored a "B." The Eastern, Southern, and Western Branches and Indian River and Paradise Creeks scores a "C." Broad Creek scored a "D."

2. METHODOLOGY FOR GRADING THE SCORECARD

SCORING OF DATA

A multiple threshold approach for grading the Elizabeth River was used in this document (Table 1). The score card is meant to communicate the status of the river in a manner similar to a report card for a student. Grading scales vary between some of the parameters and are based on the consensus of partners that collaborated throughout the development of the scorecard. 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 8-24).

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

Multiple Thresholds	Range	Mid Point	Grade	% Score
	4 to5	4.5	A	80-100
	3 to <4	3.5	B	60-<80
	2 to <3	2.5	C	40-<60
	1 to <2	1.5	D	20-<40
	0 to <1	0.5	F	<20

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 Lafayette and Western Branch averaged 10 parameters, while the Main Stem, Eastern and Southern Branches only averaged 9 parameters since data for bacteria in shellfish and fish cancer were not collected in all of the main branches (See Table 2). Grades for sub-tributaries (Broad Creek, Indian River, and Paradise Creek) were determined by averaging the grades for only five parameters (recreational bacteria, dissolved oxygen, phosphorus, nitrogen, and chlorophyll) since data for the other parameters were not collected.

Each letter grade in Table 2 was first translated into a midpoint number and then averaged to determine the letter grade for the five main branches and the three tributaries (Table 3).

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

Branch of Elizabeth River	Bacteria1 (Rec)	Clarity	DO	Phosphorus	Nitrogen	Chlorophyll	Bacteria2 (shellfish)	Bottom Health (BIBI)	Fish Cancer	Sediment
Main Stem	A	C	A	C	B	C	A	C	-	C
Lafayette	A	D	A	D	B	C	B	C	C	A
Eastern Branch	A	C	B	D	B	B	-	D	F	D
Broad Creek	D	-	C	F	D	D	-	-	-	-
Indian River	D	-	A	F	C	C	-	-	-	-
Southern Branch	A	C	B	C	B	B	-	D	D	F
Paradise Creek	B	-	B	D	C	B	-	-	-	-
Western Branch	A	D	A	D	B	C	C	F	B	B

Table 3: Letter grades associated with each of the main branches and smaller tributaries; not weighted.

Branch of Elizabeth River	SUM	AVERAGE	GRADE
Main Stem	29.5	3.28	B
Lafayette	31	3.10	B
Eastern Branch	22.5	2.50	C
Broad Creek	7.5	1.50	D
Indian River	11.5	2.30	C
Southern Branch	23.5	2.61	C
Paradise Creek	14.5	2.90	C
Western Branch	28	2.80	C

RIVER-WIDE GRADE

The overall grade for the Elizabeth River was determined by calculating a weighted average of the five main branches (Figure 1; Main Stem, Eastern, Lafayette, Southern, Western). Weights were determined based on surface area (see page 9, 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 4 and 5.

Table 4: Parameter grades for the five main branches of the Elizabeth River.

Branch of Elizabeth River	Bacteria1 (Rec)	Clarity	DO	Phosphorus	Nitrogen	Chlorophyll	Bacteria2 (shellfish)	Bottom Health (BIBI)	Fish Cancer	Sediment
Main Stem	A	C	A	C	B	C	A	C	-	C
Lafayette	A	D	A	D	B	C	B	C	C	A
Eastern Branch	B	C	B	D	C	C	-	D	F	D
Southern Branch	A	C	B	D	B	B	-	D	D	F
Western Branch	A	D	A	D	B	C	C	F	B	B

Table 5: The Elizabeth River received an overall grade of C.

Branch of Elizabeth River	AVERAGE	Letter Grade	w	Weighted Average	River Weighted Average	River Letter Grade
Main Stem	3.28	B	0.43	1.40		
Lafayette	3.10	B	0.13	0.40		
Eastern Branch	2.17	C	0.12	0.27		
Southern Branch	2.50	C	0.19	0.47		
Western Branch	2.80	C	0.13	0.37		
Total			1.00	2.91	2.91	C

Figure 2: Committee members working on the development of the State of the Elizabeth River Scorecard 2023 during their third meeting that took place at the Hampton Roads Planning District Commission's Regional Building in Chesapeake.

WATER QUALITY ANALYSIS

RESEARCHERS

Tony Timpano
Virginia Department of Environmental Quality, Blue Ridge Regional Office, 901 Russell Drive, Salem, VA 24153

SUMMARY OF APPROACH

This section applies to Water Clarity, Nitrogen, Phosphorus, Chlorophyll-a, Dissolved Oxygen, and Enterococci Bacteria grades (Pages 11-16).

Letter grades were calculated for each parameter and monitoring station using 5 years of data collected 2018 through 2022. 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. The grade scales used for each parameter and the rationale for letter grade derivation is summarized under each parameter section (Tables 9,12, 15, 18, 21, and 24). Letter grade percent scores (Table 1) were calculated using either the Percent Average Score method or Percent Violations method (see equations below). Water Clarity, Nitrogen, Phosphorus, and Chlorophyll-a were scored using the Percent Average Score method and scoring thresholds in the EcoCheck (2011) protocol. Dissolved Oxygen and Recreational Bacteria (Enterococci) were scored using the Percent Violations method and a single threshold value for each, as detailed in their respective sections below. All letter grade percent scores were then graded A to F using the Multiple Thresholds approach described above (Table 1). Letter grades for each parameter can be found in Tables 10, 13, 16, 19, 22, and 25.

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

$$Percent\ Violations = \frac{Number\ of\ exceedances\ of\ threshold\ value}{Number\ of\ samples} \times 100$$

Table 6 *Example of thresholds for calculating scores for Water Clarity based on Secchi disc depth readings and salinity regime. This table was taken directly from EcoCheck 2011 Table 7.1*

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 6). Weighted grades are only included as a comparison for the five main branches. Samples from Indian River and Broad 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 Main Stem Elizabeth River accounts for >68% of the total water by volume and >42% of the surface area (Table 7).

$$Branch\ Weighted\ Letter\ Grade\ Percent\ Score = Branch\ letter\ grade\ percent \times \frac{Branch\ volume\ or\ surface\ area\ percent}{100}$$

Table 7: The volume and surface area for each major branch of the Elizabeth River watershed. Values provided by Dr. Harry Wang and Mac Sisson, VIMS.

