Shad in the Classroom
Program Report
(2009–2022)

July 15, 2022

By
Danielle Pender
Shad in the Classroom Program Specialist

Melissa Dowland
Manager of Teacher Education

and

Megan Davis
Coordinator of Teacher Education

North Carolina Museum of Natural Sciences

Table of Contents

Executive Summary

The Shad in the Classroom Program is the result of many dedicated partners. The program is managed by the NC Museum of Natural Sciences (Museum) and it receives significant logistical and financial support from the Albemarle-Pamlico National Estuary Partnership (APNEP), the North Carolina Wildlife Resources Commission (NCWRC), and the U.S. Fish and Wildlife Service (USFWS). For the 2022 program, we received $20,000 in grant funding from APNEP. We also leveraged over $36,500 of in-kind support. Very important to the program are the many volunteers who generously give their time to enhance the program and the dedicated teachers.

The 2022 Shad year operated at closer to "normal" as the effects of the COVID-19 pandemic lessened. Some schools chose to continue to have a "hiatus" year, and one classroom operated completely remotely. The Shad in the Classroom Program reached 295 classrooms from 2009 to 2022 (Appendix A, Table 7) and many thousands of students. Between 2013─2022, approximately 20,019 students were reached (prior to 2013, the numbers of students were not tracked). Twenty-nine classrooms participated in 2022 (Table 1) with 8 of those being new to the program. Over 2,200 (2,245) students participated in the program this year and 871 participated in river releases.

Table 1. 2022 Schools Accepted to the North Carolina Shad in the Classroom Program

School	County	Numbers of Classes
Abbotts Creek ES	Wake	1
Bertie Early College HS	Bertie	1
Central Park School for Children ES	Durham	1
Exploris ES	Wake	1
Falls Lake Academy	Wake	1
First Flight MS	Dare	2
Fuquay Varina MS	Wake	3
George Moses MS	Chatham	1
Knightdale ES	Wake	1
Lakewood Montessori Middle School	Durham	2
Lincoln Heights Environmental Connections Magnet ES	Wake	1
Oberlin Magnet MS	Wake	1
Perquimans County HS	Perquimans	2
PreEminent Charter School	Wake	1
Roanoke Rapids HS	Halifax	1
Seawell ES	Orange	1
Sherwood Githens MS	Durham	2
Smithfield-Selma Senior HS	Johnston	1
South Iredell HS	Iredell	1
Terrell Lane MS	Franklin	1
Wakefield MS	Wake	2
Woods Charter MS	Chatham	1
Total Number of Schools		**22**
Total Number of Classrooms		**29**

Current new tank construction of the red tub style tanks cost approximately $406 per tank system. The plexiglass tank systems cost approximately $606 per tank system. Other substantial expenses include tank refurbishment, chemical resupply, teacher training workshop, teacher professional development trek, school field trips to release sites, travel for egg delivery, and part-time staff.

In the years from 2013–2022 (excluding 2020), each school received approximately 1,000 eggs from the NCWRC. Beginning in 2011, shad embryos were received from the Neuse River and the Roanoke River and were released in the river basin of their parentage. Starting with the 2019 season, stocking is not part of the NCWRC's American Shad Management Plan at this time. The Shad in the Classroom Program is only working with Neuse River American Shad and schools in this program are the only ones releasing American Shad in North Carolina, which are all released in the Neuse River Basin.

In summary, the Shad in the Classroom program has been led and administered by the Museum since 2011. Over the years, state and federal agencies and NCSU have played significant roles in the implementation of the program, including:

- Abermarle-Pamlico National Estuary Partnership (APNEP)
- Dominion Power
- East Carolina University (ECU)
- National Fish and Wildlife Foundation
- North Carolina Chapter of the American Fisheries Society
- North Carolina State University (NCSU)
- North Carolina Wildlife Resources Commission (NCWRC)
- United States Fish and Wildlife Service (USFWS)

American Shad have ecological, economic, and historical importance to North Carolina and much of the eastern coast of the U.S. Through the Shad in the Classroom program, students get a hands-on and real-life connection with learning about their environment while addressing the importance of American Shad restoration and water quality. Teachers report a great enthusiasm for themselves and their students through the program.

ACKNOWLEDGEMENTS

We would like to acknowledge all of the teachers and volunteers who help implement the Shad in the Classroom Program each year. The teachers and volunteers are dedicated to making the program a success and are invaluable. Specific individuals who assisted with various aspects of the program that could occur for 2021 are listed below.

Workshop Guest Speaker

Todd VanMiddlesworth todd.vanmiddlesworth@ncwildlife.org – (NCWRC, District Fisheries Biologist)

Additional Education

Fish Anatomy-Dissection Lecture
Ambar Torres Molinari atorre22@ncsu.edu – (NCSU, Grad Student) – Lecturer
Ben Makhlouf bmakhlo@ncsu.edu – (NCSU, Grad Student) – Lecturer
Chase Spicer spicerc21@students.ecu.edu – (ECU, Grad Student) – Lecturer
Clayton Lynch clynch3@ncsu.edu – (NCSU, research technician) - Lecturer
Grace Fields gnfields@ncsu.edu – (NCSU, Student) – Lecturer
Kelsey Roberts kelsey.roberts@ncwildlife.org– (NCWRC, District Fisheries Biologist) – Lecturer
Madi Polera mpolera2@ncsu.edu – (NCSU, Grad Student) – Lecturer
Reece Warfel warfelz16@students.ecu.edu – (ECU, Grad Student) – Lecturer
Tabitha Hille tmhille@ncsu.edu – (NCSU, Student) – Lecturer

Virtual Fish Anatomy-Dissection Lecture
Laura-Beth Speer laura.speer@naturalsciences.org – (Museum, coordinator of offsite and virtual outreach) – Moderator

Egg Delivery and Larvae Release Assistance

Cicero Stutts cicero.stutts@naturalsciences.org – (Museum, Guest & Volunteer Services)
Heather Jennings Heather.B.Jennings@ncdenr.gov – (APNEP, Program Manager)
Jerry Reynolds jerry.reynolds@naturalsciences.org – (Museum, Head of Outreach)
Jimmy Johnson jimmy.johnson@ncdenr.gov – (APNEP, Coastal Habitats Coordinator)
Lydia Jones lydia.jones@naturalsciences.org – (AmeriCorps Member)
Stacey Fekin stacey.feken@apnep.org – (APNEP, Policy and Engagement Manager)
Taylor Prichard taylor.prichard@naturalsciences.org – (Outdoor Curriculum Specialist, AmeriCorps Member & Teacher Education Specialist)
Dr. Tim Ellis tim.ellis@ncdenr.gov – (APNEP, Quantitative Ecologist)

In addition, we are very appreciative of the fish donations from Dr. Jim Rice, Dr. Rich Noble, Dr. Phil Doerr, and fellow anglers, and from NCWRC district biologists Kelsey Roberts and Seth Mycko, and from ECU graduate students, Chase Spicer and Reece Warfel. We greatly appreciate Todd VanMiddlesworth, Ben Ricks, and Landon Beaver at NCWRC and for coordinating shad weeks with us, and for their collection of American Shad broodstock. American Shad embryos were generously provided by Jeff Evans and the staff at the Watha State Fish Hatchery. We also appreciate Ryan Tharp, NCSU, for assisting with organizing NCSU students for the fish anatomy-dissection lessons.

Report cover photos: Top left – Seawell ES fish dissection/anatomy lesson; Bottom left – Lakewood Montessori MS egg sort; Middle – Woods Charter MS release at The Confluence Natural Area (Eno River); Right – Exploris ES release at Raleigh Beach (Neuse River) aquatic critter sampling and viewing station.

Shad in the Classroom Program 2022 Report

This report summarizes the activities accomplished for the 2022 Shad in the Classroom Program. Twenty-nine classes at 22 different schools (Table 1) were accepted into the 2022 program: 6 elementary, 17 middle, and 6 high school classes. Thirty-one classes were originally accepted, however, two had to withdraw due to issues with their school logistics. In addition, 6 classes (including Cape Fear River Watch) opted to have a hiatus year due to continued Covid-19 complications and adjustments.

Photo 1. Teacher virtual training

Yearly program planning began with forming a timeline (Figure 1), reviewing applications, and conducting a tank and parts inventory. Several teachers attended a virtual orientation and training session in February by Zoom Conference, and some attended a tour of the Watha Fish Hatchery and a lesson on submerged aquatic vegetation in Hampstead.

Photo 2. Chase Spicer, Perquimans HS Fish Anatomy lesson

Returning to their schools, teachers typically began preparing their classrooms for the arrival of the Shad eggs 2–4 weeks prior to receiving the eggs in April. NCWRC American Shad broodstock collection began the week of April 4th. There were some complications with the shad arriving later than expected, but we were able to accommodate most classes. Classes released the shad larvae primarily on the Thursday or Friday of the week that they received them. Many of the classes took advantage of an in-person fish anatomy and dissection lecture by NCSU and ECU students and by Kelsey Roberts, NCWRC, or an online lesson by Zoom conference. This year we contracted with Art Works to video document the impact of the Shad Program on one of the classes from start to finish and to add a video on how to build the clear tank.

