# An Ecological Study of Gunston Cove

## 2021

**FINAL REPORT**

September 2022

by

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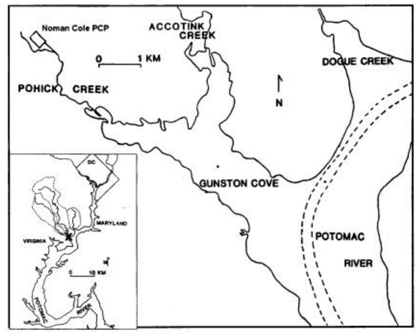
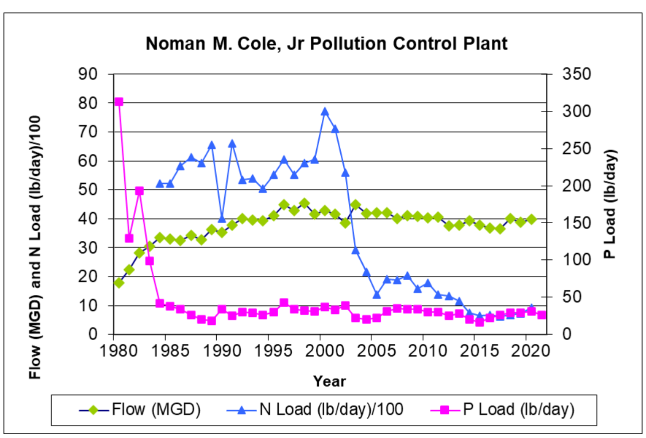
# An Ecological Study of Gunston Cove – 2021
## Executive Summary




Gunston Cove is an embayment of the tidal freshwater Potomac River located in Fairfax County, Virginia about 12 miles (20 km) downstream of the I-95/I-495 Woodrow Wilson Bridge. The Cove receives treated wastewater from the Noman M. Cole, Jr. Pollution Control Plant and inflow from Pohick and Accotink Creeks which drain much of central and southern Fairfax County. The Cove is bordered on the north by Fort Belvoir and on the south by the Mason Neck. Due to its tidal nature and shallowness, the Cove does not seasonally stratify vertically, and its water mixes gradually with the adjacent tidal Potomac River mainstem. Thermal stratification can make nutrient management more difficult, since it can lead to seasonal oxygen-diminished bottom waters that may result in fish mortality. Since 1984 George Mason University personnel, with funding and assistance from the Wastewater Management Program of Fairfax County, have been monitoring water quality and biological communities in the Gunston Cove area including stations in the Cove itself and the adjacent River mainstem. This document presents study findings from 2021 in the context of the entire data record.

The Chesapeake Bay, of which the tidal Potomac River is a major subestuary, is the largest and most productive coastal system in the United States. The use of the bay as a fisheries and recreational resource has been threatened by overenrichment with nutrients which can cause nuisance algal blooms, hypoxia in stratified areas, and a decline of fisheries. As a major discharger of treated wastewater into the tidal Potomac River, particularly Gunston Cove, Fairfax County has been proactive in decreasing nutrient loading since the late 1970's. Due to the strong management efforts of the County and the robust monitoring program, Gunston Cove has proven an extremely valuable case study in eutrophication recovery for the bay region and even internationally. The onset of larger areas of SAV coverage in Gunston Cove will have further effects on the biological resources and water quality of this part of the tidal Potomac River.

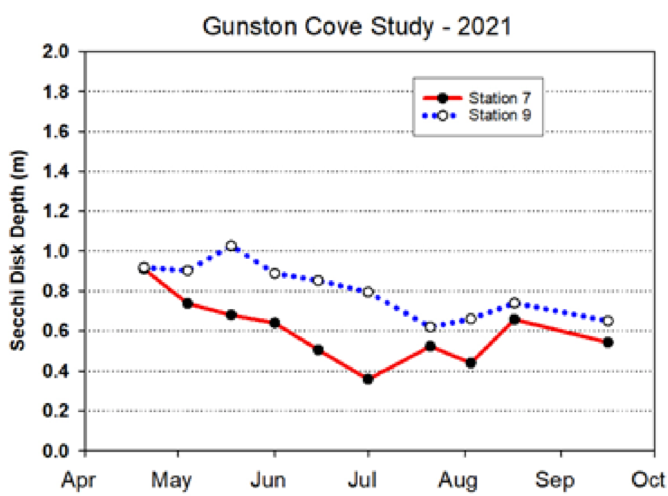



As shown in the figure to the left, phosphorus loadings were dramatically reduced in the early 1980's. In the last several years, nitrogen, and solids loadings as well as effluent chlorine concentrations have also been greatly reduced or eliminated. These reductions have been achieved even as flow through the plant has slowly increased.

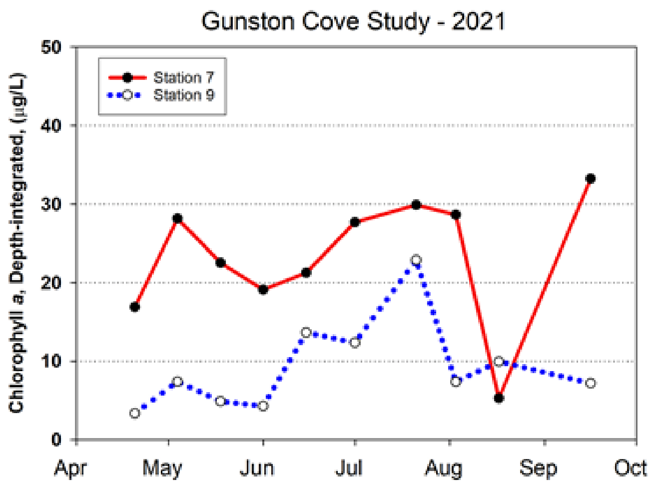
The ongoing ecological study reported here provides documentation of major improvements in water quality and biological resources which can be attributed to those efforts. Water quality improvements have been substantial in spite of the increasing population and volume of wastewater produced. The 37 year data record from Gunston Cove and the nearby Potomac River has revealed many important long-term trends that validate the effectiveness of County initiatives to improve treatment and will aid in the continued management and improvement of the watershed and point source inputs.

In 2021 temperature was above normal in all months (Table 3). There were 38 days with maximum temperature above 32.2°C (90°F) in 2021 as in 2020 which is well above the median number over the past decade. Precipitation was closer to normal in 2021 than in the extremely wet year 2018. However, it was again well above normal in 2021, especially in June and mid-August. Sample dates in June and particularly in mid-August could have been impacted by rainfall producing tributary flows. River flows which could impact the study area did not occur until September.

Mean water temperature was similar at the two stations with a pronounced dip in early June and a peak of about 30° in July. Specific conductance was mostly in the 250-400 range. Station 7 showed a general downward trend with much variability while Station 9 exhibited a slight upward trend and less variability. Dissolved oxygen saturation and concentration (DO) were consistently higher in the cove and there was a general decline through the year. Field pH patterns mirrored those in DO. Total alkalinity was generally higher in the river than in the cove. Water clarity as measured by Secchi disk transparency and light attenuation coefficient was generally better in the river than in the cove. Values indicated only moderately good water clarity.

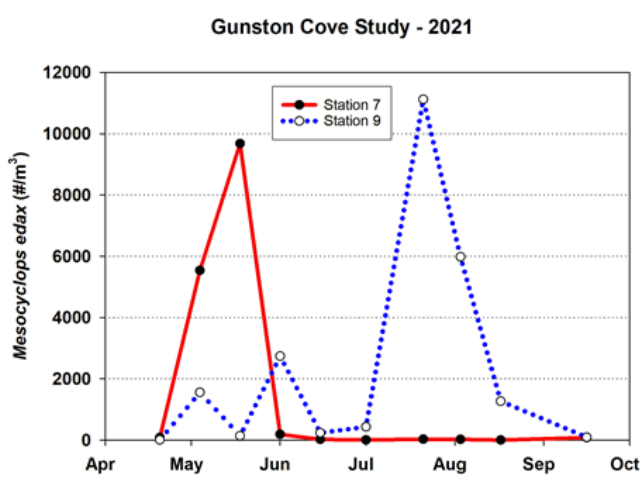



Ammonia nitrogen rarely exceeded the rather high detection limit of 0.1 mg/L making analysis of any temporal or spatial trends impossible. Nitrate values declined steadily through August at both stations with river values consistently about 0.5 mg/L than those in the cove. Nitrite was much lower overall. Organic nitrogen was generally fairly consistent through the year and about 0.1 mg/L higher in the cove than in the river. Total phosphorus showed a little seasonal or spatial trend hovering between 0.05 and 0.10 mg/L. Soluble reactive phosphorus was generally somewhat higher in the river, but showed little consistent seasonal trend. N to P ratio declined at both stations through July and August and then increased slightly in September. with most values between 10 and 30, a range which is still indicative of P limitation of phytoplankton and SAV. BOD was generally higher in the cove than in the river. TSS was consistently between 10 and 30 and varied a lot from week to week. VSS did not show strong spatial and temporal patterns.




In the cove algal populations as measured by chlorophyll *a* were consistently higher in the cove than in the river except in August when there may have been flushing from tributary runoff. There were two peaks in the cove, early May and mid-July, reaching 30 µg/L. The large decline in mid-August occurred after a large runoff even which probably flushed phytoplankton from the cove. In the river there was a steady increase through the year reaching about 20 µg /L in late July. In 2021 phytoplankton density in the cove was dominated by cyanobacteria. *Oscillatoria* was the dominant cyanobacterial taxon on most dates reaching a peak in early June. In terms of biovolume the dominant group was diatoms with the most abundant species being the filamentous diatom *Melosira*. The dominant group in terms of cell density in the river was again the cyanobacteria and the dominant taxon on many dates was *Oscillatoria*, but *Chroococcus* and *Merismopedia* made significant contributions. The peak in cell density in the river occurred in early July. In terms of biovolume diatoms were again the dominant group on most dates as in the cove. In the spring and early summer *Melosira* was the dominant diatom whereas in late summer discoid centrics assumed dominance.

Rotifers continued to be the most numerous microzooplankton in 2021. Rotifer densities in the cove were quite variable in 2021 with three distinct peaks each dominated by a different genus. Rotifer densities were consistently lower in the river than in the cove with *Brachionus* as the dominant. *Bosmina*, a small cladoceran exhibited two distinct peaks in the river and one in the cove, but values were modest. *Diaphanosoma*, a larger cladoceran, was very abundant in the river in mid-June exceeding 2500/$m^3$. At the same time there was a smaller peak in the cove. *Daphnia* was only found at very low values again in 2021. *Leptodora* exhibited a very strong peak in mid-May at over 2000/$m^3$. Copepod nauplii had a distinct bimodal seasonal pattern in the cove reaching 250/L in mid-July. In the river the peak was somewhat lower. The calanoid copepod *Eurytemora* was very abundant in the

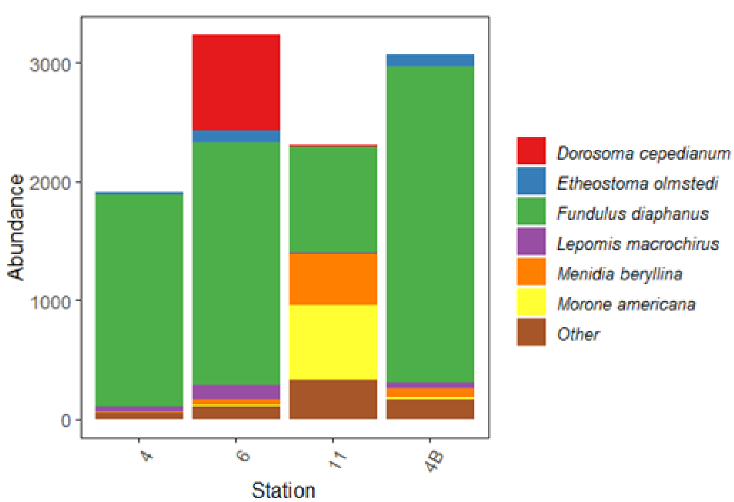


cove in mid-May attaining 14,500/$m^3$, but was much lower for the rest of the year. A second calanoid *Diaptomus* was found at much lower levels. *Mesocyclops edax* had a strong maximum in the cove in mid-May of almost 10,000/$m^3$ and in the river of 11,000/$m^3$.

Several water quality and plankton variables exhibited a strong decline in mid-August including specific conductance, chloride, dissolved oxygen, pH, total alkalinity, turbidity, secchi depth, and chlorophyll *a*. These declines were probably due to the impact of runoff from the 4 cm of precipitation in the three days preceding this sampling and the more than double the average precipitation during the month of August.