Branch	Volume m^3	Volume %	Surface Area m^2	Surface Area %
Main Stem	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 Letter Grade percent from monitoring Year. Models were created for each parameter and monitoring station using 10 years of data from 2013-2022. If a branch or tributary contained more than one monitoring station, those station grades were averaged together so that each year had only one corresponding letter grade percent value. 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. Trends for each parameter can be found in their respective sections in Tables 11, 14, 17, 20, 23, and 26.

$$Y = \beta_0 + \beta_1 X + \epsilon$$

Where:
$Y = Letter\ Grade\ percent$
$\beta_0 = intercept$
$\beta_1 = slope$
$X = Year$
$\epsilon = error$

SALINITY

Scores 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 8 and Figure 3). It’s important to note that the Virginia DEQ stations and Chesapeake Bay Program stations provided in Table 7 are essentially the exact same station with different catalog 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. Main Stem Elizabeth River is the only stream segment with the Polyhaline salinity regime.

Table 8: *Salinity regime for each Virginia 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	Main Stem	Polyhaline
DEQ	2-ELI003.52	Main Stem	Polyhaline
DEQ	2-ELI004.79	Main Stem	Polyhaline
DEQ	2-ELI006.92	Main Stem	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	Main Stem	Polyhaline
Chesapeake Bay Program	ELD01	Main Stem	Polyhaline
Chesapeake Bay Program	ELE01	Main Stem	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
Chesapeake Bay Program	WBB05	Western Branch	Mesohaline

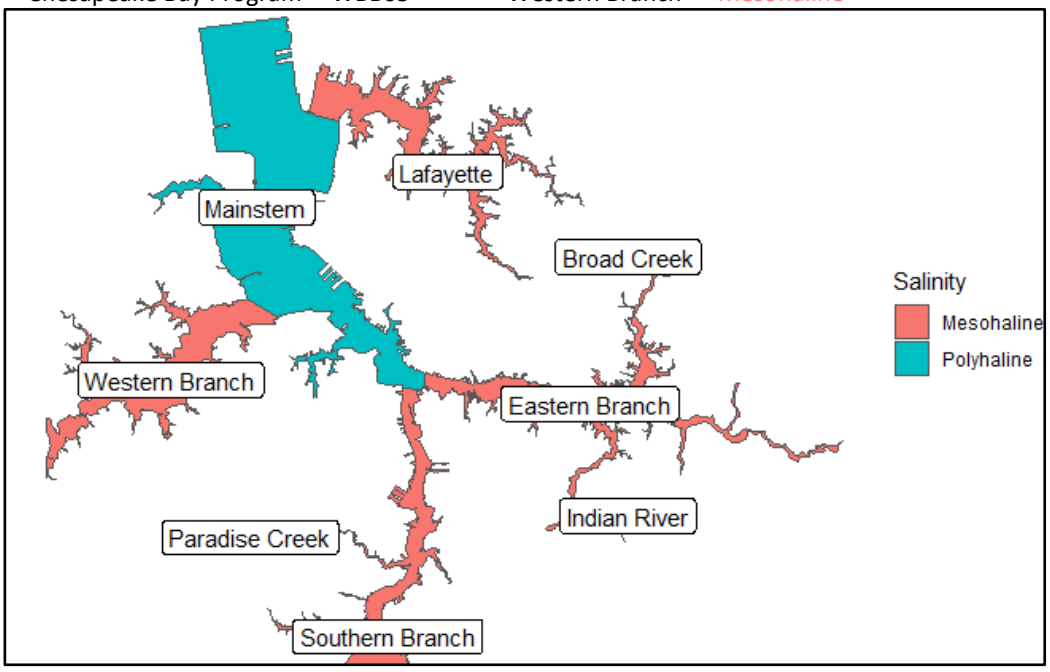

Figure 3: The Main Stem of the Elizabeth River is classified by the Polyhaline salinity regime. All other branches fall into the Mesohaline regime.

3. PARAMETER SUMMARIES

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 (2011) thresholds found in Table 7.1 of the protocol and Table 6 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.

Table 9: Grading criteria for Water Clarity.

Letter Grade	(+) Secchi Depth = (+) Score Varies by Salinity & Season
A	≥ 80%
B	60-79%
C	40-59%
D	20-39%
F	< 20%

Table 10: Letter grades for Water Clarity.

Branch Name	#Samples	Percent	2020	2023	Status
Eastern Branch	57	53	C	C	-
Main Stem	110	52	C	C	-
Lafayette River	56	37.5	D	D	-
Southern Branch	60	49.7	C	C	-
Western Branch	55	32.4	D	D	-
Area-Weighted 5 Branches	338	47.1	C	C	-

Table 11: Trends for Water Clarity.

Branch Name	#Samples	p-value	est.	Trend	Status
Eastern Branch	118	0.3202	-0.586	No Trend	-
Main Stem	223	0.2919	0.574	No Trend	-
Lafayette River	116	0.695	0.158	No Trend	-
Southern Branch	124	0.7989	-0.157	No Trend	-
Western Branch	115	0.4292	0.398	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 Nitrogen (TN) value to score for each sample collection date. 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 Virginia DEQ's internal database. Paradise Creek samples did not have TN analyzed by the lab; instead, TN values were calculated manually using TN = Kjeldahl Nitrogen + Nitrite + Nitrate. Per EcoCheck protocol only samples collected April to October were used in the analysis. Refer to Table 8.1 in the EcoCheck protocol for score thresholds.

Table 12: Grading criteria for Total Nitrogen**.**

Letter Grade	(-) TN = (+) Score Varies by Salinity
A	≥ 80%
B	60-79%
C	40-59%
D	20-39%
F	< 20%

Table 13: Letter grades for Total Nitrogen.

Branch Name	#Samples	Percent	2020	2023	Status
Broad Creek	18	33.3	D	D	-
Eastern Branch	36	64.4	C	B	Improved
Main Stem	52	60.8	C	B	Improved
Indian River	15	49.3	C	C	-
Lafayette River	42	67.1	B	B	-
Paradise Creek	30	45.3	D	C	Improved
Southern Branch	31	61.9	B	B	-
Western Branch	49	64.1	B	B	-
Area-Weighted 5 Branches	210	62.7	C	B	Improved

Table 14: Trends for Total Nitrogen**.**

Branch Name	#Samples	p-value	est.	Trend	Status
Broad Creek	37	0.1559	1.635	No Trend	-
Eastern Branch	65	0.9926	-0.01	No Trend	-
Main Stem	89	0.3890	1.049	No Trend	-
Indian River	30	0.0092	2.419	Significant 0.05	Improving
Lafayette River	85	0.1701	-1.638	No Trend	-
Paradise Creek	70	0.1437	2.424	No Trend	-
Southern Branch	51	0.8947	-0.209	No Trend	-
Western Branch	94	0.7791	0.331	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) value to score for each sample collection date. 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 Virginia DEQ's internal database. Per EcoCheck protocol only samples collected April to October were used in the analysis. Refer to Table 8.1 in the EcoCheck protocol for score thresholds.