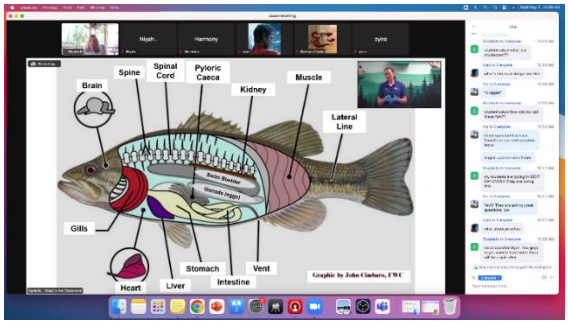
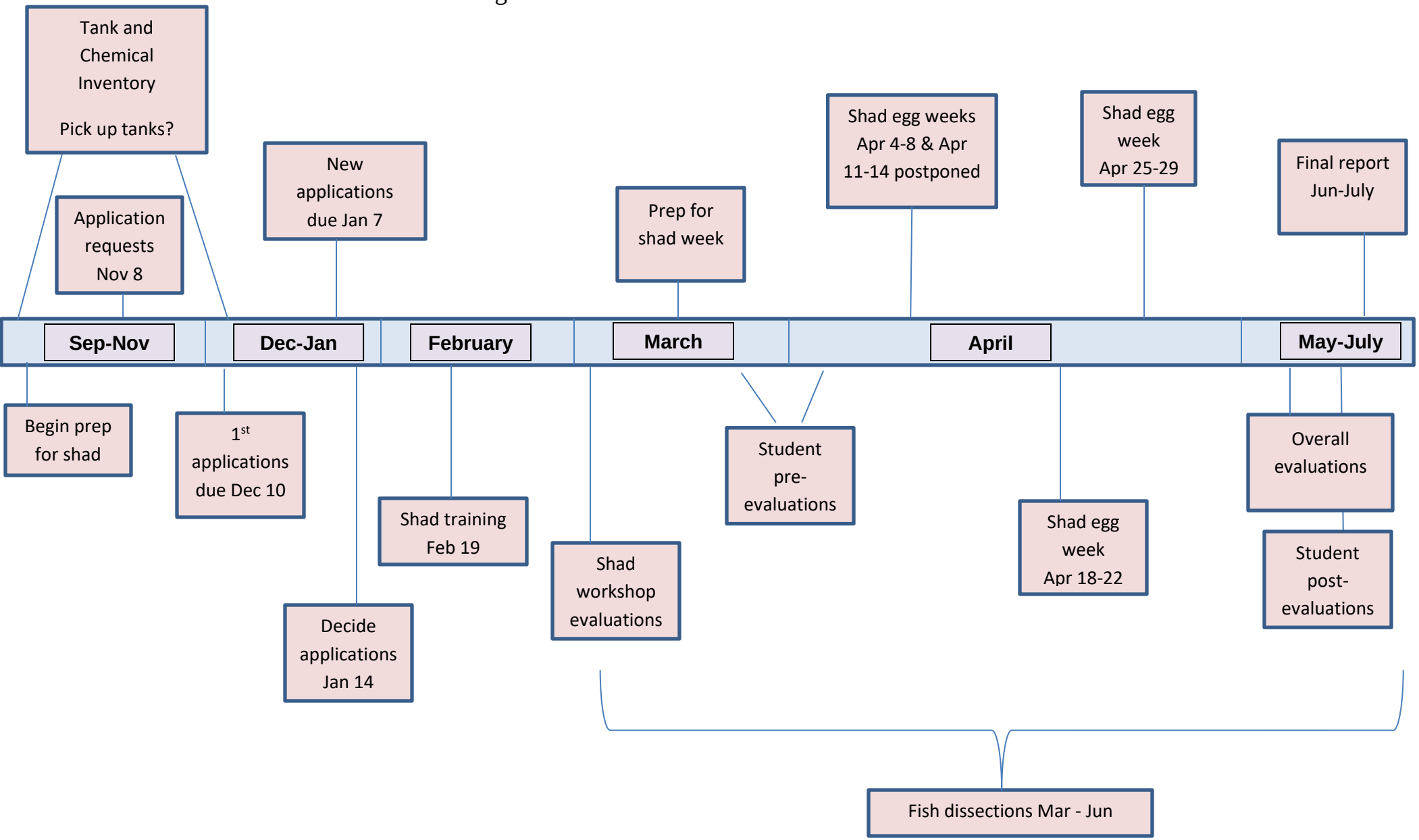


Photo 3. Largemouth bass anatomy graphic – zoom lesson

Photo 4. Art Howard filming the shad release by Exploris ES students at Raleigh Beach

Figure 1. Shad in the Classroom 2022 Timeline



Tank Inventory

At the start of the program, tank parts and chemicals were inventoried, and items purchased as needed. Tanks were retrieved from schools no longer participating in the program. Existing tanks were refurbished, as needed, with the assistance of Museum exhibits staff. Museum exhibits staff were able to construct five new tank plexiglass tank systems. An updated inventory list is on file.

Teacher Orientation and Training

Photo 5. T.D. VanMiddlesworth Lecture.

A teacher orientation and training session was conducted on February 19, 2022. Danielle Pender and Melissa Dowland co-led the session. NCWRC District Biologist, T.D. VanMiddlesworth guest lectured on American Shad Management. In addition to being provided information about American Shad life history, restoration, and management, teachers received instructions for raising shad and learned ways to incorporate shad and aquatic ecology into their curriculum. Teachers also participated in a shad origami activity.

> "They're great, enthusiastic, knowledgeable, and so very helpful (as well as kind and patient with the newbees)."

Photo 6. Shad programming information

Photo 7. Shad origami activity

Thirteen teachers attended the 2022 workshop. All responded to the 9-question survey regarding the workshop. Of the 9 questions, 5 were quantitative and are included in Table 2. For the qualitative

responses, many reported that they appreciated learning about recent conservation and management efforts. One reported that they liked the breakout rooms, similar to what we did last year, and many are hopeful we are in person next year. Overall, most teachers reported that they were very to extremely satisfied with the workshop and that the concepts were explained very to extremely well (Table 2). We held two separate zoom conference for water quality and gyotaku (fish printing) practice at a later date. Five teachers attended the water quality practice, and none attended they gyotaku demonstration, but both were recorded (as was the workshop) for the convenience of the teachers to view at another date.

Table 2. Virtual Workshop Survey Results

Question	Response variable
This workshop refreshed my knowledge of the importance of the shad restoration and management program.	77% (10) extremely well; 12% (3) very well
T.D. effectively explained current American Shad management	62% (8) extremely well; 38% (5) very well
This workshop refreshed my knowledge of the life history of shad.	69% (9) extremely well; 31% (4) very well
This workshop refreshed my knowledge of the proper components to raising shad eggs to the larval stage.	69% (9) extremely well; 31% (4) very well
Overall, how satisfied are you with the workshop?	85% (11) extremely well; 15% (2) very well

Eight teachers and educators attended the Watha State Fish Hatchery tour conducted by Jeff Evans, and 5 were able to go on to also attend the submerged aquatic vegetation (SAV) field lesson at Hampstead. Teachers indicated that they enjoyed these activities and the learning experience.

Photo 8. Watha hatchery tour

Photo 9. SAV exploration

Egg Delivery and Larval Fish Release

We coordinated the arrival of the eggs and the release of the larval fish with the schools, hatchery, drivers, and fisheries biologists. This involved foremost the timing of the spawning of the American Shad, but also considered school schedules. Although American Shad collection began the week of March 28th, the water was too cool to collect the fish. Shad were successfully collected the week of April 4th; however, they did not productively spawn. Another two weeks of sampling resulted in successful American Shad broodstock collection and spawning for the weeks of April 18th and 25th. One class had to drop out of the program for 2022 due to the changes. Many people assisted with the delivery of the eggs and with the release of the larval fish and are mentioned in the acknowledgments.

Photo 10. S. Iredell HS release Gold Park Eno River

Photo 11. Roanoke Rapids HS release Anderson Point Park.

Classes were originally divided into three groups. However, due to the circumstances listed above regarding collection and spawning, classes were moved to the Week of April 18th or Week of the 25th. Classes received their embryos on the Monday of those weeks and released on the Thursday or Friday of the same week. Twelve classes were scheduled to release on Thursday 4/21, 9 on Friday 4/22, 6 on Thursday 4/28, and 2 on Friday 4/29 (Table 3, Figure 2). Classes received approximately 1,000 eggs according to the hatchery; however, some classes reported receiving a different number (Table 4). Most classes had students at the release (871 students attending). However, four teachers elected to release "virtually" for their students. A few classes that had "failed" tanks did not attend a release; however, one class that had an unsuccessful tank did attend the scheduled "release" and participated in activities such as aquatic invertebrate sampling and nature journaling.

Photo 12. Seawell ES release Gold Park Eno River (measuring water quality)

Photo 13. Lakewood Montessori MS release West Point Eno (invert sampling).