In 2021 ichthyoplankton was dominated by clupeids, most of which were Gizzard Shad (23%), Alewife (22%), and Blueback Herring (16%). and to a much lesser extent Hickory Shad and American Shad. White Perch was found in relatively high densities (15%), mostly found in the Potomac mainstem, confirming its affinity for open water. Inland Silverside was also relatively abundant (6.4%) and found more in the mainstem. The highest density of fish larvae occurred late May, which was driven by a high density of Clupeid larvae. White perch larvae also reached a maximum in late May.

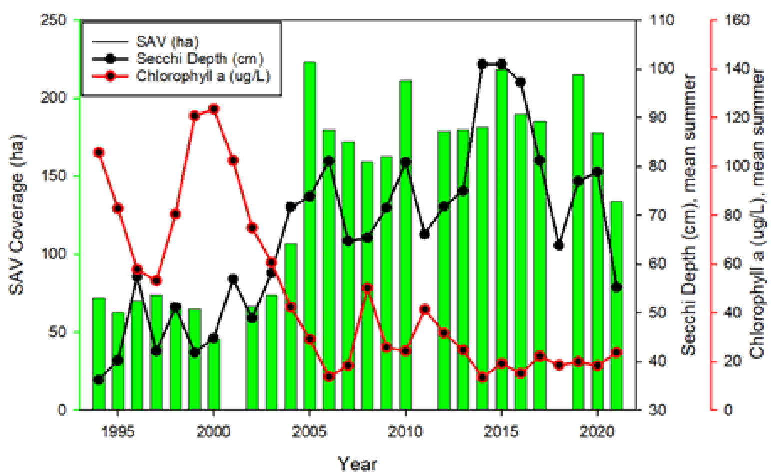
Submerged aquatic vegetation continued to be abundant in 2021 after 2018's very low cover, which resulted in fish abundances and gear efficiency that was similar to the years before 2018. In trawls White Perch dominated at 68%, followed by Spottail Shiner at 10%. No other species exceeded 5%. White Perch was by far the most abundant species and was found in all months at all stations. We collected a lot less Blue Catfish than in 2018, but still found 22 in the mainstem and 1 in the cove. We continue to find a disparity between catches of Blue Catfish in the mainstem versus the cove, which supports the theory that Blue Catfish has an affinity for the mainstem, potentially leaving embayments like Gunston Cove to serve as a refuge for native catfishes. We collected 7 native bullhead catfish in the cove and none in the mainstem.In seines, the most abundant species in 2021 was Banded Killifish comprising 70% of the catch (see figure below left). Banded Killifish (*Fundulus diaphanous*) was far more abundant in seines than in trawls, which emphasizes the preference of Banded Killifish for the shallow littoral zone (which is the area sampled with a seine, while trawls sample the open water). Other taxa with high abundances were Gizzard Shad (8%), White Perch (6%) and Inland Silverside (5%). Abundances remained substantial throughout the sampling season. In fyke nets Inland Silverside was



the dominant species in 2021 with 30% of the total catch. Sunfish (*Lepomis* species lumped together) were also abundant at 36% and Banded Killifish at 22%. White perch were rare in the fyke nets.

As in most previous years, oligochaetes were the most common invertebrates collected in ponar samples in 2021. Chironomids (midge larvae) were second most dominant in the cove and third most dominant in the river. The second most numerous taxa in the river was Amphipoda. Multivariate analysis showed a clear and consistent difference between cove benthic communities and those in the river. Shells were consistently the most abundant large substrate in river benthic samples. In the cove both shells and plant debris were abundant.

Coverage of submersed aquatic vegetation (SAV) in 2021 was down from the higher 2019 levels, but still within the range of post 2004 values. As in 2020 *Hydrilla*, coontail, and spiny naiad were the most abundant SAV taxa..Standaridized data on SAV coverage from VIMS resumed in 2019 and continues to show a major sustained improvement in water clarity and subsequent recovery of SAV beds. Jones (2020) demonstrated that the cove ecosystem changed from a “turbid water” state dominated by phytoplankton to a “clear water” state dominated by SAV in 2005. As shown in the figure above the data for 2020 indicates that the “clear water” state is continuing with improved water clarity (Secchi depth), lower phytoplankton (chlorophyll a), and greater coverage of SAV as indicated in the graph to the right.




A second significant change in water quality documented by the study has been the removal of chlorine and ammonia from the Noman M. Cole, Jr. Pollution Control Plant effluent. A decline of over an order of magnitude in ammonia nitrogen has been observed in the Cove as compared to earlier years. The declines in ammonia and the elimination of chlorine from the effluent (to values well below those that may result is toxicity problems) have allowed fish to recolonize tidal Pohick Creek which now typically has more spawning activity than tidal Accotink Creek. Monitoring of creek fish allowed us to observe recovery of this habitat which is very important for spawning species such as shad. The decreased ammonia, suspended solids, and phosphorus loading from the plant have contributed to overall Chesapeake Bay cleanup. Unfortunately, we are unable to continue to track further declines in ammonia concentrations since all values are now below the detection limit reported by the County.

Another trend of significance which is indicative of the Cove recovery is the change in the relative abundance of fish species. While it is still the dominant species in trawls, White Perch has gradually been displaced in seines by Banded Killifish. This trend continued in 2021 with Banded Killifish being much more abundant in seines than White Perch. In general this is a positive development as the net result has been a more diverse fish community. Blue Catfish have entered the area recently, were quite abundant in 2018 and maintained a presence in 2019-2021. Blue Catfish are regarded as rather voracious predators and may negatively affect the food web. Other catfish are down significantly now that the Blue Catfish is present.

Clearly, recent increases in SAV provide refuge and additional spawning habitat for Banded Killifish and Sunfish. Analysis shows that White Perch dominance was mainly indicative of the community present when there was no SAV; increased abundances of Bay Anchovy indicative for the period with some SAV; and Banded Killifish and Largemouth Bass indicative of the period when SAV beds were expansive. In 2021 seine collections were dominated by Banded Killifish. While the seine does not sample these SAV areas directly, the enhanced growth of SAV provides a large bank of Banded Killifish that spread out into the adjacent unvegetated shoreline areas and are sampled in the seines. The fyke nets that do sample the SAV areas directly documented a dominance of Sunfish, Inland Silverside and Banded Killifish in the SAV beds. In addition to the effect of SAV the increased presence of the invasive Blue Catfish may also have both direct (predation) and indirect (competition) effects, especially on species that occupy the same niche such as Brown Bullhead and Channel Catfish. Overall, these results indicate that the fish assemblage in Gunston Cove is dynamic and supports a diversity of commercial and recreational fishing activities.

In summary, it is important to continue the data record that has been established to allow assessment of how the continuing increases in volume and improved efforts at wastewater treatment interact with the ecosystem as SAV increases and plankton and fish communities change in response. Furthermore, changes in the fish communities from the standpoint of habitat alteration by SAV and introductions of exotics like snakeheads and blue catfish need to be followed. 2018 was highly instructive in showing how extreme rainfall conditions can alter the ecosystem and at least temporarily impede recovery. However, 2019 and 2020 data indicate that the ecosystem was resilient and resumed the “clear water” state in 2019.

Global climate change is becoming a major concern worldwide. Since 2000 a slight, but consistent increase in summer water temperature has been observed in the Cove which may reflect the higher summer air temperatures documented globally. Other potential effects of directional climate change remain very subtle and not clearly differentiated given seasonal and cyclic variability.

We recommend that:

1. Long term monitoring should continue. The revised schedule initiated in 2004 which focuses sampling in April through September has captured the major trends affecting water quality and the biota. The Gunston Cove study is a model for long term monitoring which is necessary to document the effectiveness of management actions. This process is sometimes called adaptive management and is recognized as the most successful approach to ecosystem management.
2. Two aspects of the program should be reviewed.

  a. In 2016 phytoplankton cell count frequency was decreased from twice monthly to monthly as a cost-saving step. But it does result in some sampling dates not having phytoplankton data to go along with the other variables. If funds are available, we recommend reinstituting twice monthly phytoplankton counts.
  b. As nutrient concentrations have decreased in the river and cove due to management successes, we are now encountering a substantial number of samples which are below detection limits. This becomes a problem in data analysis. To date we have set “below dection limits” values at ½ the detection limit, but this becomes less defensable the greater the proportion of these values. This is particularly true of ammonia nitrogen. We continue to recommend that this be addressed.
3. The fyke nets have proven to be a successful addition to our sampling routine. Even though a small, non-quantitative sample is collected due to the passive nature of this gear, it provides us with useful information on the community within the submersed aquatic vegetation beds. Efficient use of time allows us to include these collections in a regular sampling day with little extra time or cost. We recommend continuing with this gear as part of the sampling routine in future years.
4. Anadromous fish sampling is an important part of this monitoring program and has gained interest now that the stock of river herring has collapsed, and a moratorium on these taxa has been established in 2012. We recommend continued monitoring, and we plan to use the collections before and during the moratorium to help determine the effect of the moratorium. Our collections will also form the basis of a population model that can provide information on the status of the stock.
5. We have instituted some improvements to the benthic monitoring program including the quantitative characterization of larger (>5 mm) particles in the samples which we expect to help explain the variations we see in benthic communities between samples and station. This should continue.

Reference: Jones, R.C. 2020. Recovery of a Tidal Freshwater Embayment from Eutrophication: a Multidecadal Study. *Estuaries and Coasts*. Forthcoming in print. Available online at: https://link.springer.com/article/10.1007/s12237-020-00730-3

# List of Abbreviations

| | |
|---|---|
| BOD | Biochemical oxygen demand |
| cfs | cubic feet per second |
| DO | Dissolved oxygen |
| ha | hectare |
| l | liter |
| LOWESS | locally weighted sum of squares trend line |
| m | meter |
| mg | milligram |
| MGD | Million gallons per day |
| NS | not statistically significant |
| NTU | Nephelometric turbidity units |
| SAV | Submersed aquatic vegetation |
| SRP | Soluble reactive phosphorus |
| TP | Total phosphorus |
| TSS | Total suspended solids |
| um | micrometer |
| VSS | Volatile suspended solids |
| # | number |

# THE ONGOING AQUATIC MONITORING PROGRAM

# FOR THE GUNSTON COVE AREA

# OF THE TIDAL FRESHWATER POTOMAC RIVER

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## INTRODUCTION

This section reports the results of the on-going aquatic monitoring program for Gunston Cove conducted by the Potomac Environmental Research and Education Center at George Mason University and Fairfax County's Environmental Monitoring Branch. This study is a continuation of work originated in 1984 at the request of the County's Environmental Quality Advisory Committee and the Department of Public Works. The original study design utilized 12 stations in Gunston Cove, the Potomac mainstem, and Dogue Creek. Due to budget limitations and data indicating that spatial heterogeneity was not severe, the study has evolved such that only two stations are sampled, but the sampling frequency has been maintained at semimonthly during the growing season. This sampling regime provides reliable data given the temporal variability of planktonic and other biological communities and is a better match to other biological sampling programs on the tidal Potomac including those conducted by the Maryland Department of Natural Resources and the District of Columbia. The 1984 report entitled "An Ecological Study of Gunston Cove – 1984" (Kelso et al. 1985) contained a thorough discussion of the history and geography of the cove. The reader is referred to that document for further details.

This work's primary objective is to determine the status of biological communities and the physico-chemical environment in the Gunston Cove area of the tidal Potomac River for evaluation of long-term trends. This will facilitate the formulation of well-grounded management strategies for maintenance and improvement of water quality and biotic resources in the tidal Potomac. Important byproducts of this effort are the opportunities for faculty research and student training which are integral to the educational programs at GMU.

The authors wish to thank the numerous individuals and organizations whose cooperation, hard work, and encouragement have made this project successful. We wish to thank the Fairfax County Department of Public Works and Environmental Services, Wastewater Planning and Monitoring Division, Environmental Monitoring Branch, particularly Steve Winesett and Shahram Mohsenin for their advice and cooperation during the study. Benny Gaines deserves recognition for field sample collection on days when Fairfax County collected independent samples. The entire analytical staff at the Noman Cole lab is gratefully acknowledged. The Northern Virginia Regional Park Authority facilitated access to the park and boat ramp. Without a dedicated group of field and laboratory workers this project would not have been possible. PEREC field and lab technician Laura Birsa deserves special recognition for day-to-day operations. Dr. Saiful Islam conducted phytoplankton counts. Claire Buchanan served as a voluntary consultant on plankton identification. Natalie Cheryl Skolnick, Francina Osaria, Florencia Gutierrez, and Hillary Hamm were vital in handling budget, personnel and procurement functions.