Table 15: Grading criteria for Total Phosphorus.

Letter Grade	(-) TP = (+) Score Varies by Salinity
A	> 80%
B	60-79%
C	40-59%
D	20-39%
F	< 20%

Table 16: Letter grades for Total Phosphorus.

Branch Name	#Samples	Percent	2020	2023	Status
Broad Creek	18	15.6	F	F	-
Eastern Creek	57	35.8	D	D	-
Main Stem	82	47.1	C	C	-
Indian River	15	12	F	F	-
Lafayette River	55	31.3	D	D	-
Paradise Creek	30	34	D	D	-
Southern Branch	60	40.7	C	C	-
Western Branch	56	23.6	D	D	-
Area-Weighted 5 Branches	310	39.4	D	D	-

Table 17: Trends for Total Phosphorus.

Branch Name	#Samples	p-value	est.	Trend	Status
Broad Creek	37	0.6363	-0.336	No Trend	-
Eastern Branch	112	0.7758	-0.234	No Trend	-
Main Stem	164	0.7869	-0.322	No Trend	-
Indian River	30	0.1149	-1.37	No Trend	-
Lafayette River	110	0.9413	0.059	No Trend	-
Paradise Creek	71	0.7340	-0.294	No Trend	-
Southern Branch	117	0.9323	0.074	No Trend	-
Western Branch	113	0.9752	-0.022	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 (Method 446.0; U.S. Environmental Protection Agency, 1997). 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).

Table 18: Grading criteria for Chlorophyll-a

Letter Grade	(-) Chla = (+) Score Varies by Salinity & Season
A	≥ 80%
B	60-79%
C	40-59%
D	20-39%
F	< 20%

Table 19: Letter grades for Chlorophyll-a

Branch Name	#Samples	Percent	2020	2023	Status
Broad Creek	9	28.9	D	D	-
Eastern Branch	49	64.5	C	B	Improved
Main Stem	71	55.2	C	C	-
Indian River	20	42	C	C	-
Lafayette River	46	52.2	C	C	-
Paradise Creek	24	75	B	B	-
Southern Branch	49	77.1	B	B	-
Western Branch	46	49.6	C	C	-
Area-Weighted 5 Branches	261	59.3	C	C	-

Table 20: Trends for Chlorophyll-α

Branch Name	#Samples	p-value	est.	Trend	Status
Broad Creek	18	0.701	0.606	No Trend	-
Eastern Branch	99	0.2695	0.895	No Trend	-
Main Stem	146	0.0785	2.221	Significant 0.1	Possibly Improving
Indian River	39	0.8288	-0.182	No Trend	-
Lafayette River	98	0.7248	-0.376	No Trend	-
Paradise Creek	60	0.5699	0.674	No Trend	-
Southern Branch	102	0.3003	0.656	No Trend	-
Western Branch	99	0.6813	0.588	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, which would increase the number of samples considered "passing".

Table 21: Grading criteria for Dissolved Oxygen

Letter Grade	% ≥ 5 mg/L
A	≥ 80%
B	60-79%
C	40-59%
D	20-39%
F	< 20%

Table 22: Letter grades for Dissolved Oxygen

Branch Name	# Samples	# Exceed	% Passing	2020	2023	Status
Broad Creek	27	11	59.3	C	C	-
Eastern Branch	730	173	76.3	B	B	-
Main Stem	1491	198	86.7	A	A	-
Indian River	29	5	82.8	A	A	-
Lafayette River	292	20	93.2	A	A	-
Paradise Creek	52	14	73.1	B	B	-
Southern Branch	897	263	70.7	B	B	-
Western Branch	345	34	90.1	A	A	-
Area-Weighted 5 Branches	3755	688	83.7	A	A	-

Table 23: Trends for Dissolved Oxygen

Branch Name	#Samples	p-value	est.	Trend	Status
Broad Creek	56	0.1591	1.981	No Trend	-
Eastern Branch	1379	0.3934	1.142	No Trend	-
Main Stem	2917	0.196	0.846	No Trend	-
Indian River	58	0.18	2.443	No Trend	-
Lafayette River	588	0.4957	0.274	No Trend	-
Paradise Creek	115	0.6438	-0.633	No Trend	-
Southern Branch	1768	0.2681	1.034	No Trend	-
Western Branch	664	0.9563	0.035	No Trend	-

BACTERIA (ENTEROCOCCI)

Presence of Enterococci bacteria can be an indication that potentially harmful pathogens are present. Virginia 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 p 9er 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. ***Note that use of the DEQ threshold value in this independent analysis by Elizabeth River Project does not constitute an assessment of water quality by DEQ.***

Table 24: Grading criteria for Bacteria (Enterococci)

Letter Grade	% ≤ 104 cfu/100 mL
A	≥ 80%
B	60-79%
C	40-59%
D	20-39%
F	< 20%

Table 25: Letter grades for Bacteria (Enterococci)

Branch Name	#Samples	%Passing	2020	2023	Status
Broad Creek	74.1	25.9	D	D	
Eastern Branch	8	90	A	A	
Main Stem	5.1	97.9	A	A	
Indian River	79.3	25	D	D	
Lafayette River	5.6	97.8	A	A	
Paradise Creek	19.2	78.4	A	B	Degraded
Southern Branch	16.8	86.4	A	A	
Western Branch	14	92.6	A	A	
Area-Weighted 5 Branches	12.1	94.1	A	A	

Table 26: Trends for Bacteria (Enterococci)

Branch Name	#Samples	p-value	est.	Trend	Status
Broad Creek	53	0.6387	0.951	No Trend	
Eastern Branch	191	0.2724	1.153	No Trend	
Main Stem	277	0.3935	0.595	No Trend	
Indian River	54	0.8374	-0.524	No Trend	
Lafayette River	186	0.1079	1.172	No Trend	
Paradise Creek	110	0.8324	-0.329	No Trend	
Southern Branch	196	0.3916	1.152	No Trend	
Western Branch	185	0.1068	1.527	No Trend	

BACTERIA (FECAL COLIFORM & SHELLFISH SANITATION STANDARDS)

RESEARCHERS

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PURPOSE

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 monthly 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 < 14 fecal coliform colony forming units (cfu) per 100 mL and an 90th percentile of < 31 cfu/100mL.