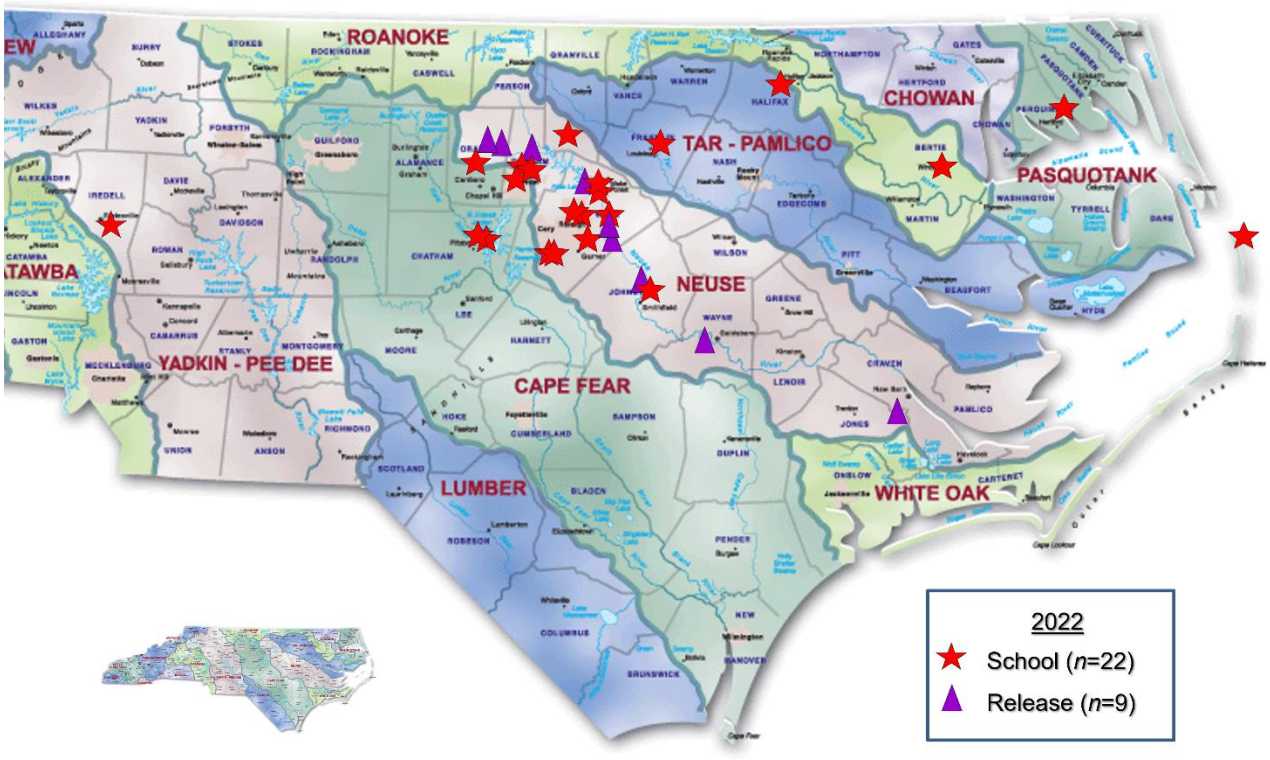
Table 3. Egg and Larval Release Timing and Release Site Information

Educator	School	Received Eggs	Released Eggs/Larva	Neuse River Release Site
Annah Riedel/Maggie Gargan	Exploris ES	4-18-2022	4-21-2022	Raleigh Beach
Audrey Siple	Wakefield MS	4-18-2022	4-22-2022	Falls Dam
Beth Selig	Fuquay Varina MS	4-18-2022	4-21-2022	Smithfield Boat Ramp
Brian Reynolds	Bertie Early College HS	4-25-2021	4-28-2022	Falls Dam
Corie Hlavaty	Lakewood Montessori MS	4-18-2022	4-21-2022	West Point Eno
Courtney Sykes	Falls Lake Academy	4-18-2022	4-21-2022	Falls Dam
Douglas Poole (larvae released by K.Russel)	Perquimans County HS	4-25-2021	4-28-2022	Cliffs of the Neuse State Park
Elizabeth Hartel	Knightdale ES	4-18-2022	4-22-2022	Anderson Point
Endiga Holdness	Fuquay Varina MS	4-18-2022	4-21-2022	Smithfield Boat Ramp
Fred Pfeiffer	Lakewood Montessori MS	4-18-2022	-	West Point Eno
Gina Bobbitt	PreEminent Charter MS	4-18-2022	4-21-2022	Anderson Point
Harlyn Strongoli	Sherwood Githens MS	4-18-2022	-	Falls Dam
Judy Compton	Central Park School for Children ES	4-18-2022	4-21-2022	Cliffs of the Neuse State Park
Kaley Kiffner	First Flight MS	4-25-2021	4-28-2022	Lawson Creek Park
Karel Klepacki	Smithfield-Selma Senior HS	4-18-2022	4-22-2022	Smithfield
Kelly Russel	Perquimans County HS	4-25-2021	4-28-2022	Cliffs of the Neuse State Park
Kim Collier	Roanoke Rapids HS	4-25-2021	4-29-2022	Anderson Point
Krista Brinchek	Abbotts Creek ES	4-18-2022	4-22-2022	Falls Dam
Kristin Ball	Wakefield MS	4-18-2022	4-22-2022	Falls Dam
Lanier “Branson” Phillips	Sherwood Githens MS	4-18-2022	-	Falls Dam
Lenae Scafidi	South Iredell HS	4-18-2022	4-22-2022	Gold Park
Mary Weinandy	First Flight MS	4-25-2021	4-28-2022	Lawson Creek Park
Matthew Lanner	Fuquay Varina MS	4-18-2022	4-21-2022	Smithfield Boat Ramp

Table 3. Egg and Larval Release Timing and Release Site Information Continued

Educator	School	Received Eggs	Released Eggs/Larva	Neuse River Release Site
Megan Jackson/Laura Wood	Lincoln Heights Environmental Connections Magnet ES	4-18-2022	4-22-2022	Anderson Point
Richard Kowaleski	Oberlin Magnet MS	4-18-2022	4-21-2022	Lassiter Mill
Rose Syroid	George Moses MS	4-25-2021	4-28-2022	Raleigh Beach
Sonja Younger	Woods Charter MS	4-18-2022	4-21-2022	The Confluence Natural Area, Hillsborough
Susette McConnell	Terrell Lane MS	4-25-2021	4-29-2022	Falls Dam
Virginia Jones	Seawell ES	4-18-2022	4-21-2022	Gold Park

Figure 2. ─ School and release site locations (approximate)



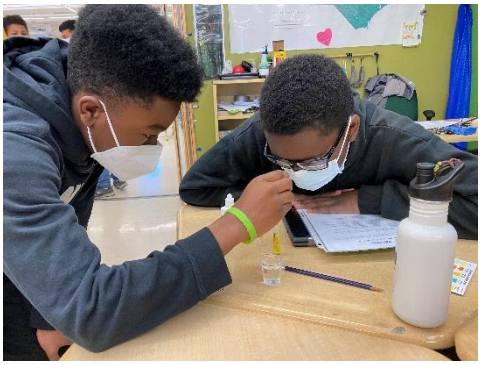


Photo 14. Lakewood Montessori MS measuring tank water quality

Overall, the shad rearing and release was fairly successful for most schools, but with a few issues for some. Each class was to receive approximately 1,000 embryos; however, counts may differ as to what the school reported receiving. Some teachers reported only the viable eggs "to start" and others reported all that they received. This difference in reporting may affect the percent survivability reported. This year 21 classes received their embryos on, Monday, April 18th and 8 received them on Monday, April 25. Several schools were re-scheduled for their embryo delivery date due to river water temperatures and spawning complications while at the hatchery, correspondingly releases were also rescheduled. Of those that turned in their water quality information (26), many that had lower survivability also reported water quality issues. Three reported higher temperature ranges, four reported low alkalinity values, and one reported a spike in ammonia. One class reported having low survivability due to tank mechanical issues. It is possible that water quality issues contributed to lower than 50% survivability for some schools. For those that reported ≥75%, 5 reported high alkalinity values, maintaining lower temperature ranges throughout the week, or both.

Overall, the percent survival ranged from a low of 0% to a high of 95% and averaged 41% (Table 4). Seventeen classes averaged ≤ 50%, 12 averaged >50%, and 8 averaged ≥75% survival to release. There were 9 classes that averaged 10% survivability or below. Average survivability was reported at 41%, which was higher than 2021 (35%) but lower than 2019 (53%). The percent of classes that were in the ≥75% (28%) category followed similarly with being higher than 2021 (11%) but lower than in 2019 (34%) (no shad were raised in 2020 due to Covid-19).

Table 4. Egg and Larval Survival and Release Numbers

Educator	School	No. Eggs Received	No. Eggs/Larva Survived to Release	Percent Survival (%)
Annah Riedel/Maggie Gargan	Exploris ES	800	400	50
Audrey Siple	Wakefield MS	500	350	70
Beth Selig	Fuquay Varina MS	1080	0	0
Brian Reynolds	Bertie Early College HS	1000	750	75
Corie Hlavaty	Lakewood Montessori MS	1000	0	0
Courtney Sykes	Falls Lake Academy	1000	350	35
Douglas Poole (larvae released by K.Russel)	Perquimans County HS	877	7	1
Elizabeth Hartel	Knightdale ES	1000	237	24
Endiga Holdness	Fuquay Varina MS	1000	600	60

Table 4. Egg and Larval Survival and Release Numbers Continued

Educator	School	No. Eggs Received	No. Eggs/Larva Survived to Release	Percent Survival (%)
Fred Pfeiffer	Lakewood Montessori MS	900	0	0
Gina Bobbitt	PreEminent Charter MS	1000	854	85
Harlyn Strongoli	Sherwood Githens MS	1000	0	0
Judy Compton	Central Park School for Children ES	957	500	52
Kaley Kiffner	First Flight MS	830	370	45
Karel Klepacki	Smithfield-Selma Senior HS	1000	1	0
Kelly Russel	Perquimans County HS	1000	50	5
Kim Collier	Roanoke Rapids HS	1000	800	80
Krista Brinchek	Abbotts Creek ES	800	30	4
Kristin Ball	Wakefield MS	1000	600	60
Lanier "Branson" Phillips	Sherwood Githens MS	1000	0	0
Lenae Scafidi	South Iredell HS	1000	839	84
Mary Weinandy	First Flight MS	1000	900	90
Matthew Lanner	Fuquay Varina MS	1000	800	80
Megan Jackson/Laura Wood	Lincoln Heights Environmental Connections Magnet ES	1000	300	30
Richard Kowaleski	Oberlin Magnet MS	500	200	40
Rose Syroid	George Moses MS	1000	800	80
Sonja Younger	Woods Charter MS	1000	950	95
Susette McConnell	Terrell Lane MS	1000	200	20
Virginia Jones	Seawell ES	400	75	19
Average survival percent				**41**

"I would say there was overall more engagement from my class during the shad unit compared to other units."

"Students are overall very motivated to engage with aquatic biology and fish conservation. I also think students are emerging with a deeper and more nuanced understanding of ecology and conservation issues surrounding American Shad."