This work would not have been possible without Dr. Kim de Mutsert ensuring that a field crew and resources were in place to continue working during the Co-PI transition. We thank her for her dedication to this project from its inception and during this transitory period. We also thank Rachel Kelmartin for taking a large role in the field collection and laboratory processing of these fishes, the work would not have been completed without her.

Thanks also go to lab and field workers Beverly Bachman, Sammie Alexander, Chelsea Gray, Rachel Kelmartin, Alex Mott, Sam Mohney, Daya Stratton-Hall, and Daria Maslyukova.

# METHODS

## A. Profiles and Plankton: Sampling Day

Sampling was conducted on a semimonthly basis at stations representing both Gunston Cove and the Potomac mainstem (Figures 1a,b). One station was located at the center of Gunston Cove (Station 7) and the second was placed in the mainstem tidal Potomac channel off the Belvoir Peninsula just north of the mouth of Gunston Cove (Station 9). Dates for sampling as well as weather conditions on sampling dates and immediately preceding days are shown in Table 1. Gunston Cove is located in the tidal freshwater section of the Potomac about 20 km (13 miles) downstream from Washington, DC.

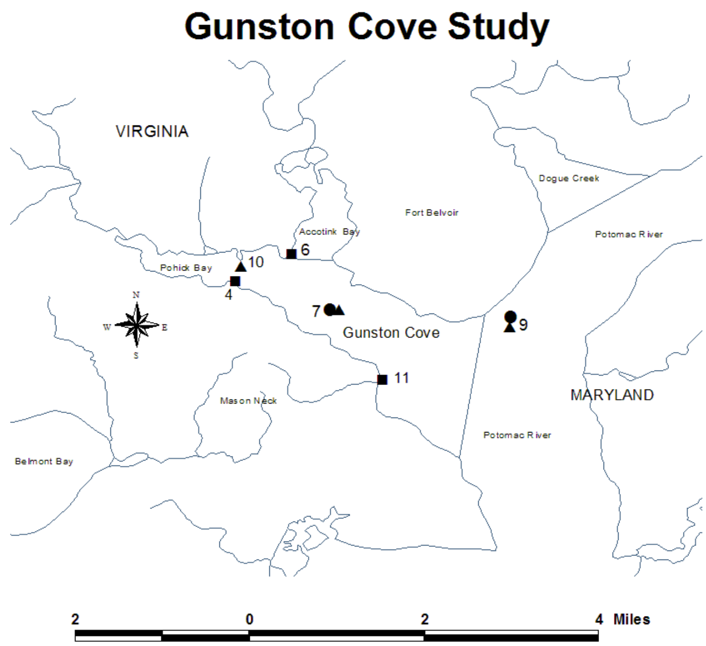



Figure 1a. Gunston Cove area of the Tidal Potomac River showing sampling stations. Circles (●) represent Plankton/Profile stations, triangles (▲) represent Fish Trawl stations, and squares (■) represent Fish Seine stations.

Figure 1b. Fish sampling stations including location and image of the fyke nets.

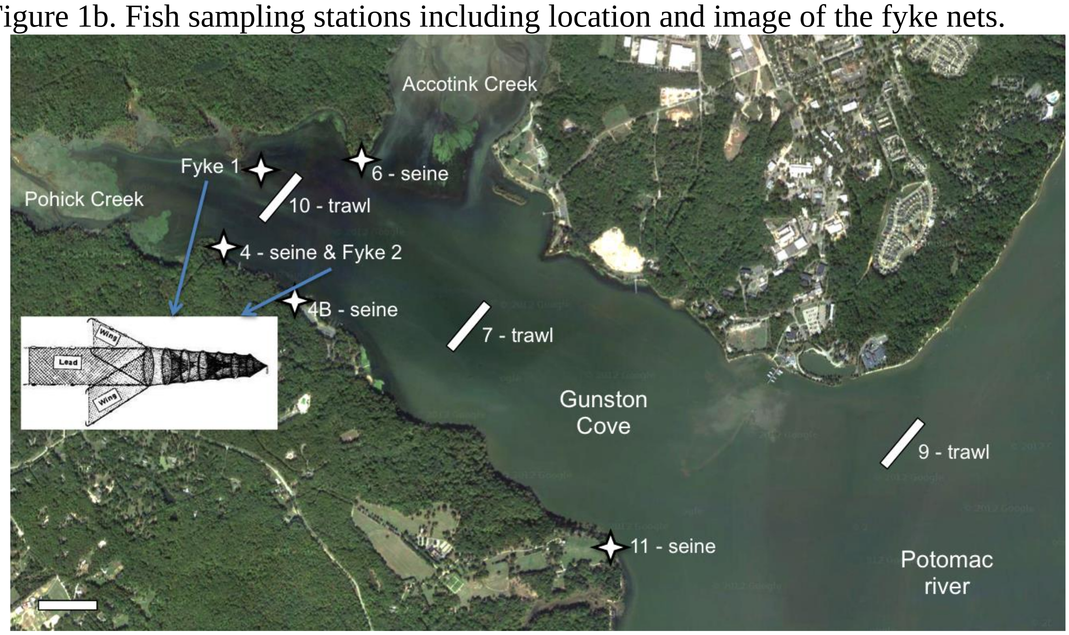


Table 1
Sampling Dates and Weather Data for 2021

| Date | Type of Sampling G | F | T | S | Y | Avg Daily Temp (ºC) 1-Day | 3-Day | Precipitation (cm) 1-Day | 3-Day |
|---|---|---|---|---|---|---|---|---|---|
| Apr 13 | | | 4 | 4 | | 15.0 | 16.7 | T | 0.50 |
| Apr 20 | G | F | | | | 16.7 | 14.8 | 0 | 0.03 |
| May 4 | G | | | | | 23.9 | 22.0 | 1.22 | 1.37 |
| May 11 | | F | | | | 16.1 | 15.7 | 0 | T |
| May 14 | | | 4 | 3 | | 17.2 | 16.3 | 0 | 0 |
| May 18 | G | F | | | | 19.4 | 18.5 | 0 | T |
| May 27 | | | 3 | 4 | 2 | 25.6 | 24.4 | 0 | 2.29 |
| Jun 1 | G | | | | | 20.0 | 16.5 | 0 | 0.38 |
| Jun 10 | | | 4 | 4 | | 26.1 | 27.4 | 2.51 | 2.55 |
| Jun 15 | G | F | | | | 23.3 | 24.3 | T | 4.67 |
| Jun 23 | | F | | | | 23.0 | 23.9 | 0 | 0.99 |
| Jun 24 | | | 3 | 3 | 1 | 20.6 | 23.9 | 0 | 0.86 |
| Jul 1 | G | | | | | 27.2 | 28.9 | 3.23 | 3.30 |
| Jul 8 | | | 3 | 3 | | 26.1 | 28.0 | 0.61 | 0.61 |
| Jul 13 | | F | | | | 30.0 | 29.3 | 0 | 0 |
| Jul 21 | G | F | | | | 27.8 | 28.0 | 1.14 | 1.16 |
| Jul 22 | | | 3 | 3 | 2 | 24.4 | 27.0 | 0 | 1.14 |
| Aug 3 | G | | | | | 23.9 | 24.1 | 0 | 0.89 |
| Aug 10 | | F | | | | 28.0 | 26.1 | 1.65 | 2.26 |
| Aug 12 | | | 3 | 3 | 2 | 29.4 | 29.3 | 0 | 1.75 |
| Aug 17 | G | F | | | | 26.7 | 26.3 | 1.50 | 4.01 |
| Aug 26 | | | 3 | 2 | 2 | 28.9 | 29.1 | 1.47 | 1.50 |
| Sep 16 | G | F | 3 | 2 | 2 | 25.6 | 26.9 | 2.01 | 2.01 |
| Sep 21 | | F | | | | 23.3 | 23.3 | T | T |

Type of Sampling: B: Benthic, G: GMU profiles and plankton, F: nutrient and lab water quality by Fairfax County Laboratory, T: fish collected by trawling, S: fish collected by seining, Y: fish collected by fyke net. Numbers in T, S, and Y columns indicate how many stations were sampled on each date. All samples were collected by GMU personnel.

Sampling was initiated at 10:30 am. Four types of measurements or samples were obtained at each station : (1) depth profiles of temperature, conductivity, dissolved oxygen, pH, and irradiance (photosynthetically active radiation) measured directly in the field; (2) water samples for GMU lab determination of chlorophyll *a* and phytoplankton species composition and abundance; (3) water samples for determination of nutrients, BOD, alkalinity, suspended solids, chloride, and pH by the Environmental Laboratory of the Fairfax County Department of Public Works and Environmental Services; (4) net sampling of zooplankton and ichthyoplankton.

Profiles of temperature, conductivity, dissolved oxygen, and pH were conducted at each station using a YSI 6600 datasonde. Measurements were taken at 0.3 m, 1.0 m, 1.5 m, and 2.0 m in the cove. In the river measurements were made with the sonde at depths of 0.3 m, 2 m, 4 m, 6 m, 8 m, 10 m, and 12 m. Meters were checked for calibration before and after sampling. Profiles of irradiance (photosynthetically active radiation, PAR) were collected with a LI-COR underwater flat scalar PAR probe. Measurements were taken at 10 cm intervals to a depth of 1.0 m. Simultaneous measurements were made with a terrestrial probe in air during each profile to correct for changes in ambient light if needed. Secchi depth was also determined. The readings of at least two crew members were averaged due to variability in eye sensitivity among individuals.

A 1-liter depth-composited sample was constructed from equal volumes of water collected at each of three depths (0.3 m below the surface, middepth, and 0.3 m off of the bottom) using a submersible bilge pump. A 100-mL aliquot of this sample was preserved immediately with acid Lugol's iodine for later identification and enumeration of phytoplankton. The remainder of the sample was placed in an insulated cooler with ice. A separate 1-liter sample was collected from 0.3 m using the submersible bilge pump and placed in the insulated cooler with ice for lab analysis of surface chlorophyll *a*. These samples were analyzed by Mason.

Separate 4-liter samples were collected monthly at each site from just below the surface (0.3 m) and near the bottom (0.3 m off bottom) at each site using the submersible pump. This water was promptly delivered to the nearby Fairfax County Environmental Laboratory for determination of nitrogen, phosphorus, BOD, TSS, VSS, pH, total alkalinity, and chloride.

Microzooplankton was collected by pumping 32 liters from each of three depths (0.3 m, middepth, and 0.3 m off the bottom) through a 44 µm mesh sieve. The sieve consisted of a 12-inch long cylinder of 6-inch diameter PVC pipe with a piece of 44 µm nitex net glued to one end. The 44 µm cloth was backed by a larger mesh cloth to protect it. The pumped water was passed through this sieve from each depth and then the collected microzooplankton was backflushed into the sample bottle. The resulting sample was treated with about 50 mL of club soda and then preserved with formalin containing a small amount of rose bengal to a concentration of 5-10%.

Macrozooplankton was collected by towing a 202 µm net (0.3 m opening, 2 m long) for 1 minute at each of three depths (near surface, middepth, and near bottom). Ichthyoplankton was sampled by towing a 333 µm net (0.5 m opening, 2.5 m long) for 2 minutes at each of the same depths. In the cove, the boat made a large arc during the tow while in the river the net was towed in a more linear fashion along the channel. Macrozooplankton tows were about 300 m and ichthyoplankton tows about 600 m. Actual distance depended on specific wind conditions and tidal current intensity and direction, but an attempt was made to maintain a constant slow forward speed through the water during the tow. The net was not towed directly in the wake of the engine. A General Oceanics flowmeter, fitted into the mouth of each net, was used to establish the exact towing distance. During towing the three depths were attained by playing out rope equivalent to about 1.5-2 times the desired depth. Samples which had obviously scraped bottom were discarded and the tow was repeated. Flowmeter readings taken before and after towing allowed precise determination of the distance towed and when multiplied by the area of the opening produced the total volume of water filtered.

Macrozooplankton and ichthyoplankton were backflushed from the net cup and immediately preserved. Rose bengal formalin with club soda pretreatment was used for macrozooplankton. Ichthyoplankton were preserved in 70% ethanol. Macrozooplankton was collected on each sampling trip; ichthyoplankton collections ended after July because larval fish were normally not found after this time.

Benthic macroinvertebrates were sampled using a petite ponar sampler at Stations 7 and 9. Triplicate samples were collected at each site on dates when water samples for Fairfax County lab analysis were not collected. The protocol in use for the past several years specified that the bottom samples were sieved on site through a 0.5 mm stainless steel sieve. Larger items like SAV, leaves, sticks, and empty shells were rinsed with tap water through the sieve and discarded. The smaller materials remaining on the 0.5 mm sieve were then preserved with rose bengal formalin.