METHODS

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), or a failing score (0) if they exceed 31. These monthly scores (100s and 0s) are averaged for each station for each year (2013-2022) to produce an annual station score. The Station Grade is based on the average of the scores the last 5 years (2018-2022). Segment Grades are based on the average of all stations within the river segment. Trends were calculated from linear regression analysis of the fecal coliform data from 2013-2022 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 0.1. Increasing concentrations of fecal coliforms were considered a declining trend. No Significant trends were observed for any of the segments during this time period. The number of samples is the total number of collections made in each branch for the time period.

Figure 4: Virginia Department of Health (VDH)'s Division of Shellfish Safety and Waterborne Hazards Control conducting routine monitoring of the Elizabeth River.

Table 27: Grading criteria for Bacteria (Fecal Coliform & Shellfish Sanitation Standards)

Letter Grade	Criteria
A	>90% of samples ≤ 31 cfu
B	80-90% of samples ≤ 31 cfu
C	70-80% of samples ≤ 31 cfu
D	60-70% of samples ≤ 31 cfu
F	<60% of samples ≤ 31 cfu

Table 28: Letter grades for Bacteria (Fecal Coliform & Shellfish Sanitation Standards)

Branch Name	#Samples	Percent	2020 Grade	2023 Grade	Date Range	Observations
Broad Creek	-	-	-	-	-	-
Eastern Branch	-	-	-	-	-	-
Main Stem	221	0.9376	A	A	2018-2022	-
Indian River	-	-	-	-	-	-
Lafayette River	785	0.835	C	B	2018-2022	Improving
Paradise Creek	-	-	-	-	-	-
Southern Branch	-	-	-	-	-	-
Western Branch	72	0.7796	B	C	2018-2022	Degrading
Elizabeth River*	478	0.8507	B	B	2018-2022	-

Table 29: Trends for Bacteria (Fecal Coliform & Shellfish Sanitation Standards)

Branch Name	#Samples	Date Range	P Value; Estimate	Trend	Status
Broad Creek	-	-	-	-	-
Eastern Branch	-	-	-	-	-
Main Stem	462	2013-2022	0.48; 0.53	No Trend	-
Indian River	-	-	-	-	-
Lafayette River	385	2013-2022	0.51; -0.63	No Trend	-
Paradise Creek	-	-	-	-	-
Southern Branch	-	-	-	-	-
Western Branch	152	2013-2022	0.17; 2.77	No Trend	-
Elizabeth River*	999	2013-2022	0.61; 0.43	No Trend	-

RIVER BOTTOM HEALTH

RESEARCHERS

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PURPOSE

Assess ecological condition (bottom health) as indicated by the macrobenthic invertebrate sedimentary community.

METHODS

The ecological condition of the benthos is characterized by the Benthic Index of Biotic Integrity (BIBI) a multimetric index that includes the following metrics: abundance, biomass, species diversity, composition of pollution sensitive species, and composition pollution indicative species. The BIBI is scaled from 1.0 to 5.0. The index period is from July 15 through September 30.

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.

For the letter grade time period of January 1, 2018 December 31, 2022, benthic community sampling occurred only in 2021 and 2022. In each year, five random sites were sampled in each of the five branches of the watershed for a total of ten samples for each branch (50 sites in total). For the long-term trend period (January 1, 2012-December 31, 2022), in addition to the above-mentioned samplings of 2021 and 2022, there was a single year (2019) with 125 random sites sampled with 25 sites allocated to each of the five branches. The 2019 sampling event repeated the 1999 intensive 125 random site benthic community study. Regular sampling of the benthos of the Elizabeth River was previously limited to two fixed-point stations in the Southern Branch (SBE2 and SB5) that have been sampled since 1989.

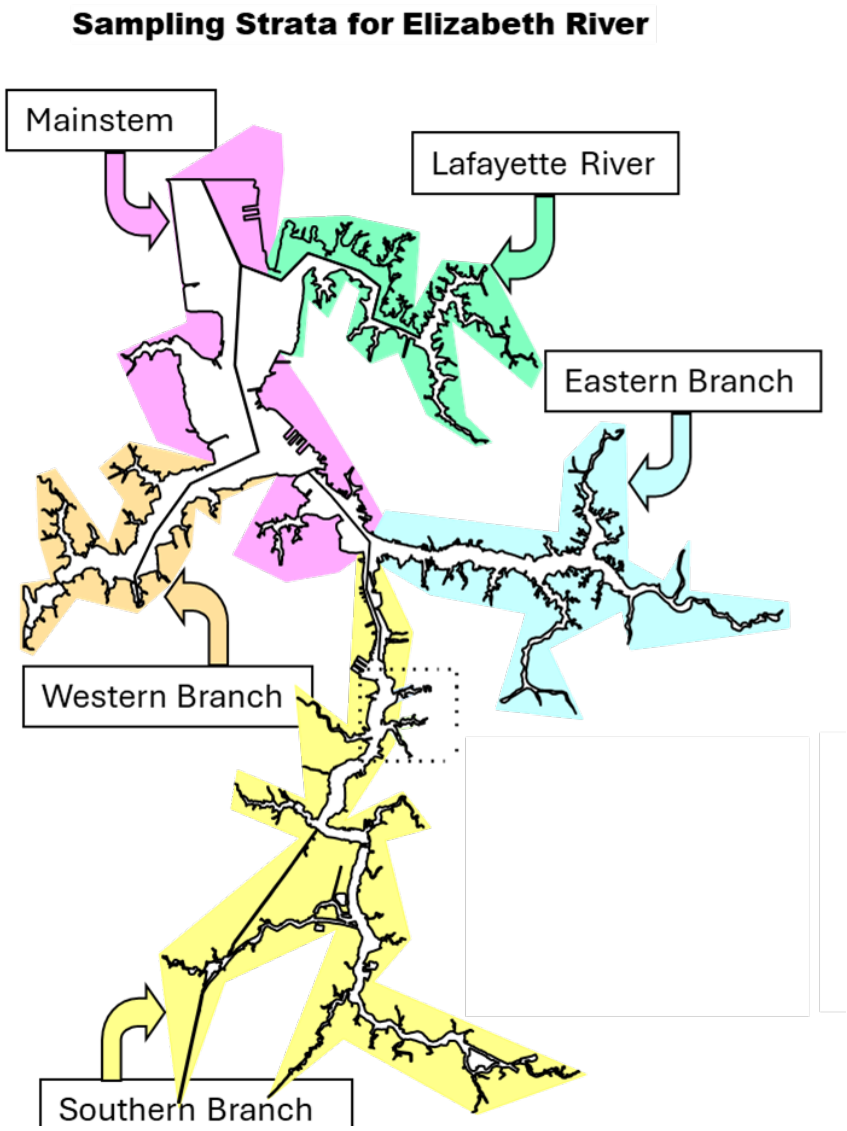

Figure 5: Sampling strata for the Elizabeth River used for the benthos study.