Teachers reported that the program creates enthusiasm with their students and increased their involvement in science and conservation issues. Many reported that the students learn more and are more engaged. The Shad Program increases students' interest and confidence in science. We have received great feedback on the program from the teachers throughout the 2022 program year.

Photo 15. Lakewood Montessori MS release West Point Eno (invert sampling)

Additional Student Education

In addition to learning concepts related to the shad survival, cultural and biological importance of the species, its ecological connections to community assemblages and habitat, and the significance of genetic integrity, we have made available additional educational activities to enhance the program. All teachers responded to the program evaluation survey (Table 5).

Gyotaku (fish printing)

We purchased enough American Shad polyurethane plastic casts so that every class who wanted to have a set for their class to do the Gyotaku activity would have one. The kit consists of 4 shad casts, supporting instructions, and prints of American Shad photos. Schools provide the paint and materials to print on (e.g., t-shirts, bags, posters). Thirteen classes reported doing this activity and that it enhanced learning.

Photo 16. Exploris ES release Raleigh Beach (sporting their shad shirts)

Fish Dissection

Photo 17 Ambar Torres (NCSU grad student) conducting a fish anatomy lesson at Fuquay-Varina MS

We coordinated with the NC State University (NCSU) Student Fisheries Subunit, the East Carolina University (ECU) Student Fisheries subunit, and the NCWRC Division of Inland Fisheries to conduct fish anatomy/morphology and dissection lessons. Nine students and educators from NCSU, ECU, and the NCWRC volunteered (listed in acknowledgments) to conduct these lessons. Danielle also conducted one virtual lecture by Zoom Conferencing. Because of these volunteers and the generosity of fish donations (211 fish), we were able to facilitate the dissection lecture for 13 classrooms (753 students). Ten teachers (3 had not had their lessons yet at the time of filling out the survey; Table 5) reported that these lectures enhanced learning.

Photo 18. Reece Warfel (ECU grad student) conducting a fish anatomy lesson at Perquimans HS

Photo 19. Danielle conducting a virtual fish anatomy lesson from the NCMNS

"Grace was wonderful, and the experience was something I would not normally get to do with the kids. The kids really enjoyed it."

"By the end they were regularly using vocabulary accurately and able to identify various parts of the fish."

Curriculum Activities and Videos

We continually add or update supplementary materials for the teachers to use to augment the learning process in the classroom and at the release. This year we revamped the NCMNS website and all materials, activities, and exercises have all been uploaded and are shared with the teachers on a Google Drive site. This updated location and format will make it easier for the teachers and the public to find materials on shad. Materials include, but are not limited to, a lifecycle activity, a Shad Scent exercise, Shad pipette art, Fintastic Sort, a dichotomous key activity, a guide for stream sampling, a watershed GIS exercise, a genetic exercise, and materials provided by the teachers. Recent additions include How old is your Shad (10 reported it useful), an update to Wishes of Fishes (6 reported it useful), and a shad origami activity (was not included in the final survey). (See Table 5 for the analysis of activities and videos)

Photo 20. Shad origami examples

We developed short videos focusing on the diversity of North Carolina fish/aquatic biologists and accompanying questions in 2020 (10 reported enhanced learning). Five of the videos were conducted at the end of the Shad 2020 season and 2 additional interviews were conducted in the Fall of 2020. These videos were created as an attempt to address the difference in learning revealed in the student surveys from 2016−2019 (and continued in 2021-2022) where students who self-identified as white showed greater increases in learning relative to students who self-identified as other races, particularly those that self-identified as Black or African American and Hispanic or Latino (see Student Analytics 2016−2019 –

Appendix B). We hope that having the opportunity to hear from experts from diverse backgrounds will help students of color to picture themselves pursuing careers more readily in science and/or fisheries.

The genetic based exercise, "Who's your Shaddy", (developed in 2013 and updated in 2014) was continued. Six teachers (2 high schools and 4 middle schools) reported this exercise was "just right" as far as understandability and complexity for their students. Additional curriculum activities are available for the teachers to use including Food Web Activities (21 reported as useful), GIS Watershed Activity (8 reported as useful), How Old is your Shad (10 reported as useful), Shad Lifecycle Activity (27 reported as enhanced learning), Dichotomous Key Activity (8 reported as enhancing learning), Fintastic Sort (6 reported as enhanced learning), Shad Scents (8 reported as enhanced learning), and a pipette art activity (5 reported as enhancing their learning). Seven videos were created for the program previously, most teachers reported using at least some videos, and many reported that they were very useful.

Table 5. Additional Education and Video Use Survey Results

Question	Response variable
Biologist Interviews – enhance learning?	10% (3) greatly enhanced; 24% (7) enhanced; 66% (19) did not use
Dichotomous Key – enhance learning?	7% (2) greatly enhanced; 17% (5) enhanced; 3% (1) somewhat; 72% (21) did not use
Fintastic Sort – enhance learning?	3% (1) greatly enhanced; 14% (4) enhanced; 3% (1) somewhat; 79% (23) did not use
Food Web Activities – usefulness?	34% (10) very useful; 28% (8) useful; 10% (3) somewhat; 28% (8) did not use
Fish Dissection – enhance learning?	21% (6) greatly enhanced; 7% (2) enhanced; 72% (21) did not attend
Fish Dissection (virtual) – enhance learning?	14% (4) greatly enhanced; 86% (25) did not attend
Genetic Exercise – complexity or understanding?	21% (6) just right; 7% (2) too hard; 72% (21) did not use
GIS Watershed Activity – usefulness?	7% (2) very useful; 21% (6) useful; 72% (21) did not use
How Old is Your Shad?	24% (7) useful; 10% (3) somewhat; 66% (19) did not use
Shad Lifecycle Activity – enhance learning?	45% (13) greatly enhanced; 41% (12) enhanced; 7% (2) somewhat; 7% (2) did not use
Shad Pipette Art – enhance learning?	7% (2) enhanced; 10% (3) somewhat; 83% (24) did not use
Shad Scents – enhance learning?	10% (3) greatly enhanced; 17% (5) enhanced; 3% (1) somewhat 69% (20) did not use
Wishes of Fishes Activity – usefulness?	10% (3) very useful; 7% (2) useful; 3% (1) somewhat useful; 79% (23) did not use
Video -Add the eggs – usefulness?	38% (11) very useful; 34% (10) useful; 3% (1) somewhat; 24% (7) did not use
Video –Build the Tank – usefulness?	28% (8) very useful; 24% (7) useful; 3% (1) somewhat; 45% (13) did not use
Video – Fish Passage – usefulness?	31% (9) very useful; 28% (8) useful; 7% (2) somewhat; 34% (10) did not use
Video – History – usefulness?	66% (19) very useful; 28% (8) useful; 3% (1) somewhat; 3% (1) did not use

Table 5. Additional Education and Video Use Survey Results Continued

Question	Response variable
Video – It is Time usefulness?	31% (9) very useful; 21% (6) useful; 7% (2) somewhat; 41% (12) did not use
Video - Lifecycle – usefulness?	59% (17) very useful; 31% (9) useful; 3% (1) somewhat; 7% (2) did not use
Video – Overview – usefulness?	38% (11) very useful; 41% (12) useful; 7% (2) somewhat useful; 14% (4) did not use

Additional Teacher Education Programs

On April 9-10, we conducted a Secrets of the Swamp Educator Trek, a one-night canoe camping trip on tributaries of the Roanoke River. Ten educators participated in this workshop. We covered topics including the flora and fauna of the bottomland hardwood forest with a specific focus on birds, trees, and aquatic organisms; historical representations of species native to the area; and nature journaling. Participants were overwhelmingly satisfied with the experience and rated the workshop as "excellent."

Program Outcomes

Student Impact

The Shad in the Classroom Program exposes students to important science and math concepts including those listed below.

1. History, cultural and biological importance, and life cycle of the American Shad
2. The shad's ecological connections to other species
3. The significance of genetic integrity to population studies
4. Scientific procedures for measuring, testing, collecting, and organizing data
5. Mathematics to estimate, calculate, and predict results
6. Charts, maps, and graphs to aid in using information
7. Information exchange among other classes in the school and to parents and adults
8. The delicate balance of nature and work toward conserving or improving natural resources
9. American Shad restoration in rivers
10. Reporting and presentation techniques, both oral and written

This program provides a valuable experiential learning opportunity for students in the classroom that houses the tank (direct involvement) and those indirectly involved (e.g. collecting and recording water quality during their science period).

Student Analytics 2022

We continue our evaluation of the Shad in the Classroom Program's impact on student's understanding and learning with a questionnaire that uses multiple choice questions to determine a participant's knowledge of the American Shad. Demographic questions about age, gender, grade level, and whether the participant hunted or fished are included. Teachers who agreed to participate (15 in 2016, 18 in 2017, 16 in 2018, 18 in 2019, 14 in 2021, 25 in 2022) provided the pre- and post-tests to their students (n=505 for 2016, n=835 for 2017, n=591, n=672 for 2019, n=393 for 2021, n - = 711). See Appendix B for a detailed explanation of the analysis for 2016–2019. For the year 2020, there was no data as most students were unable to participate in the program (one classroom from Exploris ES did a few shad activities). In addition, there were two "control" classrooms in 2017 and 2018, four control classrooms in 2019, two control classrooms in 2021, and three control classrooms for 2022 that completed both the pre- and post-tests. The control classrooms were non-participating classrooms from the same schools that participate in the Shad in the Classroom program.

Similar to the other years' analysis, although all student groups in the program had a significantly positive increase in learning, students that self-identified as Black or African American or Hispanic or Latino showed a significant difference in learning from White students ($p=0.0006$ and $p=0.0002$, respectively), and from "two or more" ($p=0.0048$ and $p=0.0017$, respectively), but there was no significant difference in learning between each other or from students identifying as "other" (Figure 3). What this means is that although all students gained knowledge, students identifying as Black or African American and as Hispanic or Latino race/ethnicity fell behind their peers. There was no significant difference in learning detected among students who identified as males, females, or preferred not to answer (N/A) (Figure 4). However, it is notable, the "catch-up" in learning for female students in 2022. There was no significant difference (no increase in knowledge) for the pre- and post-survey for control students.