In an effort to understand the role of larger particulate material in structuring the benthic community, a new field protocol was instituted in August 2018. Samples were first sieved through a 5 mm coarse mesh to remove larger items mentioned above. Materials remaining on the 5 mm sieve were thoroughly washed in the field and the material retained on the sieve was transferred to a zip lock bag and placed on ice for further processing in the lab.

Samples were delivered to the Fairfax County Environmental Services Laboratory by 2 pm on sampling day and returned to GMU by 3 pm. At GMU 10-15 mL aliquots of both depth-integrated and surface samples were filtered through 0.45 µm membrane filters (Gelman GN-6 and Millipore MF HAWP) at a vacuum of less than 10 $lbs/in^2$ for chlorophyll a and pheopigment determination. During the final phases of filtration, 0.1 mL of $MgCO_3$ suspension (1 g/100 mL water) was added to the filter to prevent premature acidification. Filters were stored in 20 mL plastic scintillation vials in the lab freezer for later analysis. Seston dry weight and seston organic weight were measured by filtering 200-400 mL of depth-integrated sample through a pretared glass fiber filter (Whatman 984AH).

Sampling day activities were normally completed by 5:30 pm.

**B. Profiles and Plankton: Follow-up Analyses**

Chlorophyll *a* samples were processed using an overnight soaking procedure which has been shown to give comparable results to the traditional homogenization process. (Huntley et al. 1987). The filters had been stored in the freezer in 20 mL plastic scintillation vials pending analysis in October. 15 mL of 90% acetone was added to each vial and the vials were shaken.

They were placed in the refrigerator overnight. The next day they were mixed and assayed fluorometrically.

Chlorophyll *a* concentration in the extracts was determined fluorometrically using a Turner Designs Trilogy fluorometer configured for chlorophyll analysis as specified by the manufacturer. The instrument was calibrated using standards obtained from Turner Designs. Chlorophyll was determined and then after acidification with 2 drops of 10% HCl pheophytin was determined.

Phytoplankton species composition and abundance was determined using the inverted microscope-settling chamber technique (Lund et al. 1958). Ten milliters of well-mixed algal sample were added to a settling chamber and allowed to stand for several hours. The chamber was then placed on an inverted microscope and random fields were enumerated. At least two hundred cells were identified to species and enumerated on each slide. Counts were converted to number per mL by dividing number counted by the volume counted. Biovolume of individual cells of each species was determined by measuring dimensions microscopically and applying volume formulae for appropriate solid shapes.

Microzooplankton and macrozooplankton samples were rinsed by sieving a well-mixed subsample of known volume and resuspending it in tap water. This allowed subsample volume to be adjusted to obtain an appropriate number of organisms for counting and for formalin preservative to be purged to avoid fume inhalation during counting. One mL subsamples were placed in a Sedgewick-Rafter counting cell and whole slides were analyzed until at least 200 animals had been identified and enumerated. A minimum of two slides was examined for each sample. References for identification were: Ward and Whipple (1959), Pennak (1978), and Rutner-Kolisko (1974). Zooplankton counts were converted to number per liter (microzooplankton) or per cubic meter (macrozooplankton) with the following formula:

$$\text{Zooplankton } (\#/\text{L or } \#/\text{m}^3) = NV_s/(V_c V_f)$$

where $N$ = number of individuals counted
$V_s$ = volume of reconstituted sample, (mL)
$V_c$ = volume of reconstituted sample counted, (mL)
$V_f$ = volume of water sieved, (L or $m^3$)

When the large cladoceran *Leptodora* was visible in a sample we used a modified method in which a know subsample was placed in a small petri dish and the entire number of *Leptodora* in this subsample were tallied using a dissecting microscope. These counts were converted to $\#/m^3$ using the above equation.

Ichthyoplankton samples were sieved through a 333 µm sieve to remove formalin and then reconstituted in ethanol. Larval fish were picked from this reconstituted sample with the aid of a stereo dissecting microscope, and the total number of larval fish was counted. Identification of ichthyoplankton was made to family and further to genus and species where possible. The works of Hogue et al. (1976), Jones et al. (1978), Lippson and Moran (1974), and Mansueti and Hardy (1967) were used for identification. The number of ichthyoplankton in each sample was expressed as number per 10 $m^3$ using the following formula:

Ichthyoplankton ($\#/10m^3$) = 10N/V

where N = number ichthyoplankton in the sample
V = volume of water filtered, ($m^3$)

**C. Adult and Juvenile Fish**

Fishes were sampled by trawling at stations 7, 9, and 10, seining at stations 4, 4B, 6, and 11. For trawling, a try-net bottom trawl with a 15-foot horizontal opening, a ¾ inch square body mesh and a ¼ inch square cod end mesh was used. The otter boards were 12 inches by 24 inches. Towing speed was 2-3 miles per hour and tow length was 5 minutes. In general, the trawl was towed across the axis of the cove at stations 7 and 10 and parallel to the channel at station 9. The direction of tow should not be crucial. Dates of sampling are found in Table 1.

Typically, each trawl site is sampled once per sampling event. However, on 4/23/2021 our first trawl sample at station 9 seemed to come off of the bottom. Therefore, we repeated this site resulting in 4 (2 at site 9) trawl samples on that date. On 6/10/2021, we got stuck during our first trawl attempt at station 9 and repeated that trawl. Unfortunately we became stuck in our second attempt as well, but this resulted in 4 total trawls (2 at site 9) for that sampling date. When a trawl gets stuck our CPUE is adjusted to account for the fact that the net sampled for a shorter duration.

Seining was performed with seine net that was 50 feet long, 4 feet high, and made of knotted nylon with a ¼ inch square mesh. The seining procedure was standardized as much as possible. The net was stretched out perpendicular to the shore with the shore end in water no more than a few inches deep. The net was then pulled parallel to the shore for a distance of 100 feet by a worker at each end moving at a slow walk. Actual distance was recorded if in any circumstance it was lower than 100 feet. At the end of the prescribed distance, the offshore end of the net was swung in an arc to the shore and the net pulled up on the beach to trap the fish.

Dates for seine sampling were generally the same as those for trawl sampling. We conducted seine sampling bimonthly from mid-April to mid-September 2021. Stations 4, 6, and 11 have been sampled continuously since 1985. 4B was added to the sampling stations since 2007 because extensive SAV growth interferes with sampling station 4 in late summer. Station 4B is a routine station now, also when seining at 4 is possible, resulting in a maximum of 4 seining sites per sampling trip. This allows for comparison between 4 and 4B. In 2021, SAV growth was too extensive to seine at Station 4 starting in June and SAV impeded sampling at station 6 starting in August. Therefore as seen in table 1, seine samples decreased throughout the year.

Fyke nets are set at station fyke 1 (near trawl station 10) and station fyke 2 (near seine station 4). Setting fyke nets when seining and trawling is still possible allows for gear comparison. Fyke nets were set within the SAV to sample the fish community that uses the SAV cover as habitat. Moving or discontinuing the trawl and seine collections when sampling with those gear types becomes impossible may underrepresent the fish community that lives within the dense SAV cover. Fyke nets are set for 5 hours to passively collect fish. The fyke nets have 5 hoops, a 1/4 inch mesh size, 16 feet wings and a 32 feet lead. Fish enter the net by actively swimming and/or due to tidal motion of the water. The lead increases catch by capturing the fish swimming parallel to the wings (see insert Figure 1b).

Although we strive to set two fyke nets per sampling trip, adverse weather, crew size, and the presence of commercial fisherman precluded fyke sampling on some 2021 sampling dates. Unfortunately, our crew was greatly reduced at the start of the sampling season due to researchers leaving the university. Therefore, Fyke sampling could not commence until 5/27/2021. On 6/10/2021, flash flood warnings and thunderstorms were present during sampling so fyke nets could not be deployed given dangerous weather conditions. We also do not set fyke nets if commercial fisherman have deployed gear in the study site and unfortunately on 6/24/2021, this was the case at our 1$^{st}$ site, resulting in only 1 net set on that date. On 7/8/2021, we experienced adverse weather conditions again precluding fyke sampling on that date.

After collection, the fishes were measured for standard length to the nearest mm. Standard length is the distance from the front tip of the snout to the end of the vertebral column and base of the caudal fin.  This is evident in a crease perpendicular to the axis of the body when the caudal fin is pulled to the side.

If the identification of the fish was not certain in the field, the specimen was preserved in 70% ethanol and identified later in the lab.  Identification was based on characteristics in dichotomous keys found in several books and articles, including Jenkins and Burkhead (1983), Hildebrand and Schroeder (1928), Loos et al (1972), Dahlberg (1975), Scott and Crossman (1973), Bigelow and Schroeder (1953), Eddy and Underhill (1978), Page and Burr (1998), and Douglass (1999).

**D. Submersed Aquatic Vegetation**

Data on coverage and composition of submersed aquatic vegetation (SAV) were obtained from the SAV webpage of the Virginia Institute of Marine Science (http://www.vims.edu/bio/sav).  Information on this web site was obtained from aerial photographs near the time of peak SAV abundance as well as ground surveys which were used to determine species composition. SAV abundances were also surveyed on August 29. As the research vessel slowly transited the cove, a weighted garden rake was dragged for 10-15 seconds along the bottom and retrieved. Adhering plants were identified and their relative abundance determined. About 40 such measurements were made on that date.

**E. Benthic Macroinvertebrates**

In the laboratory, materials collected on the 5 mm sieve for each sample were sorted into several groups: SAV, leaves/sticks/wood, shells. Each group was them dried and weighed separately. This was completed within 48 hours of sample collection

In the laboratory materials collected on the 0.5 mm sieve were rinsed with tap water through a 0.5 mm sieve to remove formalin preservative and resuspended in tap water. All organisms were picked, sorted, identified and enumerated. Picked organisms were retained in ethanol/glycerine.

**F. Data Analysis**

Several data flows were merged for analysis. Water quality data emanating from the Noman Cole laboratory was used for graphs of both current year seasonal and spatial patterns and long-term trends. Water quality, plankton, benthos and fish data were obtained from GMU samples. Data for each parameter were entered into spreadsheets (Excel or SigmaPlot) for graphing of temporal and spatial patterns for the current year. Long term trend analysis was conducted with Systat by plotting data for a given variable by year and then constructing a LOWESS trend line through the data. For water quality parameters the trend analysis was conducted on data from the warmer months (June-September) since this is the time of greatest microbial activity and greatest potential water quality impact. For zooplankton and fish all data for a given year were used. When graphs are shown with a log axis, zero values have been ignored in the trend analysis. JMP v8.0.1was used for fish graphs. Linear regression and standard parametric (Pearson) correlation coefficients were conducted to determine the statistical significance of linear trends over the entire period of record.

## RESULTS

### A. Climatic and Hydrologic Factors - 2021

In 2021 temperature was above normal in all months (Table 2). There were 38 days with maximum temperature above 32.2°C (90°F) in 2021 as in 2020 which is well above the median number over the past decade. Precipitation was closer to normal in 2021 than in the extremely wet year 2018. However, it was again well above normal in 2021, especially in June and August.

Table 2. Meteorological Data for 2021. National Airport. Monthly Summary.

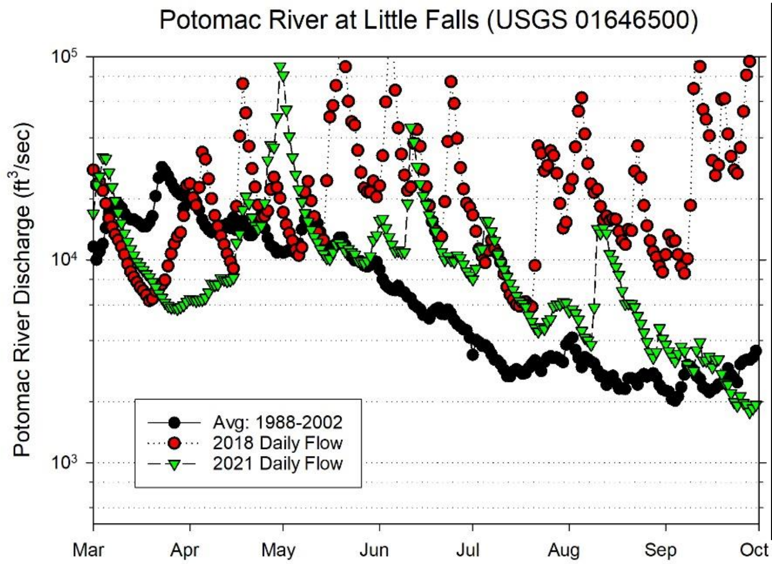
| MONTH | Air Temp (°C) | | Precipitation (cm) | |
|---|---|---|---|---|
| March | 10.8 | (8.1) | 9.7 | (9.1) |
| April | 14.7 | (13.4) | 5.6 | (7.0) |
| May | 19.1 | (18.7) | 9.6 | (9.7) |
| June | 24.9 | (23.6) | 14.0 | (8.0) |
| July | 27.3 | (26.2) | 10.8 | (9.3) |
| August | 27.3 | (25.2) | 23.1 | (8.7) |
| September | 23.1 | (21.4) | 10.3 | (9.6) |

Note: 2021 monthly averages or totals are shown accompanied by long-term monthly averages (1971-2000). Source: Local Climatological Data. National Climatic Data Center, National Oceanic and Atmospheric Administration.