Table 30: Grading criteria for River Bottom Health

Letter Grade	Criteria (BIBI value)
A	≥ 4.0
B	3.0 – 3.9
C	2.6 – 2.9
D	2.1 – 2.5
F	≤ 2.0

Table 31: Letter grades for River Bottom Health

Branch Name	#Samples	B-IBI (2020)	2020 Grade	B-IBI (2023)	2023 Grade
Broad Creek	-	-	-	-	-
Eastern Branch	10	1.8	F	2.2	D
Main Stem	10	2.8	C	2.6	C
Indian River	-	-	-	-	-
Lafayette River	10	2.1	D	2.8	C
Paradise Creek	-	-	-	-	-
Southern Branch	10	2.5	D	2.3	D
Western Branch	10	2.2	D	1.9	F
Elizabeth River*	50	2.4	D	2.4	D

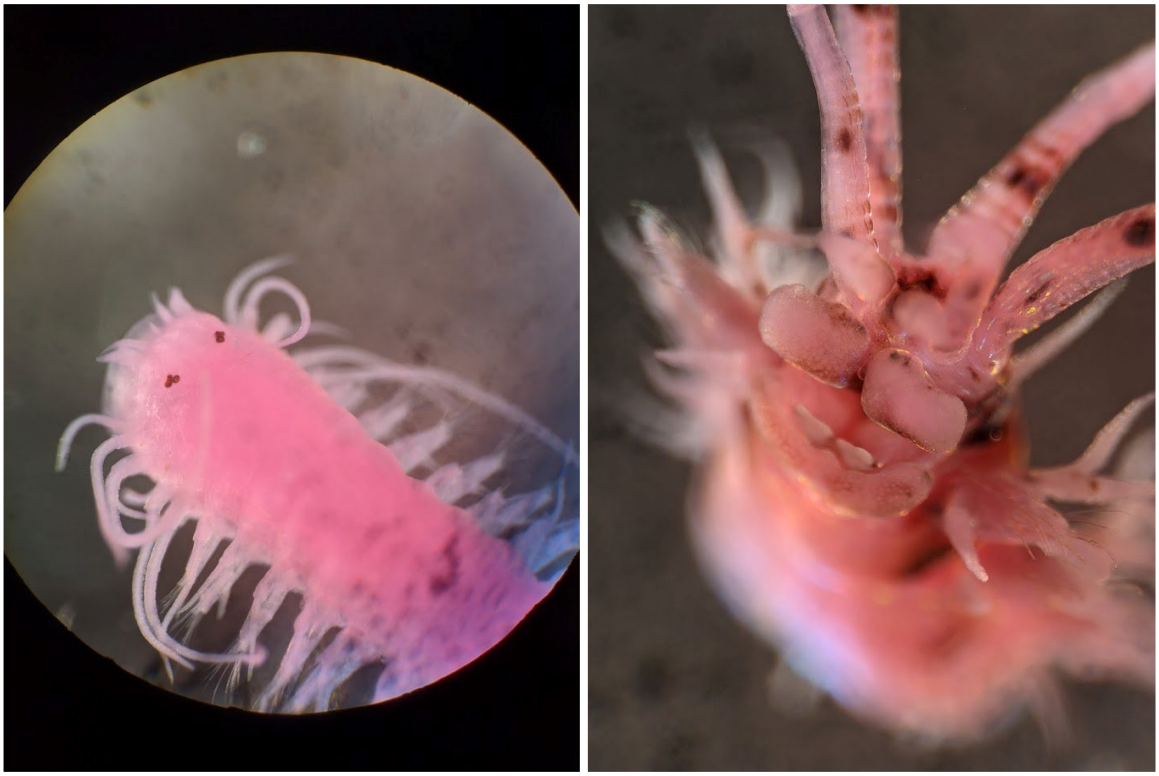

Figure 6: A couple of polychaetes, also known as bristle worms, from Elizabeth River benthos sampling. On the left is a *Podarkeopsis* and on the right is a *Diopatra*.

SEDIMENT QUALITY

RESEARCHERS

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PURPOSE

Evaluate river bottom quality using total polycyclic aromatic hydrocarbon (PAH) concentrations in bulk sediment samples and sediment porewater samples as the primary river bottom quality indicator.

METHODS

Sediment contamination throughout the river was evaluated for PAH because the river is known to have high levels from defunct wood treatment facilities and urban stormwater runoff. Multiple databases were reviewed as sources for evaluation and are listed in Table 32.

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). The grading criteria developed for each branch of the river and their grades can be found in Table 33 and 34.

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 35 for a summary of branch status.

Table 32: Databases used for evaluating the sediment quality throughout the river.

DATA USED FOR EVALUATION
NOAA Query Manager (Version 2.96)
2022 – USACE CIEE Pre-dredge sampling (MS)
2022 – LRT Money Point Phase 1&2 sampling (SB)
2022 – ERP Scuffletown Creek sampling (SB)
2022 – DEQ Scuffletown Creek sampling (SB)
2021 – VIMS Vibrio/PAH study (SB)
2021 – VIMS Fundulus cancer study (SB)
2021 - VIMS ER PAH Porewater monitoring (all)
2020 – USACE channel deepening (MS)
2020 – Peck Iron and Metal Remedial Invest. (SB)
2020 – LRT Paradise Creek sampling (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)

Table 33: Grading criteria for Sediment Quality

Letter Grade	Criteria
A	< 4 ppm in sediment at all sites and all porewater < 10 ppb
B	one site > 4 ppm in sediment and all porewater < 10 ppb
C	> 4 ppm in sediment at multiple sites but < 45 ppm and porewater < 10 ppb
D	any site > 45 ppm in sediment or porewater > 10 ppb
F	multiple sites > 45 ppm in sediment or porewater > 10 ppb

Table 34: Letter grades for Sediment Quality

Branch Name	Parameter	2020 Grade	2023 Grade	Date Range
Broad Creek	-	-	-	-
Eastern Branch	tpah	D	D	1998 to 2022
Main Stem	tpah	C	C	1998 to 2022
Indian River	-	-	-	-
Lafayette River	tpah	B	A	1998 to 2022
Paradise Creek	-	-	-	-
Southern Branch	tpah	F	F	1998 to 2022
Western Branch	tpah	C	B	1998 to 2022

Table 35: Status of Sediment Quality by branch.