Figure 3. ─ Change in student knowledge by race (2022)

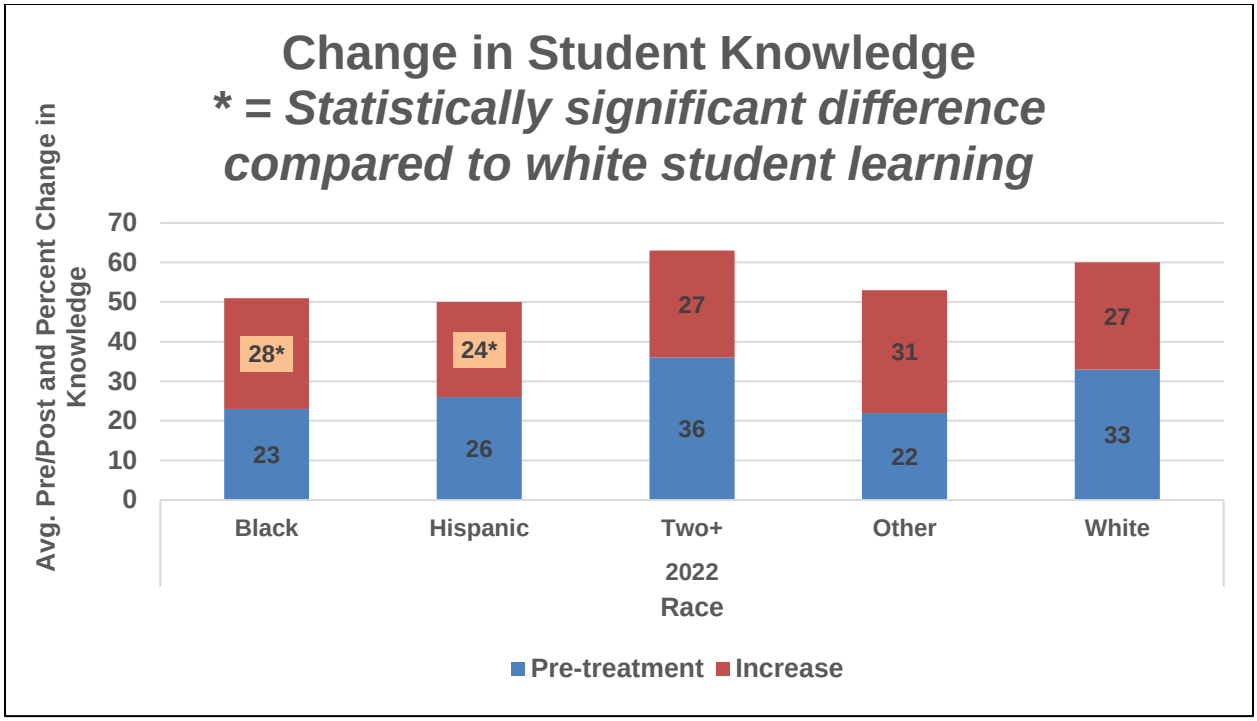
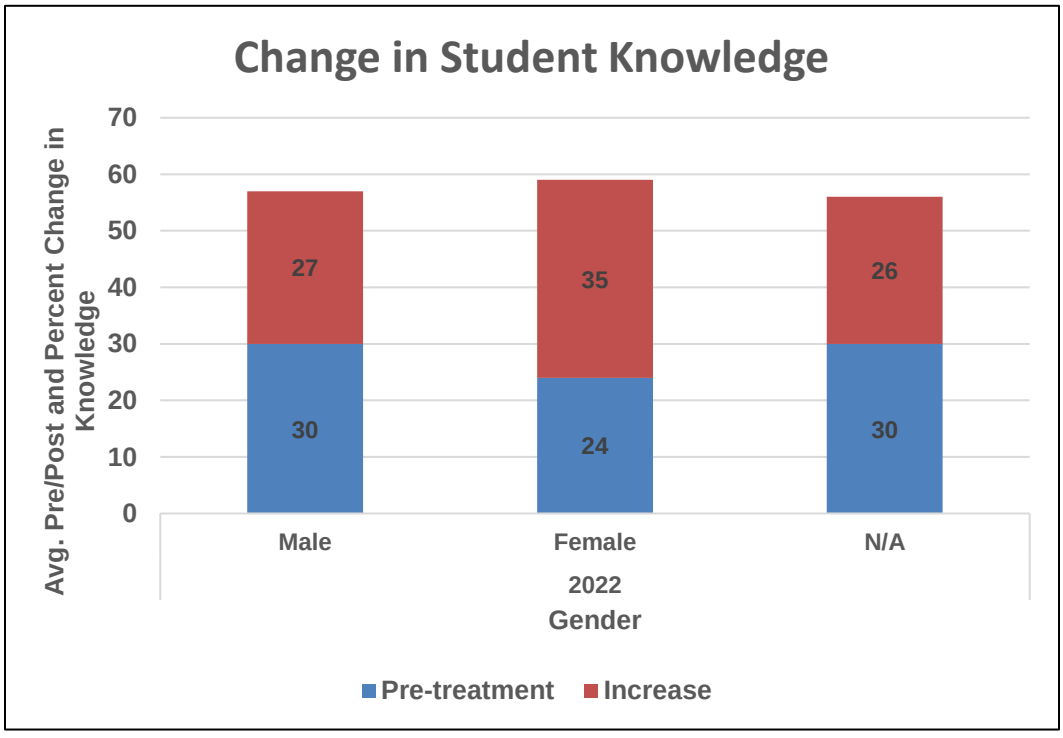


Figure 4. ─ Change in student knowledge by gender (2022 – note no significant difference)



The student surveys also contained questions to assess environmental attitudes and behaviors of the students. The analysis focused on the following 4 questions:

1. **I talk to my family or friends outside of school about what I've learned about science**
2. **I feel I can do something to help my local watershed or river**
3. **I feel I can do something to help fish like the American Shad**
4. **I ask others about things I can do about environmental problems**

Table 6 shows pre- and post-program percentages for those that answered "Agree or Strongly Agree" for questions 1-3 or "sometimes, often, or always" for question 4. We looked at all students and groupings by general grade (Elementary Students ES, Middle School Students MS, and High School students HS), gender, and race. Attitude and behavior changes that reflect an increase of 10% or more from pre- to post-survey are marked with an asterisk in the table. Overall, there was an increase in attitude from the pre- to post- survey for Question 3 – students' attitude that they can help American Shad. This was reflected in most of the groups and was at ≥ 20% for high school and unstated gender students (N/A) (it was just under 10% for middle school students and those self-identified as females or white). N/A gender students and those who self-reported their race as "Other" (includes those that chose "Other" and includes Asian and Native American) showed an increase of more than 10% in their answers to Question 1, indicating a positive shift in attitude regarding talking to family or friends outside of school about science learning. Also, elementary and high school students, and students self-identified as females, N/A gender, and black students showed a ≥10% increase from pre- to post-survey in their responses to Question 2, indicating a positive shift in attitude regarding helping their local watershed or river. Additionally, high school and students self-identified as "Other" showed a positive increase (≥10%) in their behavior regarding talking to others about environmental problems.

Table 6. 2022 Analysis of Student Attitude and Behavior (* and ** = notable increase of more than 10% and more than 20%, respectively)

Category	Q.1 % Pre	Q.1 % Post	Q.2 % Pre	Q.2 % Post	Q.3 % Pre	Q.3 % Post	Q.4 % Pre	Q.4 % Post
All	46	47	50	59	51	62*	45	48
ES	49	51	55	67*	52	67*	48	47
MS	45	47	50	56	53	62	45	48
HS	35	35	30	50**	28	48**	33	48*
Female	49	51	54	64*	53	62	48	51
Male	42	42	47	54	52	62*	42	44
N/A	47	63*	40	60**	37	63**	53	53
Black	33	38	47	59*	48	60*	50	52
Hispanic	39	41	42	50	41	57*	47	42
Other	41	57*	59	64	45	59*	50	73**
Two	38	41	48	57	49	59*	46	43
White	54	52	52	61	57	65	46	50

In summary, it is notable that all student groups in the program had a significantly positive increase in learning for all the years that these parameters have been evaluated (2016–2019, 2021, and 2022). However, students identified as Black or African American were found to fall behind their peers in learning in each year. Other groups showing significantly lower learning levels for some comparisons were those self-identified as Hispanic or Latino (4 of the years) and those self-identified as "Other" (2 of the years). We plan to continue collecting student questionnaires and refine questions as necessary so that we can monitor student learning and attitudes and behavior in all groups between the beginning and end of the Shad program. We will also continue to look for more ways to address any issues identified.

Public Outreach

Information on the Shad in the Classroom Program is available on the Museum's website. The program also receives a lot of publicity by word-of-mouth from those who have participated in the program previously (including teachers, students, and volunteers). In addition to the students and teachers reached with the Shad in the Classroom Program:

- NCMNS Member Night showcase June 2022
- The "We are the River Film" won the Gold Telly award in the nature category in 2018.
- The 2017 student analysis was published in Fisheries. Reaching Underserved Populations Through a Fisheries Education Program (Fisheries | Vol. 45 • No. 3 • March 2020).

An update on the Shad in the Classroom Program will be published in the North Carolina Chapter American Fisheries Society Fall Newsletter in 2022.