River and tributary stream flow in 2021 were close to average for all months except September in the Potomac mainstem, and in Accotink were well above average in August (Table 3).

Table 3. Monthly mean discharge at USGS Stations representing freshwater flow into the study area. (+) 2021 month > 2x Long Term Avg. (-) 2021 month < ½ Long Term Avg.

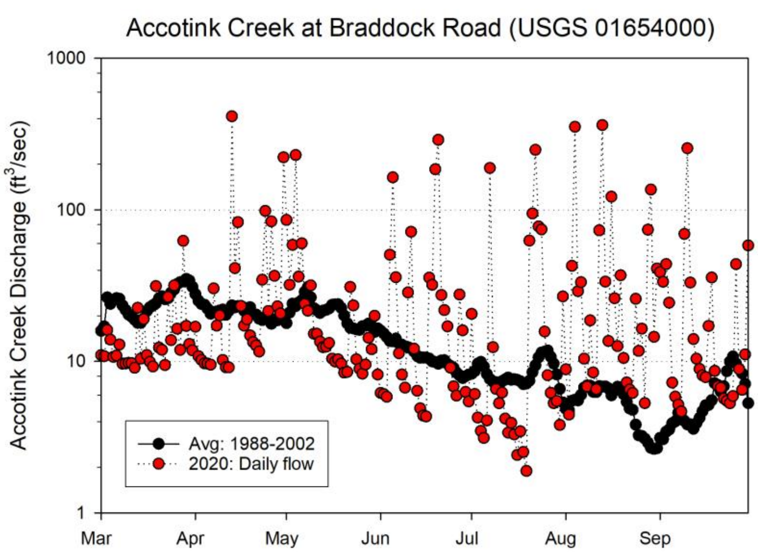
| | **Potomac River at Little Falls (cfs)** | | **Accotink Creek at Braddock Rd (cfs)** | |
|---|---|---|---|---|
| | **2021** | **Long Term Avg.** | **2021** | **Long Term Avg.** |
| March | 21614 | 23600 | 34 | 42 |
| April | 15746 | 20400 | 27 | 36 |
| May | 7978 | 15000 | 23 | 34 |
| June | 6884 | 9030 | 34 | 28 |
| July | 3022 | 4820 | 26 | 22 |
| August | 2748 | 4550 | 65 (+) | 22 |
| September | 14873 (+) | 5040 | 52 | 27 |




In a tidal freshwater system like the Potomac River, river flow entering from upstream is important in maintaining freshwater conditions and also serves to bring in dissolved and particulate substances from the watershed. High freshwater flows may also flush planktonic organisms downstream and bring in suspended sediments that decrease water clarity. The volume of river flow per unit time is referred to as "river discharge" by hydrologists. Note the long-term seasonal pattern of higher discharges in winter and spring and lower discharges in summer and fall.

Figure 2. Mean Daily Discharge: 2021. Potomac River at Little Falls (USGS Data). Month tick is at the beginning of the month.

These same patterns were seen in the graphs of daily river flow when compared to long-term averages (Figure 2). The long-term average shows a steadily decreasing trend from April through September. In 2021 this general seasonal pattern was observed except for the notable surges in June, July, and September which have the potential to strongly impact the ongoing growth of SAV and plankton in the river. Local inflow to the cove from Accotink followed the long-term pattern of decreasing base flow through the summer punctuated by storm flows (Figure 3). The high flows were most frequent during August.




In the Gunston Cove region of the tidal Potomac, freshwater discharge is occurring from both the major Potomac River watershed upstream (measured at Little Falls) and from immediate tributaries. The cove tributary for which stream discharge is available is Accotink Creek. Accotink Creek delivers over half of the stream water which directly enters the cove. While the gauge at Braddock Road only covers the upstream part of the watershed it is probably representative.

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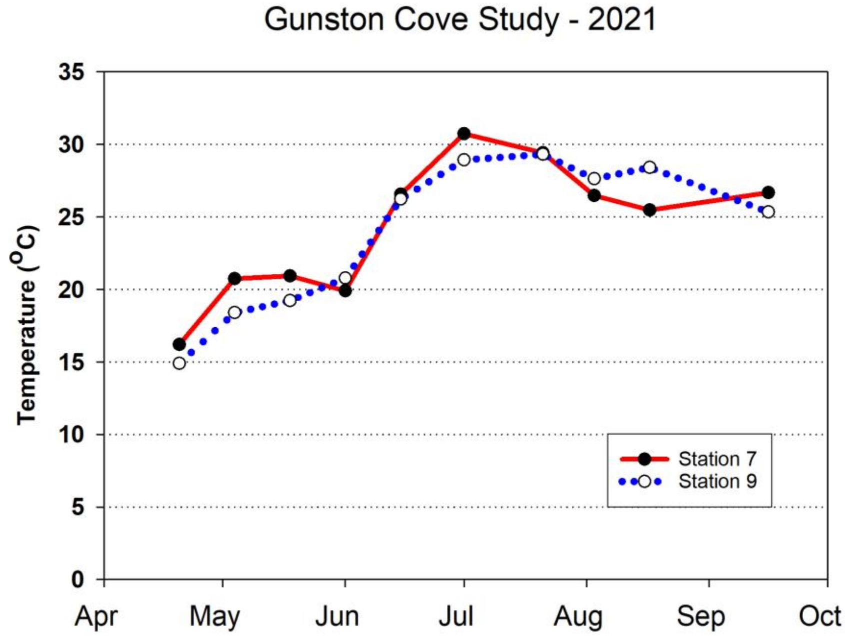
Figure 3. Mean Daily Discharge: 2021. Accotink Creek at Braddock Road (USGS Data).

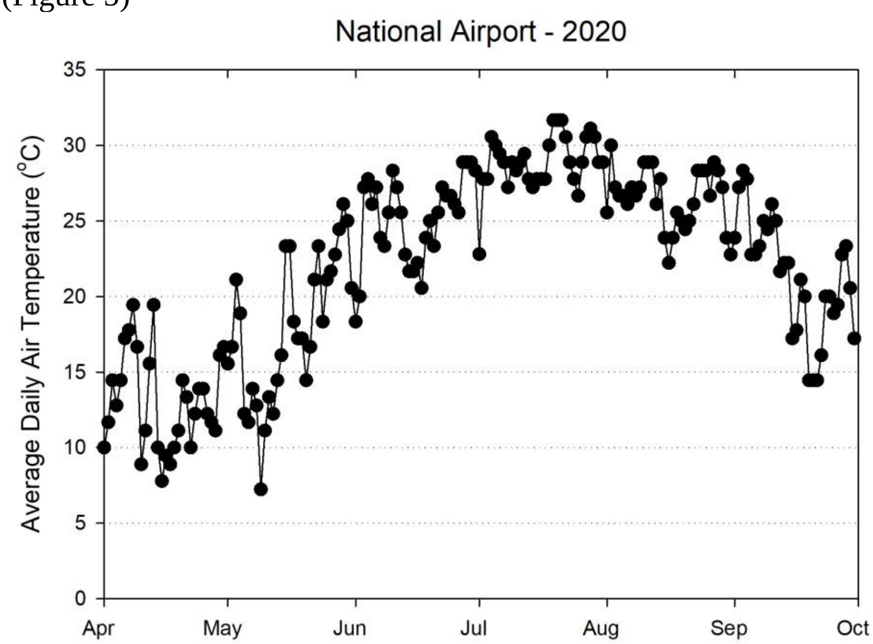
**B. Physico-chemical Parameters – 2021**




Water temperature is an important factor affecting both water quality and aquatic life. In a well-mixed system like the tidal Potomac, water temperatures are generally fairly uniform with depth.
In a shallow mixed system such as the tidal Potomac, water temperature often closely tracks daily changes in air temperature.

Figure 4. Water Temperature (°C). GMU Field Data. Month tick is at first day of month.

In 2021, water temperature followed the typical seasonal pattern at both sites with the exception of a slight cooling in early June (Figure 4). Both sites were between 25°C and 30°C from late June through September exceeding 30°C in early July. For most of the study period, the two stations showed very similar water temperatures and fairly closely tracked air temperature (Figure 5)




Mean daily air temperature (Figure 5) was a good predictor of water temperature (Figure 4). Variations in daily air temperature were more pronounce in the spring than in the summer.

Figure 5. Average Daily Air Temperature (°C) at Reagan National Airport.

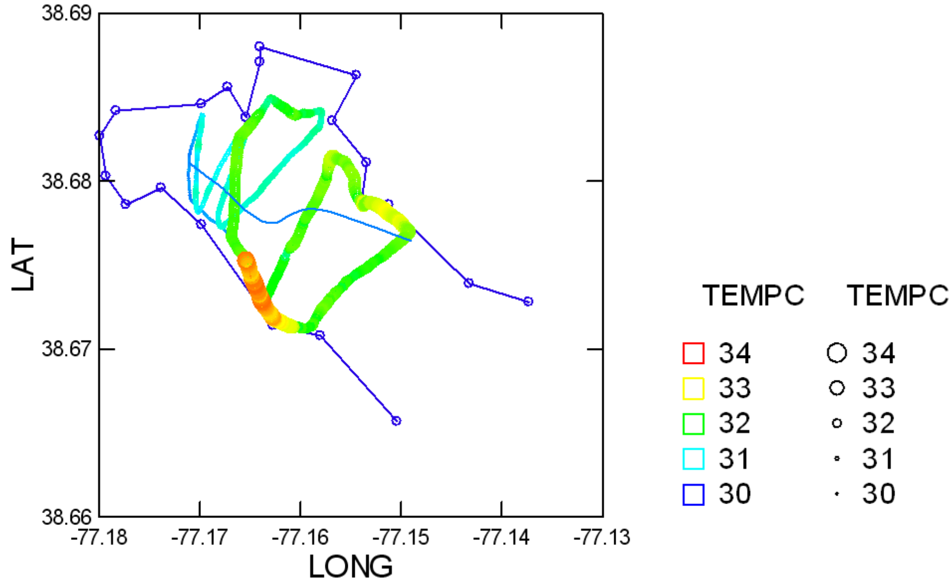



Figure 6. Temperature (ºC) observed in transects across Gunston Cove during data mapping cruise on August 26, 2021.

Temperature and Specific Conductance were measured during data mapping cruise on August 26, 2021 to assess spatial patterns in Gunston Cove. Temperature was slightly higher in the outer part of the cove along the south shore and slightly lower in Pohick Bay (Figure 6). Specific conductance showed a somewhat higher values in Pohick Bay and outer Gunston Cove (Figure 7). Accotink Bay was also lower. Pattern suggests an effect of Noman Cole effluent which has higher specific conductance than Gunston Cove. However, higher specific conductance was also seen in the outer part of Gunston Cove which may have seen an influence from the river mainstem..