Branch Name	Date Range	Status	Rational
Broad Creek	-	-	-
Eastern Branch	1998 to 2022	Upward/ Improving	Trend based on active cleanup efforts
Main Stem	1998 to 2022	No Change	
Indian River	-	-	-
Lafayette River	1998 to 2022	No Change	Improved letter grade is related to a grading scheme change
Paradise Creek	-	-	-
Southern Branch	1998 to 2022	Upward/ Improving	Trend based on active cleanup efforts
Western Branch	1998 to 2022	No Change	Improved letter grade is related to a grading scheme change

Figure 7: Dr. Mike Unger using a Ponar Sampler to collect sediment samples in the Elizabeth River.

FISH CANCER RESEARCHERS

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PURPOSE

The health status of mummichog (*Fundulus heteroclitus*) reflects habitat quality where the fish reside. Prior studies have shown that mummichog exposed to elevated concentrations of polycyclic aromatic hydrocarbons (PAHs) develop lesions and cancer in their liver tissues. The health status of mummichog from contaminated and remediated sites in the Elizabeth River is used to track progress in cleaning up contaminated sites. 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.

METHODS

Fish collections for the 2023 scorecard: A total of 60 of the largest mummichogs captured at each site were collected within the Elizabeth River system at each of 10 study sites (600 fish total). Fish were collected in October of 2021. The 600 mummichog livers were processed for routine paraffin histology by the VIMS Shellfish Pathology Laboratory. Dr. Hamish Small reviewed the resulting slides and recorded and prevalence of precancerous liver lesions (Total Altered Foci; TAF) and liver cancers (Total Hepatic Neoplasms; THN). Methods were the same as the 2020 scorecard except that %Total Hepatic Neoplasms (%THN) were recorded rather than %Total Neoplasms (%TN). A better-defined letter grade criteria was also established for this scorecard (Table 36; Letter grades in Table 37). Only a single site (Republic Creosote) is used for the Southern Branch score (6 additional sites within the Southern Branch were assessed and details presented in the raw data section, Table 38).

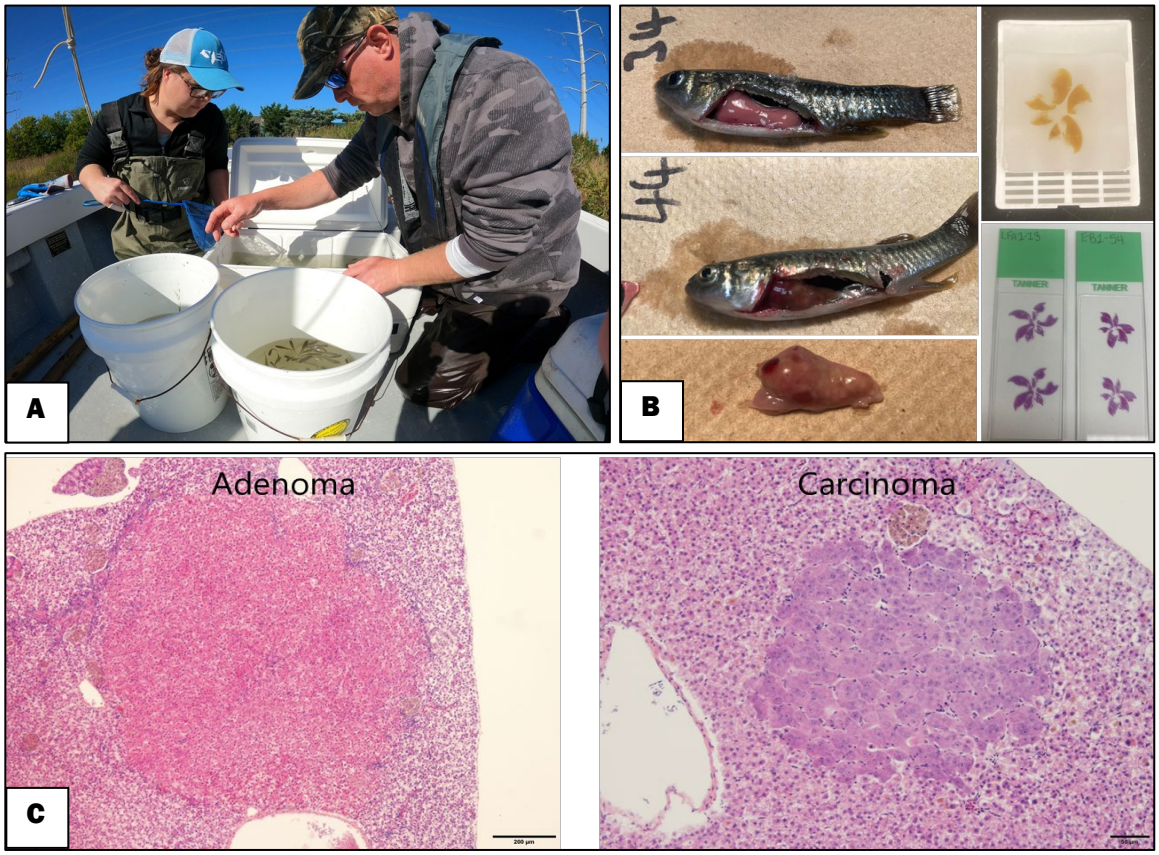

Figure 8: Mummichog were captured using standard metal minnow traps baited with frozen blue crab. (A) The largest 60 fish from each sited were collected and (B) processed for routine paraffin histology and (C) reviewed for precancerous lesions and liver cancer.