Future Planning

We hope to continue with "in-person" fish dissections next year as school really value this activity. We will continue to transition classes to the plexiglass tanks as the teachers report that the new, clear tanks enhance students' experience since they can more readily see the tiny fry. We will also continue to make additional curriculum activities available for in-classroom and at-release use. One activity we plan to have for teachers next year will be related to submerged aquatic vegetation. Videos on how to build the clear tank and of the impact of the Shad Program on one of the classes from start to finish in 2022 will be available for the 2023 Shad year.

Shad in the Classroom was very successful again this year, sixty-six percent of teachers reported that they were extremely satisfied and 28% reported they were very satisfied with the Shad in the Classroom experience [7% (2) teachers reported being moderately satisfied]. For one of those teachers their lower satisfaction level reportedly stemmed from the group of students that they taught that year and the distance needed to travel to release the shad from their school (4-hour bus ride). The other teacher only relayed positive comments. Most teachers and students provided positive feedback on all aspects of the program including the workshop, activities, and the overall program. Twenty-four of the 29 teachers participating in the Shad in the Classroom Program in 2022 reported that they would like to continue with the program next year. Those not returning stated reasons are retirement, sabbatical, maternity leave, and unsure of 2023 curriculum. It is expected that 6 teachers on "hiatus" for this year plan to return for 2023. At present, we have four new teachers on the waiting list for the program in 2023. We received invaluable assistance from partners and volunteers helping with the deliveries of eggs and educational lectures. Working with this program is a positive experience for all involved.

"I just absolutely LOVE this program. It is a wonderful learning opportunity for students and allows them to be stewards of their environment."

"I would say there was overall more engagement from my class during the shad unit compared to other units."

"Yes! Students are overall very motivated to engage with aquatic biology and fish conservation. I think kids also are taking on more responsibility in the classroom because they had to be responsible for the tank. I also think students are emerging with a deeper and more nuanced understanding of ecology and conservation issues surrounding American shad."

"Students were excited to do something that had a real impact.

Appendix A

Table 7. Schools Participating in the North Carolina Shad in the Classroom Program (2009–2022)

Release Basin School	Nos. of Classes	Years
Cape Fear River Basin		
Harnett Central Middle School (NCWRC)	2	2009-2010
Lake Rim Elementary (NCWRC)	2	2009-2010
Overhills Elementary (NCWRC)	1	2010
Neuse River Basin		
Abbotts Creek Elementary School	6	2016-2022
Angier Elementary	2	2013-2014
Ballentine Elementary	4	2017-2021
Bertie Early College High School	3	2019-2022
Brogden Middle School	5	2015-2019
Broughton High School	3	2014-2015
Bunn High School	6	2012-2015
Cedar Creek Middle School	1	2015
Centennial Campus Magnet Middle School	2	2009-2010
Central Park School for Children	11	2013-2022
Chaloner Middle School	1	2019
Chatham Central High School	1	2012
Chestnut Grove Middle School	1	2012
Clarkton School of Discovery (CFRW)	1	2019
Clayton High School	3	2016-2018
Cleveland High School	3	2016-2018
Cook Literacy Model School	2	2017-2018
Daniels IBMYP Magnet Middle School/Oberlin MS	15	2010-2019, 2022
Dillard Middle School	1	2017
Don D. Steed Elementary	1	2012
East Garner Middle School	4	2018-2021
East Wake Middle School	11	2010-2015, 2017
East Wake School of Integrated Technology	1	2014
E.B. Frink Middle School	1	2019
Emereau Bladen (CFRW)	1	2019
The Expedition School	8	2015-2019
Exploris Elementary School	8	2017-2022
Exploris Middle School	7	2010-2016
Falls Lake Academy	1	2022
First Flight Middle School	3	2021-2022
Forest Pines Dr Elementary	1	2013
Fuquay Varina Middle School	17	2014-2022
George Moses Middle School	1	2022
Grady A. Brown Elementary	1	2018
Hall Woodward Elementary	2	2012-2013

Table 7. Schools Participating in the North Carolina Shad in the Classroom Program (2009–2022) continued

Release Basin School	Nos. of Classes	Years
Neuse River Basin		
Horton Middle School	3	2017-2019
Knightdale Elementary School	1	2022
Lakewood Montessori Middle School	12	2013-2017, 2022
Lincoln Heights Elementary	2	2021-2022
Lead Mine Elementary	3	2009-2011
Lillington Shawtown Elementary	2	2011-2012
Longleaf School of the Arts	1	2019
Longview Middle School	1	2021
McLauchlin Elementary	1	2012
Midway Middle School	1	2012
Millbrook Environmental Connections Magnet Elementary	2	2018-2019
Mills Park Middle School	1	2017
Mineral Springs Middle School	1	2014
Moss Hill Elementary	3	2017-2019
North Duplin JR/SR High School	2	2015-2016
Northeast Academy for Aerospace & Advanced Technologies	2	2021
Perquimans County Middle School	1	2019
Perquimans County High School	3	2021-2022
Petree Elementary	1	2019
Pine Hollow Middle School	2	2018-2019
PreEminent Charter School	1	2022
Roanoke Rapids High School	1	2022
Rolesville Middle School	1	2017
Sandy Grove Middle School	2	2012-2013
Seawell Elementary School	1	2022
Sherwood Githens Middle	4	2019, 2022
Smithfield-Selma Senior High School	5	2018-2022
South Asheboro Middle School	1	2012
South Iredell High School	7	2013-2018, 2022
South View High School	1	2012
Southern Vance High School	4	2012-2015
Speas Elementary	1	2012
Tar Heel Middle School	1	2016
Terrell Lane Middle School	2	2021-2022
The Oakwood School	1	2012
Tiller Elementary School (Carteret County Charter School)	7	2013-2019
Upchurch Elementary	7	2012-2018

Table 7. Schools Participating in the North Carolina Shad in the Classroom Program (2009–2022) Continued

Release Basin School	Nos. of Classes	Years
Neuse River Basin		
Uwharrie Charter Academy	1	2016
Wake Forest Middle School	2	2015-2016
Wakefield Middle School	2	2022
Walkertown Middle School	1	2016
West Hoke Elementary	1	2012
West Johnston High School	1	2019
W.G. Enloe High School	4	2017-2021
W.J. Gurganus Elementary School	1	2021
Woods Charter Middle School	8	2012-2017, 2019-2022
Roanoke River Basin		
Bartlet Yancey High School	1	2010
Bertie Early College High School	4	2015-2018
Cedar Creek Middle School	1	2016
Chaloner Middle School	1	2018
Chestnut Grove Middle School	3	2010-2012
Don D. Steed Elementary	1	2011
Hall Woodward Elementary	1	2011
East Bladen High School (CFRW)	1	2018
Hawk Eye Elementary	1	2011
Hertford County High School	2	2014-2015
McLauchlin Elementary	1	2011
Pasquotank county High School	1	2018
Perquimans County Middle School	2	2017-2018
Red Oak Middle School	2	2013
Rockfish Hoke Elementary	1	2011
Sandy Grove Middle School	1	2011
Scurlock Elementary	1	2011
Southern Vance High School	4	2011-2012, 2017-2018
Speas Elementary	2	2010-2011
The Oakwood School	1	2011
Upchurch Elementary	1	2011
Vance Charter School	1	2016
West Hoke Elementary	1	2011
Windsor Elementary	1	2010
W.L. Manning Elementary School	2	2016-2017
Total Number of Schools	**111**	**2009-2022**
Total Number of Classrooms	**295**	**2009-2022**

Appendix B

Student Analytics 2016–2019

To better evaluate the Shad in the Classroom Program's impact on student's understanding and learning, we created a questionnaire that used multiple choice questions in order to determine a participant's knowledge of the American Shad. We also included demographic questions about age, gender, grade level, and whether the participant hunted or fished. Teachers who agreed to participate (15 in 2016, 18 in 2017, 16 in 2018, 18 in 2019, 14 in 2021) provided the pre- and post-tests to their students (n=505 for 2016, n=835 for 2017, n=591, n=672 for 2019). In addition, there were two "control" classrooms in 2017 and 2018 and four control classrooms in 2019 that completed both the pre- and post-tests. The control classrooms were non-participating classrooms from the same schools and grade level that participate in the Shad in the Classroom program.

We partnered with Dr. Nils Peterson, Dr. Kathryn Stevenson, and graduate students Kalysha Clark, Danielle Lawson, and Rachel Szczytko at the NCSU Human Dimensions of Conservation Biology Lab for the 2017 analysis. The results of the 2017 shad season's questionnaire analysis were published in Fisheries (Fisheries | Vol. 45 • No. 3 • March 2020). Analysis of the 2017 data showed that participation in the program created large improvements in American Shad knowledge between pre-and post-tests ($\overline{x}$=0.67, SD=1.22, $p < 0.001$). All students gained knowledge, but African American ($p<0.001$) and students identifying as "other" race/ethnicity ($p=0.003$) fell behind their peers. These results point to the need for improvement in reaching these race/ethnic groups. However, the human dimensions researchers concluded that increased exposure to nature, such as working with hands-on programs like Shad in the Classroom, may be the most consistent pathway to making students comfortable with learning in natural environments.

During the COVID-19 shutdown, we analyzed the larger pool of student knowledge data from 2016-2019 (student surveys began in 2016). In the survey, students self-selected race from the following options: Asian or Pacific Islander, Black or African American, Hispanic or Latino, Native American, White, two or more of the above, or other. Because in each of the years Asian or Pacific Islander and Native American were found to be a low percentage of the student population, these two groups were combined with the "other" category for analysis. Student knowledge data was analyzed by race and gender for pre- and post-knowledge and change in knowledge. Over the four years, we found similar results to those mentioned above for the 2017 analysis (Figure 5). All races and genders were found to have a significant positive increase in knowledge for all four years ($p<0.0001$). However, there were statistically significant differences in learning between some race groups, when compared to White students, in each of the four years.