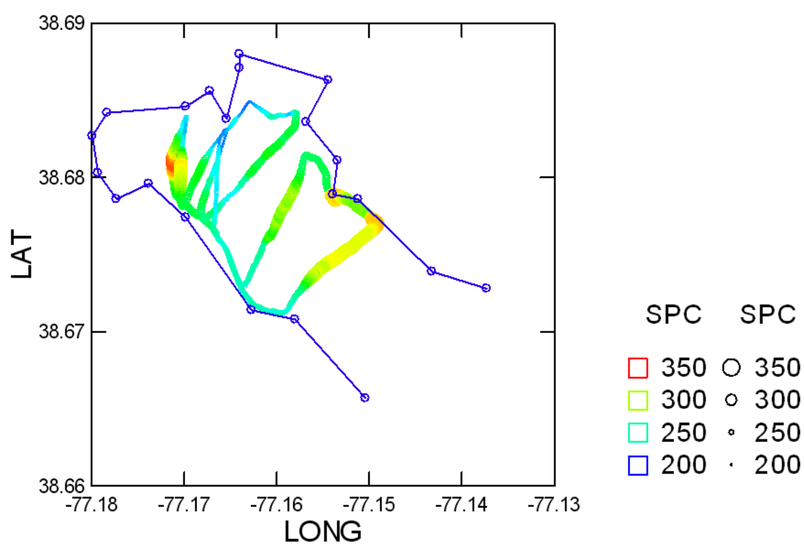
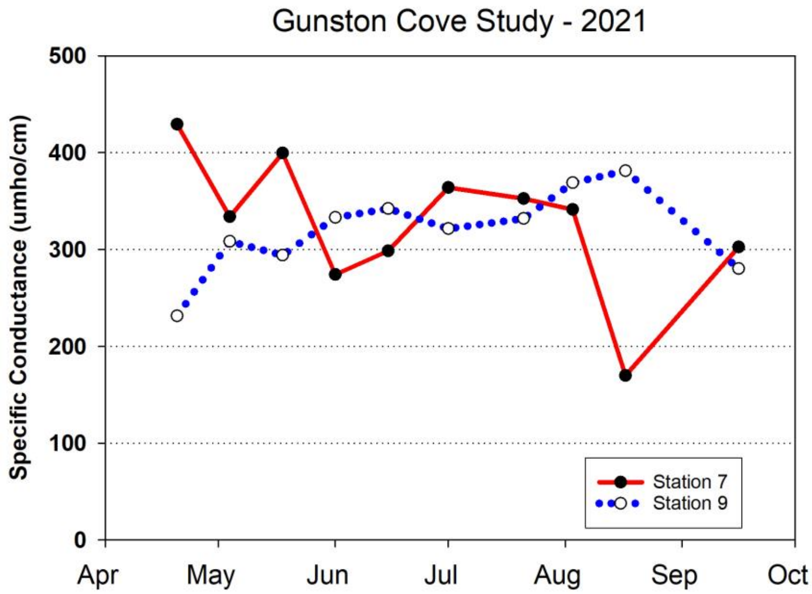


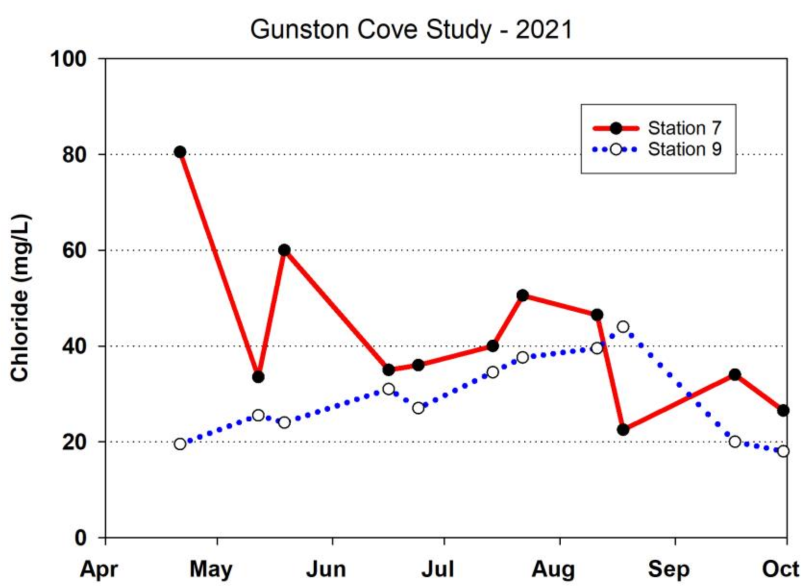

Figure 7. Specific Conductance (uS/cm) observed in transects across Gunston Cove during data mapping cruise on August 26, 2021.




Specific conductance measures the capacity of the water to conduct electricity standardized to 25ºC. This is a measure of the concentration of dissolved ions in the water. In freshwater, conductivity is relatively low. Ion concentration generally increases slowly during periods of low freshwater inflow and decreases during periods of high freshwater inflow. In years of low freshwater inflow during the summer and fall, conductance may increase dramatically if brackish water from the estuary reaches the study area.

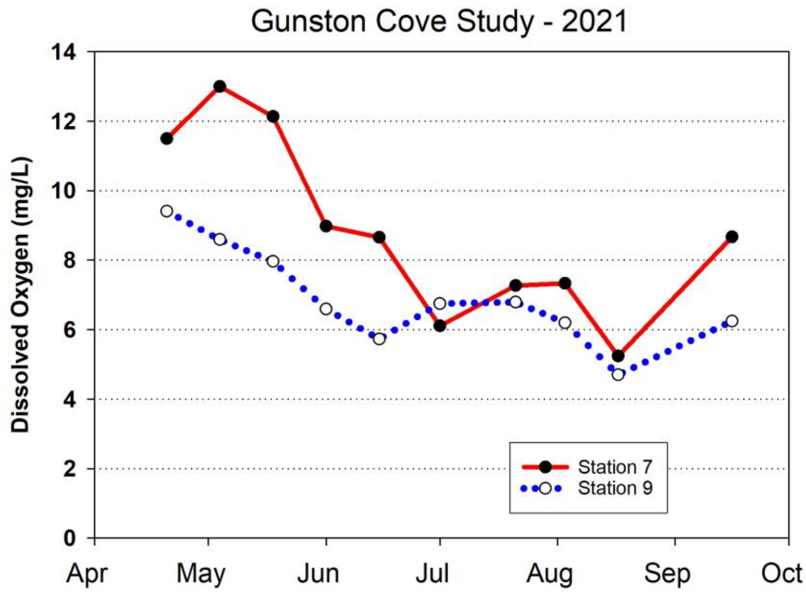
Figure 8. Specific Conductance (uS/cm). GMU Field Data. Month tick is at first day of month.

Specific conductance was mostly in the 250-400 range (Figure 8). Station 7 showed a general downward trend with much variability while Station 9 exhibited a slight upward trend and less variability. Values were similar at both stations from May through July. A marked decline was observed in the cove in mid-August. Chloride ion was consistently higher at Station 7 except for mid-August, probably due to the Noman Cole effluent, but all values were well within the freshwater range (Figure 9).




Chloride ion (Cl-) is a principal contributor to conductance. Major sources of chloride in the study area are sewage treatment plant discharges, road salt, and brackish water from the downriver portion of the tidal Potomac. Chloride concentrations observed in the Gunston Cove area are very low relative to those observed in brackish, estuarine, and coastal areas of the Mid-Atlantic region. Chloride often peaks markedly in late summer or fall when brackish water from down estuary may reach the cove as freshwater discharge declines.

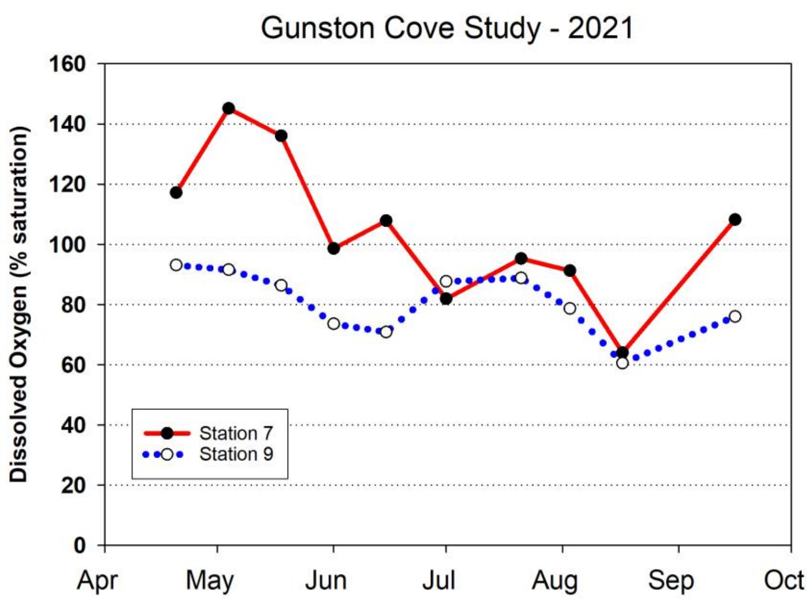
Figure 9. Chloride (mg/L). Fairfax County Lab Data. Month tick is at first day of month.




Oxygen dissolved in the water is required by freshwater animals for survival. The standard for dissolved oxygen (DO) in most surface waters is 5 mg/L. Oxygen concentrations in freshwater are in balance with oxygen in the atmosphere, but oxygen is only weakly soluble in water so water contains much less oxygen than air. This solubility is determined by temperature with oxygen more

Figure 10. Dissolved Oxygen (mg/L). GMU Field Data. Month tick is at first day of month.

Dissolved oxygen in mg/L showed a gradual decline through the year at both stations with Station 7 maintaining higher values through most of the year (Figure 10). Figure 11 shows that dissolved oxygen levels in the cove were substantially above 100% in spring 2021 indicating abundant photosynthesis by SAV and phytoplankton. In the river values were generally equal or less than 100% indicating lower photosynthesis and an excess of respiration.




The temperature effect on oxygen concentration can be removed by calculating DO as percent saturation. This allows examination of the balance between photosynthesis and respiration both of which also impact DO. Photosynthesis adds oxygen to the water while respiration removes it. Values above 120% saturation are indicative of intense photosynthesis while values below 80% reflect a preponderance of respiration or decomposition.

Figure 11. Dissolved Oxygen (% saturation). GMU Field Data. Month tick is at first day of month.

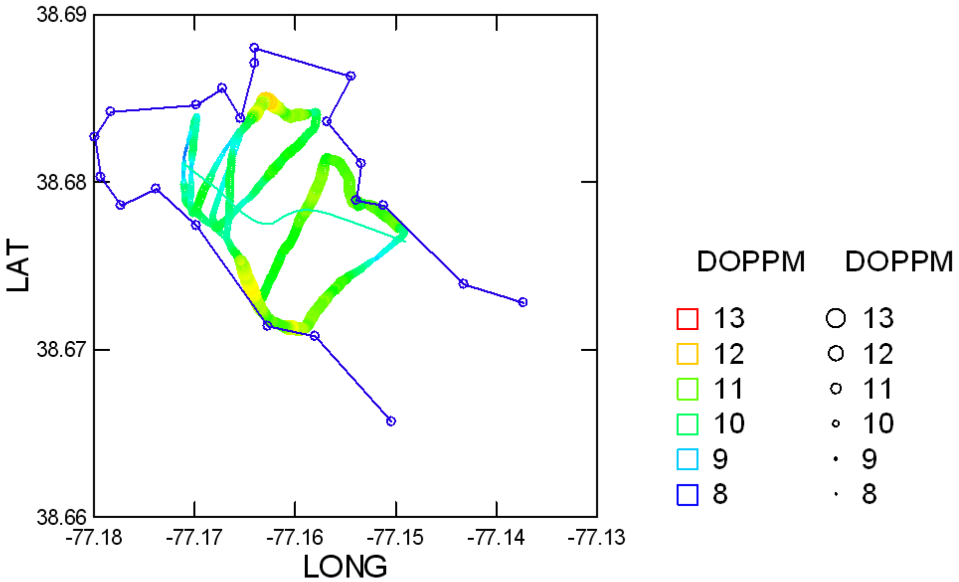



Figure 12. Dissolved Oxygen (mg/L) observed in transects across Gunston Cove during data mapping cruise on August 26, 2021.

Dissolved oxygen levels were highest in the middle part of Gunston Cove, especially along the shoreline and in Accotink Bay (Figures 12&13). The supersaturated DO values indicated strong photosynthetic activity probably due to dense SAV in those two shoreline areas.