Table 36: Grading criteria for Fish Cancer

Letter Grade	Criteria
A	≤2% TAF, 0% THN
B	>2 ≤5% TAF, 0% THN
C	>5-10% TAF, <2% THN
D	>10% TAF, ≤5% THN
F	>10% TAF, >5% THN

Table 37: Letter grades for Fish Cancer

Branch Name	# Samples	# Sites	%TAF (2023)	%THN (2023)	2020 Grade	2023 Grade	Date Range
Broad Creek	-	-	-	-	-	-	-
Eastern Branch	60	1	75	26.7	F	F	10/18/2021
Main Stem	-	-	-	-	-	-	-
Indian River	-	-	-	-	-	-	-
Lafayette River	60	1	8.3	0	C	C	10/20/2021
Paradise Creek	-	-	-	-	-	-	-
Southern Branch	60	1*	28.3	0	F	D	10/6/2021
Western Branch	60	1	3.3	0	A	B	10/20/2021

*The worst site sampled on the Southern Branch, Republic Creosote, was used in to determine the grade in 2023. See Raw Data.

Table 38: Raw data for Fish Cancer

Date	Location	Location Code	Branch	Total Samples	%TAF	%THN	Grade
10/20/2021	Lafayette River	LFA	Lafayette Branch	60	8.3	0	C
10/20/2021	Western Branch	WB	Western Branch	60	3.3	0	B
10/18/2021	Colonna's Shipyard	CS	Eastern Branch	60	75	26.7	F
10/18/2021	Scuffeltown Creek B	SC-B	Southern Branch	60	8.3	0	C
10/18/2021	Atlantic Wood	AW-B	Southern Branch	60	0	0	A
10/6/2021	Republic Creosote	RC	Southern Branch	60	28.3	0	D
10/6/2021	Blow Creek	BC	Southern Branch	60	1.7	0	A
10/4/2021	Money Point Phase 3	MP3	Southern Branch	60	3.3	0	B
10/4/2021	Money Point Phase 2	MP2	Southern Branch	60	1.7	0	A
10/6/2021	Money Point Phase 1	MP1	Southern Branch	60	3.3	0	B

3. SIDEBARS EXPLORED

JUVENILE FISH TRAWL SURVEY

Elizabeth River Fisheries Monitoring: Fall/Winter Survey

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The Virginia Institute of Marine Science Juvenile Fish Trawl Survey (Trawl Survey) completed monthly monitoring at two fixed sites in the Elizabeth River between September 2021 and March 2022 and again during the same period the following fall/winter 2022-2023. We targeted the fall and winter to assess the importance of the Elizabeth River as nursery habitat for juvenile American shad, blueback herring, and alewife. Sampling was conducted in the same manner as other sites routinely visited by the Trawl Survey so that future comparisons could be made with sites in the lower James River. In each year (from September to March) we completed 14 tows in the Elizabeth River. We captured 2,971 individuals from 33 species at the two sites in the Elizabeth River the first fall/winter 2021-2022, and 4,399 individuals from 25 species in fall 2022. Though we completed trawling in winter 2023, data are not yet available. Bay anchovy was the most numerous species captured in all seasons. Bay anchovy is a forage species that is consumed by many predators and tend to occur in large numbers compared with other species. Importantly, we confirmed the use of the Elizabeth River as a nursery habitat for juvenile American shad, and blueback herring; these species are under fishing moratoria due to historically low numbers throughout the east coast of the US. Furthermore, other managed species such as blue crab, white shrimp, spotted seatrout, summer flounder, weakfish, black sea bass, and Atlantic menhaden were also captured demonstrating that a variety of commercially and recreationally important species are making use of the Elizabeth River. This monitoring effort will continue and will provide much needed information on aquatic resources found in Elizabeth River habitats. Check out the story map link below to see some of the species we have encountered as well as a brief description of the methods we use.

Table 39: Species captured by VIMS Juvenile Fish Trawl Survey at two sites in the Elizabeth River. Shown are total counts for each species by month for fall and winter and the total caught each month and each species. Missing values indicate that none were captured that month.

	2021				2022							
	Fall				Winter			Fall				Total by
Species	September	October	November	December	January	February	March	September	October	November	December	species
American Shad							7					7
Atlantic Croaker	1	8		6	4			43	1	2	1	66
Atlantic Cutlassfish	2											2
Atlantic Menhaden					9	13						22
Atlantic Moonfish	1									1		2
Atlantic Silverside					11						2	13
Bay Anchovy	1,263	169	628	213	38	61	407	2,204	32	4	1,433	6,452
Black Sea Bass	1	1								2		4
Blackcheek Tonguefish		3		1						1		5
Blue Crab, adult female			1					2		1		4
Blue Crab, juvenile female	1		2	4			1	9	1	3	5	26
Blue Crab, male		1	1	3		1	1	10		3	4	24
Blueback Herring					8							8
Brief Squid	1	5	10						20	17		53
Brown Shrimp	3	2						19		4		28
Fringed Flounder										1		1
Gizzard Shad			2									2
Green Goby	1											1
Hogchoker								1		1		2
Inshore Lizardfish		1						1				2
Lined Seahorse					1							1
Lookdown	1											1
Naked Goby								1				1
Oyster Toadfish	2	1						1		1	1	6
Pigfish	1											1
Pinfish								4				4
Pink Shrimp	1		1	1							2	5
Scup			1					1				2
Seaboard Goby						1						1
Silver Perch	8	18	1	2				79	12			120
Spot	8	1	11	1				384	32	2		439
Spotted Hake							1					1
Spotted Seatrout				1						1		2
Star Drum	1											1
Striped Anchovy	1	2							3	6		12
Striped Searobin				1							1	2
Summer Flounder		1		2				1			1	5
Weakfish		1						34	1			36
White Shrimp				2	1					3		6
Total caught	1,297	214	658	237	72	76	417	2,794	102	53	1,450	7,370

The story map will be updated as new data are collected. https://storymaps.arcgis.com/stories/dcde18fd19c040b3afe4d6bb792fbcb5

Mummichog Tagging Study (2021-2022)

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Mummichog (*Fundulus heteroclitus*) is a common small estuarine finfish found throughout the Elizabeth River watershed. Previous studies have shown that mummichogs inhabiting areas adjacent to historical creosote coating facilities (ex. Atlantic Wood and Money Point) situated within the Southern Branch of the Elizabeth River have high prevalences of liver cancer indicative of exposure to polycyclic aromatic hydrocarbons (PAHs). Mummichog are reported to have extremely small home ranges, which makes them ideal for integrating toxic exposure, and are currently used to as an indicator species to help assess the health of remediated locations within the watershed. However, this home range assumption has never been tested at contaminated locations where fish may move to find more suitable habitat.