For the 2016 year, students that self-identified as Black or African American showed a significant difference in learning from White students ($p=0.0188$), but there was no significant difference ($p>0.05$) in learning for Black or African American students compared to other race categories. For the 2017 year, those analysis were explained in detail above; in summary, all races were

significantly different from White students but were not significantly different from each other. For the 2018 year, students that self-identified as Black or African American or Hispanic or Latino showed a significant difference in learning from White students (p=0.0002 and p=0.0013, respectively) and "other" (p=0.0125 and p=0.0241, respectively), but there was no significant difference in learning between each other or from “two or more”. Finally, for the 2019-year students, it was found that students that self-identified as Black or African American or Hispanic or Latino showed a significant difference in learning from White students (p<0.0001 for both), "other" (p=0.039 and p=0.0155, respectively), and “two or more” (p<0.0001 for both). There was no significant difference (no increase in knowledge) for the pre- and post-survey for control students for all years tested.

In summary, although all students groups in the program had a significantly positive increase in learning, students identified as Black or African American were found to have a significant difference in learning in every year and those self-identified as Hispanic or Latino had a significant difference in learning in three of the four years from their White peers. Also, for the 2019 year, we found a small significant difference in learning for gender (p=0.04), which was in the positive direction for females, and no significant difference for all other years (p>0.05) (Figure 6).

Figure 5. ─ Change in student knowledge by race (2016–2019)

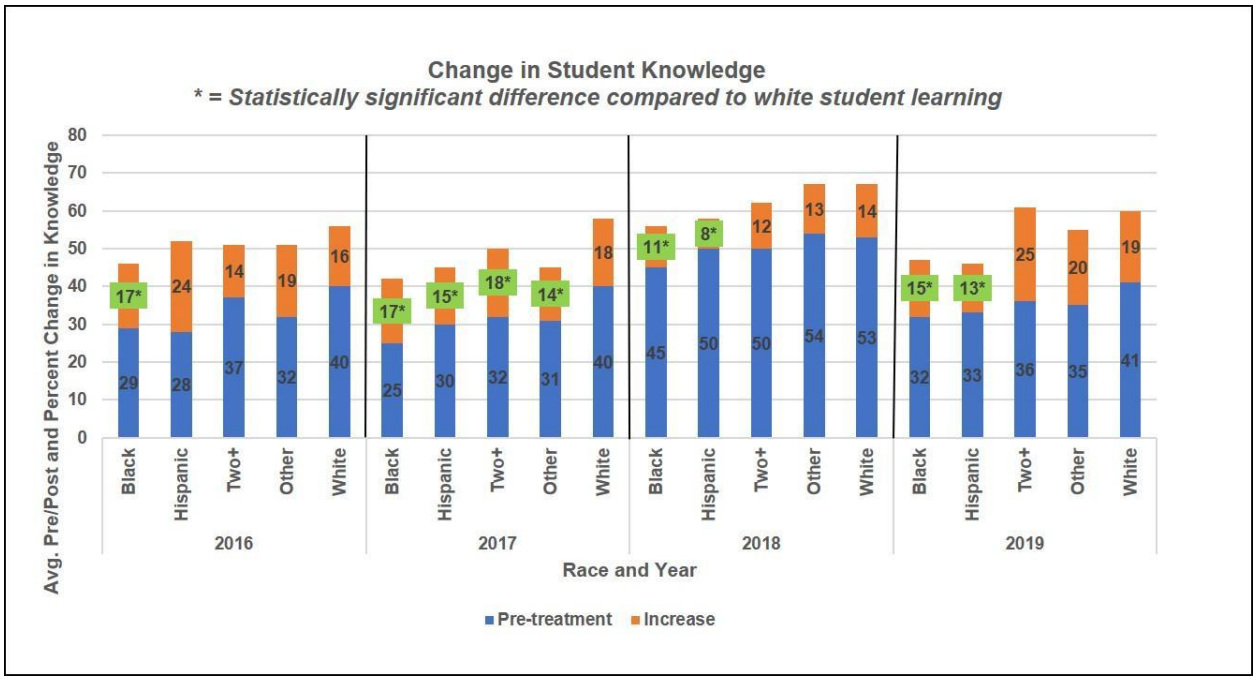
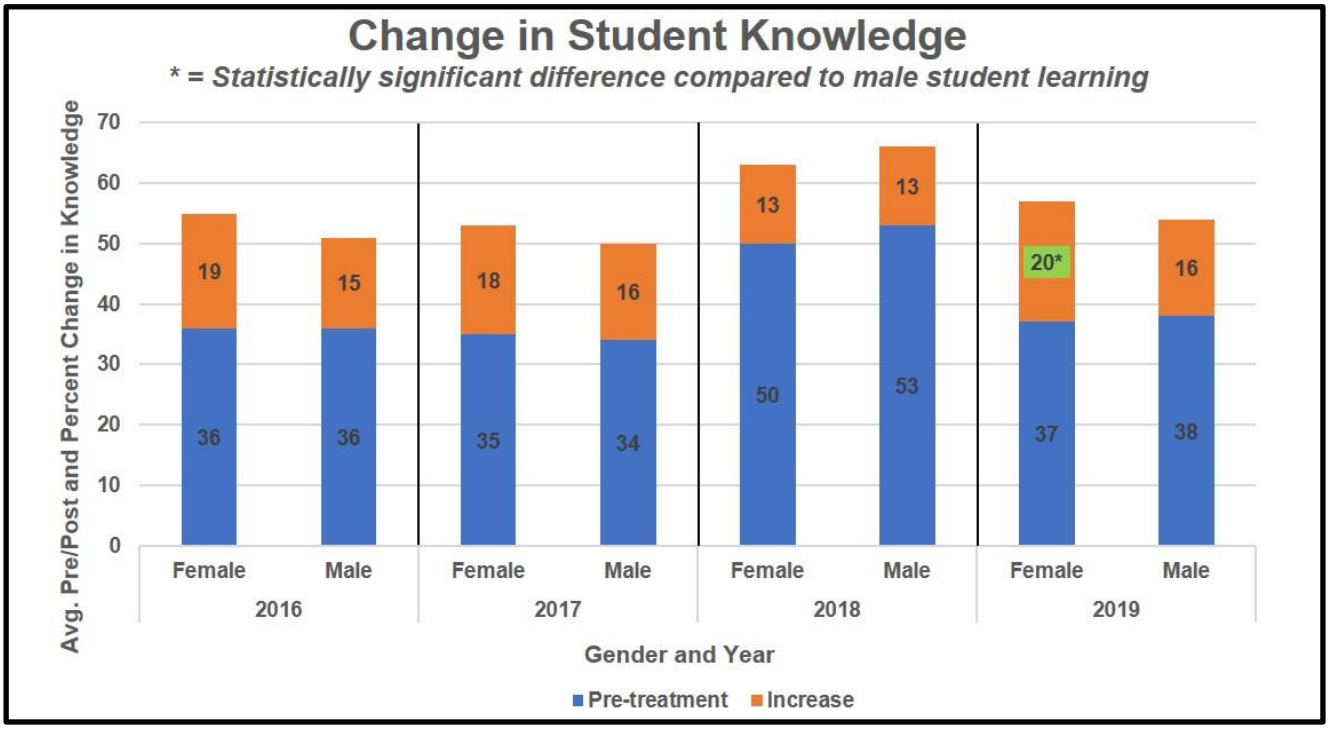


Figure 6. ─ Change in student knowledge by gender (2016–2019)



One way we are addressing the results of these student surveys is to create a series of video interviews of a diverse group of aquatic or fisheries biologists, as mentioned in the Curriculum Activities and Videos section. These videos will be made available to teachers and students. Our hope is that these videos will help students of color to more easily relate to scientists and begin to envision careers in the aquatic biology field. We continue to look for additional ways to engage these populations and increase their knowledge over the scope of the program.

The student surveys also contained questions to assess environmental attitudes and behaviors of the students. In our 2019 analysis we focused on the following 4 questions (this analysis was done only for 2019 as that is the year these particular questions were given):

1. **I talk to my family or friends outside of school about what I've learned about science**
2. **I feel I can do something to help my local watershed or river**
3. **I feel I can do something to help fish like the American Shad**
4. **I ask others about things I can do about environmental problems**

Table 8 shows pre- and post-program percentages for those that answered "Agree or Strongly Agree" for questions 1-3 or "sometimes, often, or always" for question 4. We looked at all students and groupings by general grade (Elementary Students ES, Middle School Students MS, and High School students HS), gender, and race. We found no discernable pattern between pre- and post-responses with a few notable exceptions, in which students had an increase of 10% or more from pre- to post-survey (marked with an asterisk in the table). Both elementary students and those who

self-reported their race as "other" (other includes those that chose “other” and also includes Asian and Native American) showed an increase of more than 10% in their answers to Question 3, indicating a positive shift in attitude regarding American Shad restoration. Additionally, high school students showed an 11% increase from pre- to post-survey in their responses to Question 4, indicating a positive change in behavior. Also notable was those students that self-reported as Black and “other” showed a positive increase in responses to all questions (though only at the 10% level for “other” in Question 3).

Table 8. 2019 Analysis of Student Attitude and Behavior (* = notable increase of more than 10%)

Category	Q.1 % Pre	Q.1 % Post	Q.2 % Pre	Q.2 % Post	Q.3 % Pre	Q.3 % Post	Q.4 % Pre	Q.4 % Post
All	44	43	54	55	61	61	49	53
ES	46	49	71	70	65	**77***	57	59
MS	45	42	50	51	59	57	47	41
HS	36	44	53	56	64	59	49	**60***
Female	49	46	60	64	64	66	55	59
Male	39	38	48	45	58	56	43	47
Black	36	43	48	53	57	58	35	43
Hispanic	47	39	57	55	63	57	52	52
Other	43	47	45	52	53	**70***	57	58
Two	45	43	51	48	56	55	48	51
White	46	43	57	57	64	62	52	56

Additional notable results were females answered 10% or more higher in positive answers (except question 1 post- at 8% higher) compared to males, and elementary students answered 10% or more higher in positive answers for pre- and post- question 2 and post- question 3 compared to middle school and high school. We plan to continue collecting student questionnaires and refine questions as necessary so that we can monitor student learning and attitudes and behavior in all groups between the beginning and end of the Shad program.