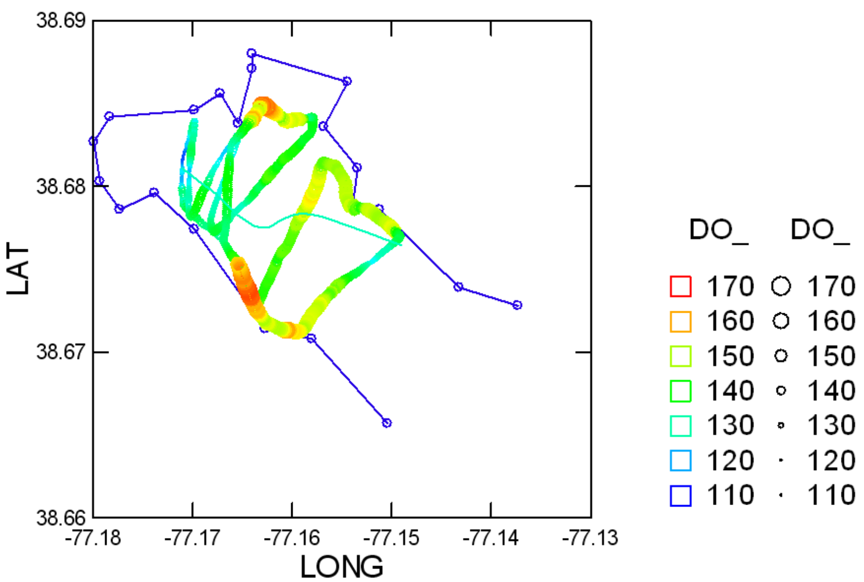
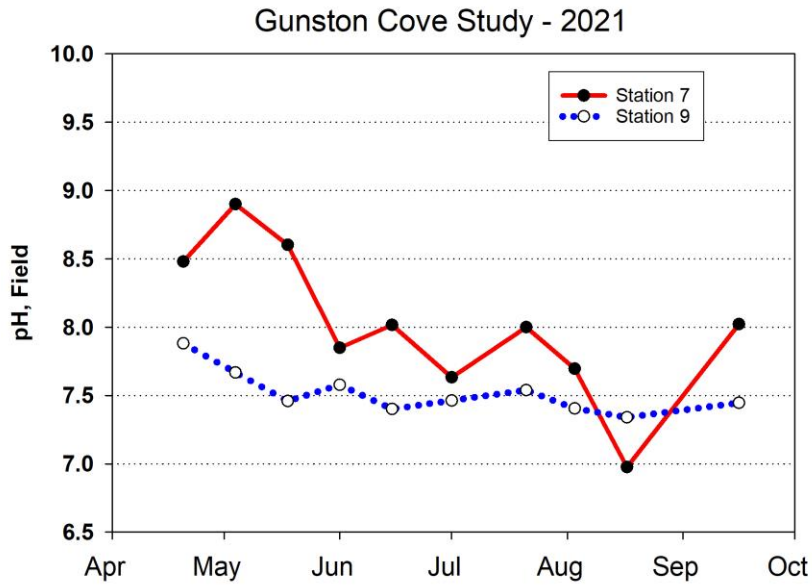



Figure 13. Dissolved Oxygen (% saturation) observed in transects across Gunston Cove during data mapping cruise on August 26, 2021.




pH is a measure of the concentration of hydrogen ions (H+) in the water. Neutral pH in water is 7. Values between 6 and 8 are often called circumneutral, values below 6 are acidic and values above 8 are termed alkaline. Like DO, pH is affected by photosynthesis and respiration. In the tidal Potomac, pH above 8 indicates active photosynthesis and values above 9 indicate intense

Figure 14. pH. GMU Field Data. Month tick is at first day of month.

Field pH was consistently greater in the cove than in the river again reflecting differences in photosynthetic activity (Figure 14). Times of elevated pH generally corresponded to those in dissolved oxygen. This was also true comparing the spatial pattern of pH (Figure 15) with that of DO (Figure 13) and again is consistent with a photosynthetic activity effect, probably due to SAV since the high values were observed in shallow water near the shoreline where SAV are most abundant..

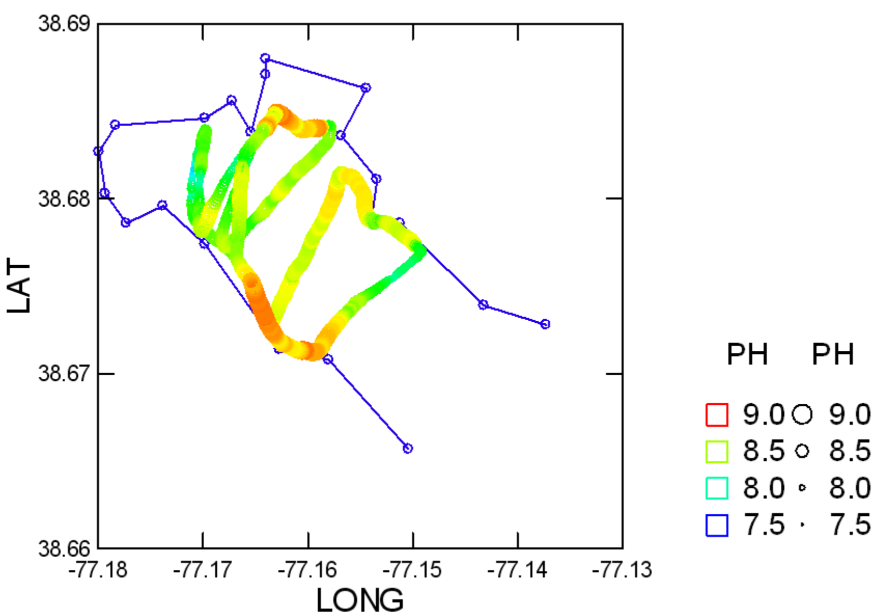
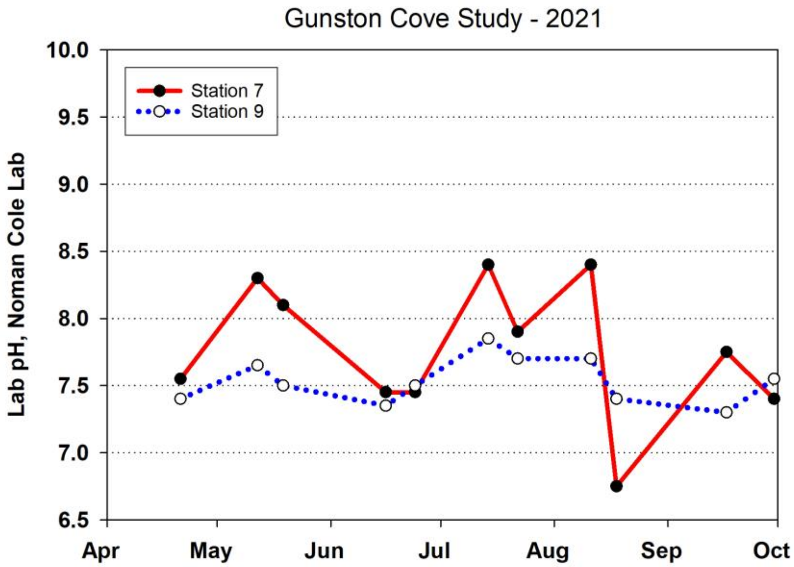


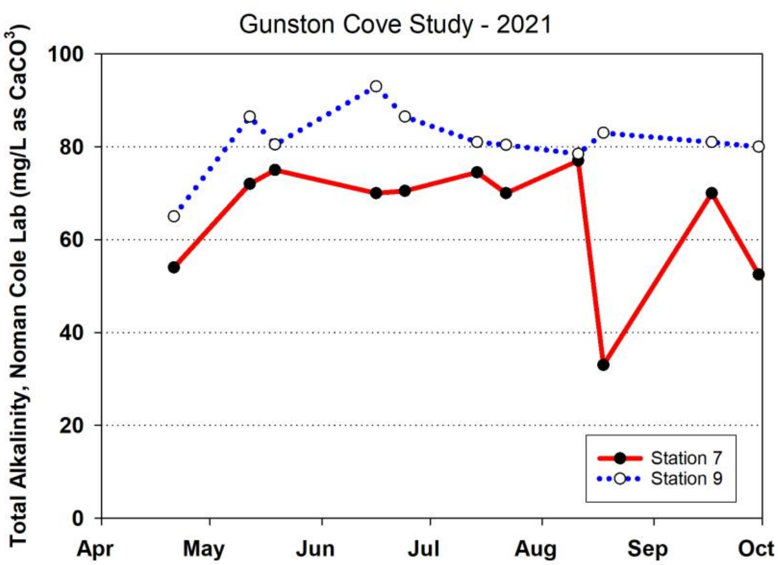

Figure 15. Field pH observed in transects across Gunston Cove during data mapping cruise on August 26, 2021.




pH may be measured in the field or in the lab. Field pH is more reflective of in situ conditions while lab pH is done under more stable and controlled laboratory conditions and is less subject to error. Newer technologies such as the Hydrolab and YSI sondes used in GMU field data collection are more reliable than previous field pH meters and should give results that are most representative of values actually observed in the river.

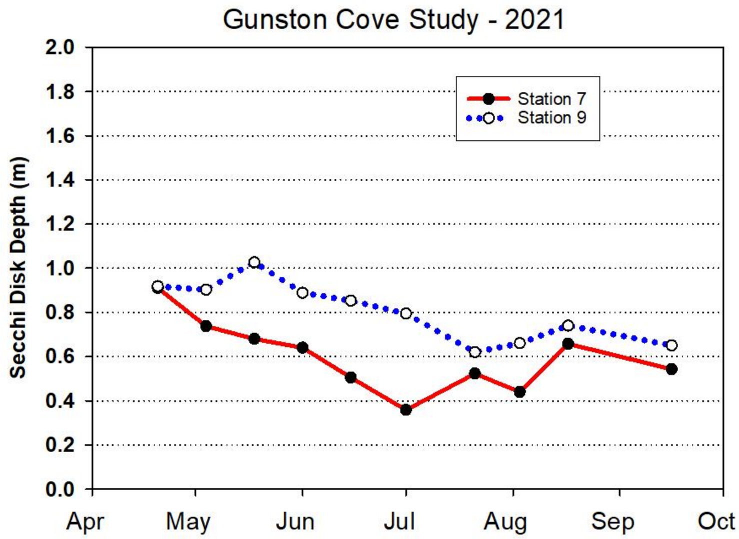
Figure 16. pH. Noman Cole Lab Data. Month tick is at first day of month.

Lab pH was collected less frequently, but also to resulted in enhanced values in the cove (Figure 16). Total alkalinity was consistently higher in the river than in the cove by about 5 units with an exceptionally large difference in mid-August (Figure 17).




Total alkalinity measures the amount of bicarbonate and carbonate dissolved in the water. In freshwater this corresponds to the ability of the water to absorb hydrogen ions (acid) and still maintain a near neutral pH. Alkalinity in the tidal freshwater Potomac generally falls into the moderate range allowing adequate buffering without carbonate precipitation.

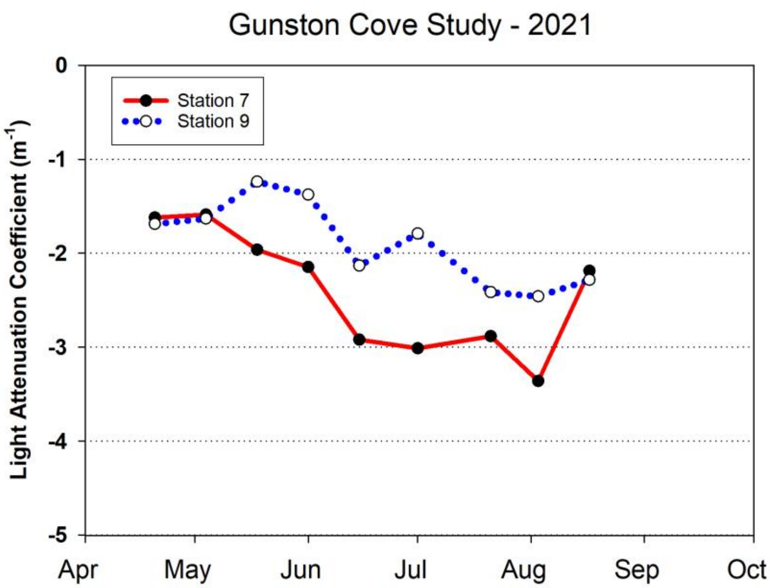
Figure 17. Total Alkalinity (mg/L as $CaCO_3$). Fairfax County Lab data. Month tick is at first day of month.