In early summer 2021 we trapped approx. 1200 mummichog from two adjacent areas (phase 2 and 3) at Money Point on the Southern Branch of the Elizabeth River. These locations represent PAH-remediated (phase 2) and unremediated (phase 3) habitats. Fish were tagged with small Passive Integrated Transponder (PIT) tags and released alive at their capture location. In 2022 we repeated the process described above except that we tagged 1200 mummichog residing within the artificial marsh at Money Point phase 1. Each PIT tag has a unique identifying number and can be used to record the movement of individual fish. During the summer of 2021 and 2022 at approx. 2, 6, and 10-weeks after tagging mummichog residing in these areas were recaptured and screened for the presence of PIT tags to better understand fish movement at this location in the Elizabeth River.

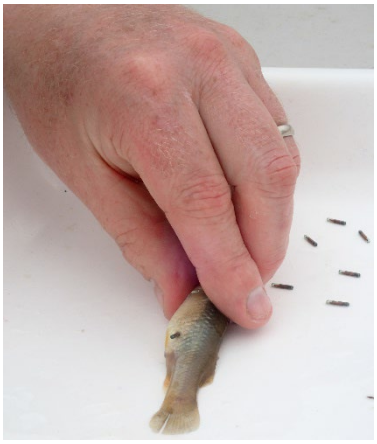

Figure 9: Mummichog with small Passive Integrated Transponder (PIT) tag.

2021: Overall, the majority of mummichog remained within the area they were tagged. However, a small proportion of mummichog originally tagged in phase 3 (unremediated) were recaptured in adjacent areas (phase 2 and downstream of phase 3) indicating that a small portion of the population travel substantial distances.

2022: The majority of mummichog tagged in phase 1 were recaptured in phase 1 during a high tide. Unlike the above areas, the artificial marsh in phase one dries out on low tides forcing the resident fish to leave this area. We found evidence of this as tagged fish were found in adjacent phase two and even travelled into phase 3 which is a considerable distance away.

Overall, our tagging studies suggest that a small proportion of mummichog can range considerable distances. Because of this newly discovered movement, unremediated areas may still influence the rates of cancer formation in fish trapped from adjacent remediated habitats, and that entire areas need to be cleaned up (for example the whole of Money Pt) before we can expect to see the health of fish living in these areas improving.

TBT (Tributyltin) RECOVERY

New direct evidence that the TBT recovery continues!

Mike Unger
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Tributyltin (TBT) 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 for this scorecard to monitor the current conditions in the Elizabeth River to assess the recovery of river biota.

The previous ERP Scorecard showed that TBT levels in the Elizabeth River's waters had decreased over time and were barely detectable, but we still wondered if the potential adverse effects to the River's most sensitive organisms were also diminished. TBT is a known endocrine disrupting compound and can affect hormone levels in some invertebrates, causing sex change and infertility in the populations. In 2021, Dr. Roger Mann's research group at VIMS received funding from the Mid Atlantic Panel on Aquatic Invasive Species (MAPAIS) to evaluate these changes in Rapana Whelks in the Elizabeth River, an invasive species but one that is very sensitive to TBT exposure and a good indicator organism for TBT effects. They found that sex changes in these large snails were diminished relative to the last surveys in 1999-2009. Dr. Mike Unger's lab at VIMS followed up this work with new funding from the Virginia Elizabeth River Monitoring Initiative and found that TBT levels in these same animals were below detection limits, much lower than previous surveys. They also found increased levels of TBT degradation products, further evidence that the TBT left in the sediments of the river is degrading over time. This new work shows that with proper control and remediation efforts, the River can eventually recover from past pollution problems and support a healthier ecosystem.

Figure 10: Tributyltin (TBT) is a biocide additive to antifoulant paints that was used on the bottom of boats and ships. TBT is a known endocrine disrupting compound and can affect hormone levels in some invertebrates, such as the Rapana Whelk, causing sex change and infertility in the populations.

Impact of PAHs pollution on concentrations of human-pathogenic Vibrio species in the Elizabeth River system

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The bacteria *Vibrio vulnificus* and *Vibrio parahaemolyticus* are known for causing vibriosis, an illness acquired after exposure of a wound to estuarine waters or after consumption of raw or undercooked oysters (CDC, 2019). Vibriosis is generally a mild illness limited to gastroenteritis, however, it can become severe and even become fatal in immunocompromised patients.

Figure 11: Dr. Corinne Audemard, Dr. Kristen Prossner and Matt Mainor preparing oyster bags for deployment in an area of know sediment contaminations along Money Point, Chesapeake, VA.

Vibrio vulnificus and *Vibrio parahaemolyticus* occur naturally in estuarine waters and living organisms such as oysters, so they differ from human pathogens such as *Escherichia coli* or norovirus that are associated with human pollution. The risks of becoming infected with *Vibrio* increases when these bacteria are more abundant, so identifying the factors favoring an increase in their abundance is key for minimizing risks of exposure and infection. Warm temperatures are linked to higher abundance of these bacteria in water or in oysters, however, temperature alone does not fully explain their spatial and temporal distribution suggesting that other factors are at play. Based on previous work, the pollution by polycyclic aromatic hydrocarbons (PAHs) is a factor requiring further studies due the potential degradation of this pollutant by *Vibrio* bacteria (West et al., 1984; Hedlund & Staley, 2001).

In this study, we further explored the potential impact of PAHs contamination on *Vibrio vulnificus* and *Vibrio parahaemolyticus* in the Elizabeth River. We conducted our study in the Southern Branch of the estuary (Money Point and Republic) where sites of particularly elevated PAHs levels occur in proximity to sites that underwent remediation. We collected sediment and oyster samples early summer in 2021 and in 2022 and measured both PAHs (using biosensor, Prossner et al., 2022) and *Vibrio* levels (using the FDA method: US FDA, 2010) in these samples.

The *Vibrio* levels observed in this preliminary study tended to be of the same order as levels observed in other lower Chesapeake Bay sites, however, our ability to compare the levels observed in the Elizabeth River to other sites was limited due to the small number of sites and sampling events. With regards to the potential influence of PAHs on these bacteria, we observed a tendency for these contaminants to have either no effect or a negative effect on levels of *V. vulnificus* and *V. parahaemolyticus* in sediment or oysters. These results suggest that in the Elizabeth River, PAHs contamination may not be associated with higher risks of infection with these bacteria.

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5. IMAGE, FIGURE, AND SYMBOL CREDIT

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Figure 9, Page 25; Mummichog Tagging by Mary Bennett.
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Figure 11, Page 27; PAH/ Vibrio Oyster Deployment by Mike Unger.

STATE OF THE ELIZABETH RIVER STEERING COMMITTEE 2023

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

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