Appendix C

Shad in the Classroom Background (Updated 2020)

The American Shad fishery was once one of the East Coast's most abundant and economically important. However, by the mid-1970s water pollution, over-harvesting and the blocking of spawning habitat by dams led to their decline. Today, American Shad continue to have ecological, economic, and historical importance to North Carolina and much of the eastern seaboard of the U.S.

Many programs across the nation introduce fish and their associated habitats into the classroom to teach students about nature and the environment. These programs go by various names, including Trout in the Classroom, Salmon in the Classroom, and Shad in the Classroom. In North Carolina, Trout in the Classroom began in 2007 and Shad in the Classroom began in 2009. Trout in the Classroom is administered by the North Carolina Trout Unlimited Chapter. The Chapter started with two schools, by 2014 there were 37 schools, and by 2020 they increased to 73 schools in North Carolina. Schools receive between 100 and 150 trout eggs (embryos) and they raise them about 7 months to the fingerling stage prior to release. The cost of the trout program is about $900 per classroom (includes cost of cooling system; 2015 costs). Shad programs from other states have reported the costs for tank construction and running their program ranges from $550 to $2,000 per system (with some programs, some of those costs are due to a cooling system).

Shad in the Classroom is led by the North Carolina Museum of Natural Sciences (Museum). Comparable to the Trout in the Classroom, the Shad in the Classroom program provides a hands-on, real-life science learning opportunity. Similar American Shad programs have existed in the Potomac River basin since 1996, setting the groundwork for the Shad in the Classroom program in North Carolina. In addition to North Carolina, several states participate in similar shad in the classroom programs: Delaware, Maryland, Pennsylvania, Virginia, and West Virginia, and the District of Columbia (Figure 7). The Connecticut River Museum was looking into starting a Shad in the Classroom Program in their state, but the program got suspended. Previously, a number of participating states were part of the Interstate Commission on the Potomac River Basin (ICPRB). However, as of 2020, Anacostia Watershed Society continues the work and includes schools in Maryland, DC, and Virginia. The Delaware River Shad Fishermen's Association is another large organization that works with a shad in the classroom program. Some of the names used for these programs include Shad in the Classroom, Schools in Schools, and Shad in Schools. Some of the states also have a Trout in the Classroom program and some even have Perch or American eels in the Classroom Programs.

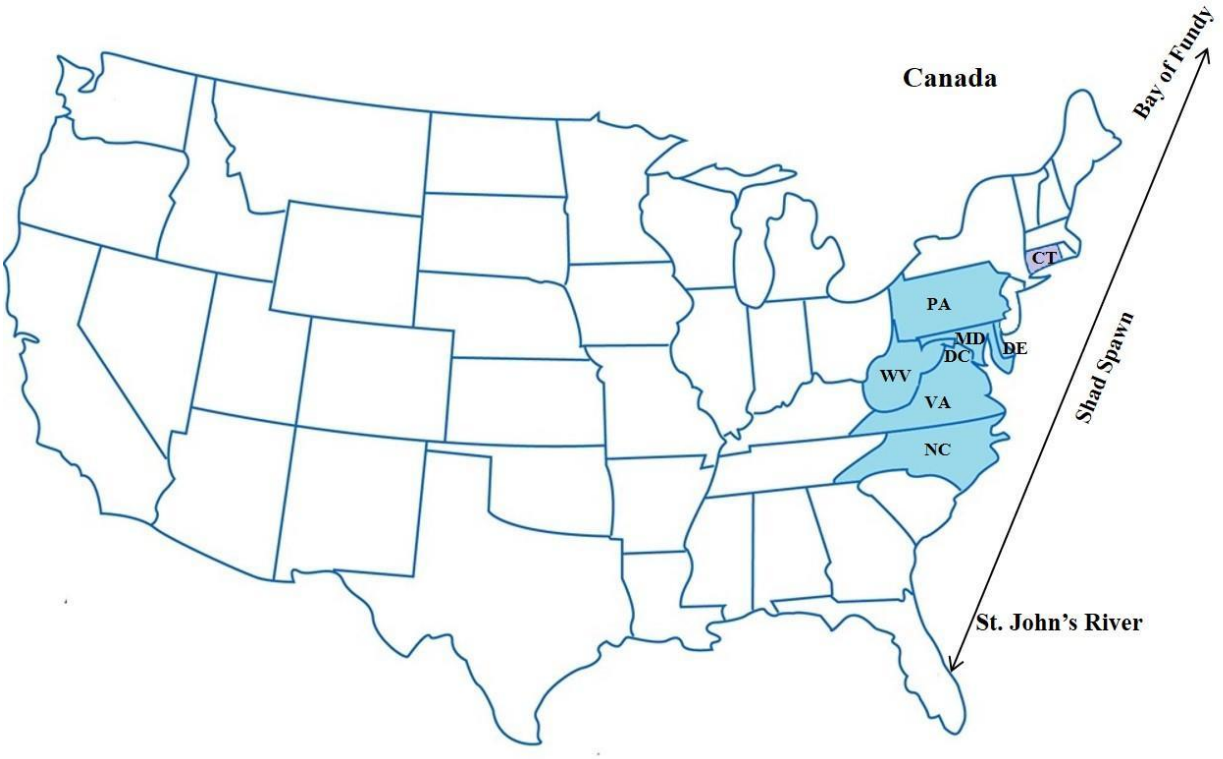


Figure 7. ─ Map of the states we found to participate in some version of a shad in the classroom program: Delaware, Maryland, North Carolina, Pennsylvania, Virginia, and West Virginia, and the District of Columbia (a program in Connecticut in proposed). Arrow depicts American Shad spawning distribution which ranges from the Bay of Fundy in Canada to the Saint John's River in Florida.

In North Carolina, the United States Fish and Wildlife Service (USFWS) started a pilot American Shad program with four schools in 2009. Two of those school programs were administered by the North Carolina Wildlife Resources Commission (NCWRC), Education Section. The following year (2010) the USFWS partnered with the North Carolina Museum of Natural Sciences (Museum), and the program grew to 13 schools (USFWS funding), three of which were administered by the NCWRC, Education Section. Beginning in 2011, the Museum assumed control of the Shad in the Classroom program and worked with 19 classrooms [with funding provided by the Albemarle-Pamlico National Estuary Partnership (APNEP), Dominion Power, and National Fish and Wildlife Foundation], while the NCWRC, Education Section continued a separate program. Under the Museum's guidance (and with funding provided solely through APNEP), the Shad in the Classroom program reached 20 classrooms each in 2012 and 2013, 23 classrooms in 2014, and 27 classrooms in the 2015 and 2016 program years. Funding was provided through APNEP and the USFWS for the

years 2017-2019 and 33 classrooms were reached for the 2017 year, 30 for the 2018 year, and 32 for the 2019 year. Note that these numbers generally reflect the number of tanks that are in a school; some schools had multiple classrooms sharing in the shad rearing or at least observing the program. A comprehensive list of the participating schools (2009 – 2021) is included in Table 7. Students and teachers become involved in the program several weeks prior to receiving American Shad eggs (fertilized embryos) spawned in NCWRC and USFWS hatcheries. For 2018, all shad used for the program were spawned in the USFWS hatchery, and all shad used for the program in 2019 were spawned at the NCWRC Watha State Fish Hatchery.

The program timeline begins with the teacher workshop in February and concludes with the release of fry reared by students into native rivers in April to early May. Each February participating teachers attend an all-day workshop and learn how to construct their fish hatcheries, attend expert presentations, participate in hands-on activities, and receive curriculum materials to use in their classrooms. The timing for delivery of eggs to the classrooms is dependent on the natural spawning of the fish. Teachers typically begin setting up their tanks and teaching materials related to the program 2–4 weeks prior to receiving the eggs. Students learn how to set up the tank and pump system, monitor water quality, and tend their shad eggs in special rearing systems prior to the arrival of their eggs. For one week during the spawning period, each classroom receives, monitors, and cares for a batch of shad eggs as part of this hands-on approach to learning about water quality, fisheries science, ecology, and history. Fry hatch within 4−5 days and are then released by the students in their river basin of origin. Lessons and activities related to the American Shad are prime examples of cross curricular connections, integrating history, social studies, ecology, and management. Some teachers elect to have students keep journals throughout the course of the program, further incorporating writing components and practice. Teachers in the program have also participated in an overnight canoe trip along the Roanoke River in late April or early May to explore the river-swamp ecosystem and its resources and to gain valuable insight to take back to their classrooms.

In the wild, or after release for hatchery-reared fish, the fry move downstream, and come together in schools. They will eventually leave the river and move into the sounds and then to the ocean. They will remain in the ocean for 4−6 years and then return to spawn in their native river basin in the spring to complete the life cycle. The NCWRC sample the young shad (collecting genetic material) as they move downstream and prior to moving into the sounds. They use this information to determine the proportion of shad that have been reared in the state and federal hatcheries (including the schools) compared to shad that were spawned directly in the river. These data help the NCWRC determine the management strategies for the American Shad fishery. Due to the results of multiple years of study, the NCWRC is presently (as of 2019) not stocking American Shad in NC waters, but are continuing to monitor the populations. American Shad are collected and brought to the Watha State Fish Hatchery solely for the Shad in the Classroom Program. Even though the NCWRC are not collecting broodstock, they continue to monitor the fishery as part of their restoration program. Having the schools be part of this restoration program is a valuable educational tool.