Secchi Depth is a measure of the transparency of the water. The Secchi disk is a flat circle or thick sheet metal or plywood about 6 inches in diameter which is painted into alternate black and white quadrants. It is lowered on a calibrated rope or rod to a depth at which the disk disappears. This depth is termed the Secchi Depth. This is a quick method for determining how far light is penetrating into the water column. Light is necessary for photosynthesis and thereby for growth of aquatic

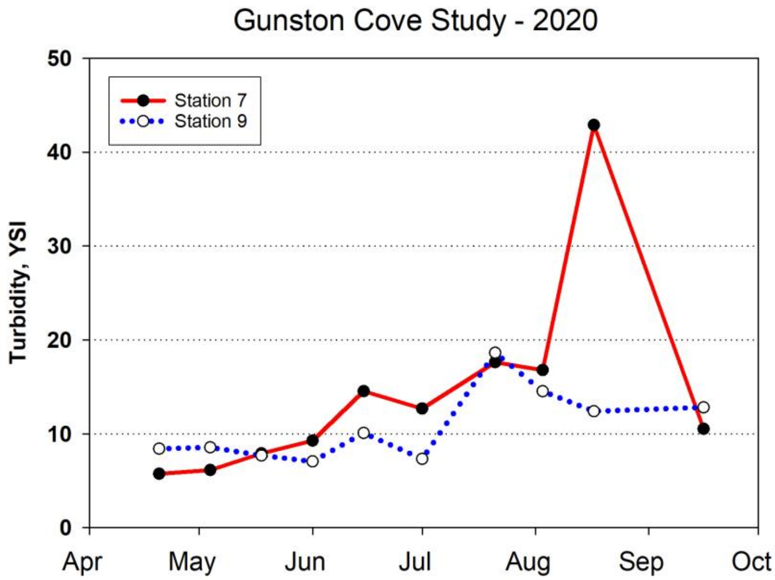
Figure 18. Secchi Disk Depth (m). GMU Field Data. Month tick is at first day of month.

Water clarity as reflected by Secchi disk transparency showed a consistent decline in the cove from around 0.9 m in April to 0.4 m in early July before rising again. In the river values were more constant averaging about 0.8 m (Figure 18). Light attenuation coefficient exhibited a similar spatial and temporal patterns (Figure 19).




Light Attenuation is another approach to measuring light penetration. This is determined by measuring light levels at a series of depths starting near the surface. The resulting relationship between depth and light is fit to a semi-logarithmic curve and the resulting slope is called the light attenuation coefficient. This relationship is called Beer's Law. It is analogous to absorbance on a spectrophotometer. The greater the light attenuation, the faster light is absorbed with depth. More negative values indicate greater attenuation. Greater attenuation is due to particulate and dissolved material which absorbs and deflects light.

Figure 19. Light Attenuation Coefficient ($m^{-1}$). GMU Field Data. Month tick is at first day of month.




Turbidity is yet a third way of measuring light penetration. Turbidity is a measure of the amount of light scattering by the water column. Light scattering is a function of the concentration and size of particles in the water. Small particles scatter more light than large ones (per unit mass) and more particles result in more light scattering than fewer particles.

Figure 20. Turbidity (NTU). GMU Lab Data. Month tick is at first day of month.

Turbidity increased consistently in the cove from April through early August (Figure 20). A very large peak was observed in mid-August. Turbidity was fairly constant in the river with a slight seasonal increase. In the September datamapping cruise, turbidity was generally low except in along the north shore of Gunston Cove where it was somewhat higher, perhaps due to sediment resuspension during the cruise (Figure 21).

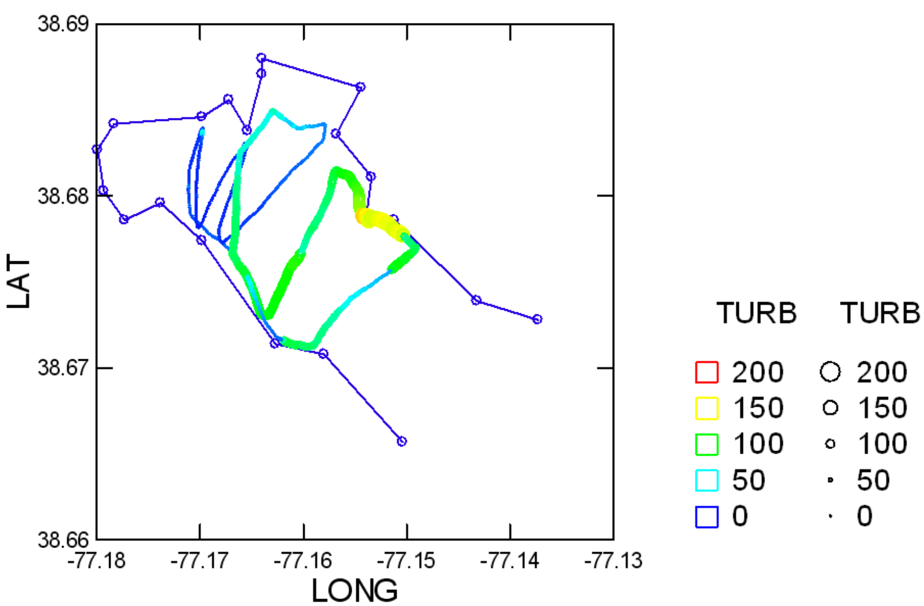
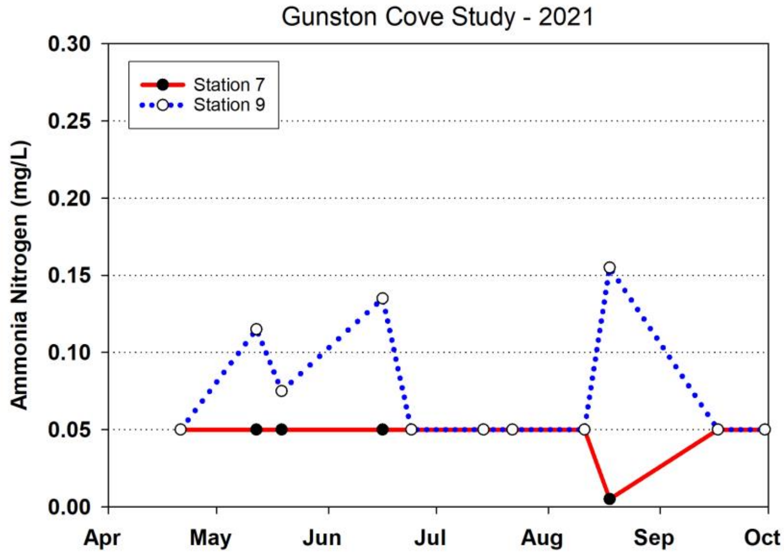


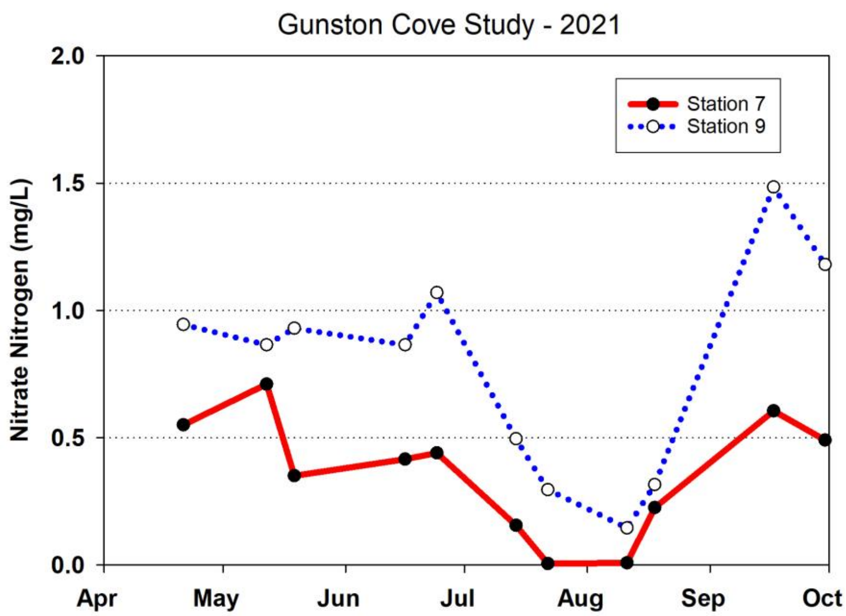

Figure 21. Turbidity (NTU) observed in transects across Gunston Cove during data mapping cruise on August 26, 2021.




Ammonia nitrogen measures the amount of ammonium ion ($NH_4^+$) and ammonia gas ($NH_3$) dissolved in the water. Ammonia nitrogen is readily available to algae and aquatic plants and acts to stimulate their growth. While phosphorus is normally the most limiting nutrient in freshwater, nitrogen is a close second. Ammonia nitrogen is rapidly oxidized to nitrate nitrogen when oxygen is present in the water.

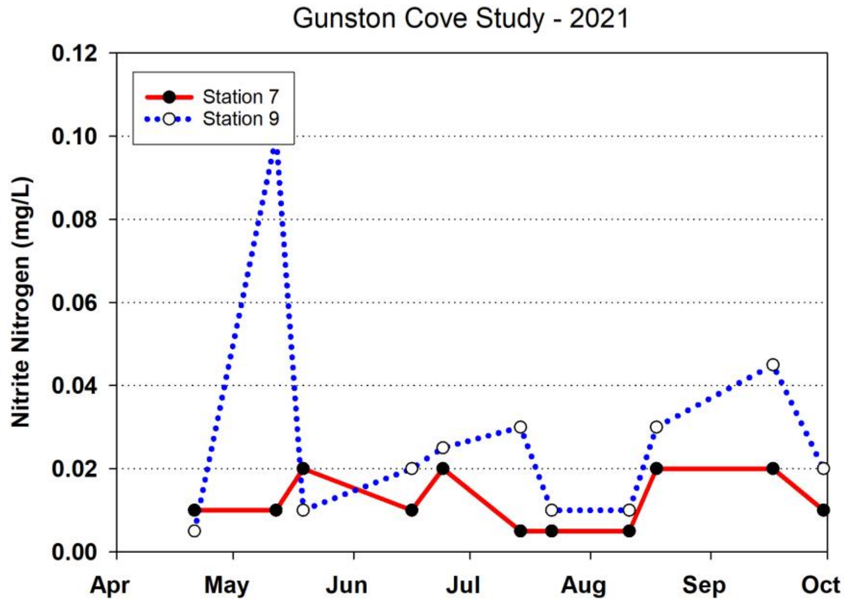
Figure 22. Ammonia Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month. (Limit of detection: 0.10 mg/L, LD values graphed as 0.05 mg/L)

Ammonia nitrogen was below detection limits in all samples reported in 2021 in all cove samples and almost all river samples (Figure 22). Unfortunately, the detection limit at the Fairfax County Lab has increased substantially in the past several years from 0.01 mg/L to 0.1 mg/L. As we pointed out in the 2019 report, this has made it impossible to detect any further improvements in ammonia levels. Nitrate nitrogen levels were consistently higher in the river than in the cove (Figure 23). A clear seasonal decline was observed at both stations, with values at the limit detection in late July and early August in the cove.




Nitrate Nitrogen refers to the amount of N that is in the form of nitrate ion ($NO_3^-$). Nitrate ion is the most common form of nitrogen in most well oxidized freshwater systems. Nitrate concentrations are increased by input of wastewater, nonpoint sources, and oxidation of ammonia in the water. Nitrate concentrations decrease when algae and plants are actively growing and removing nitrogen as part of their growth.

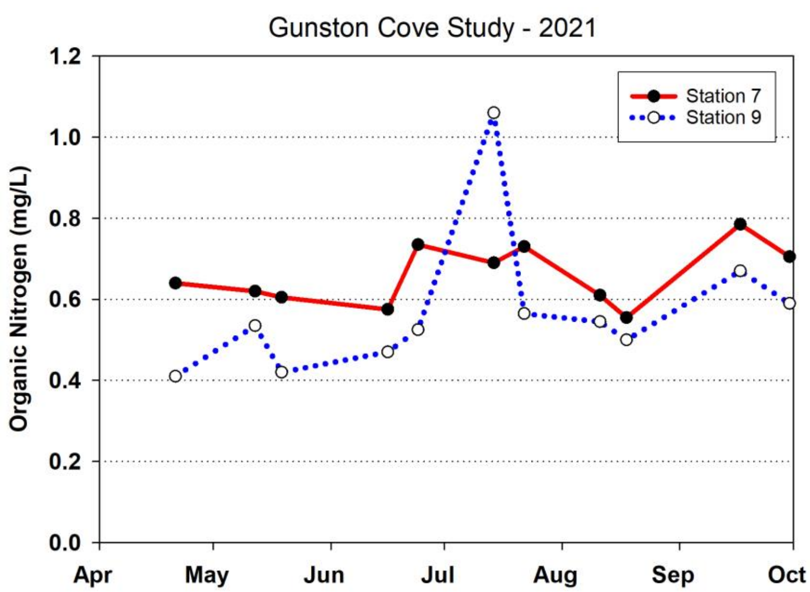
Figure 23. Nitrate Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month. (Limit of detection: 0.01 mg/L; LD values graphed as 0.005 mg/L)




Nitrite nitrogen consists of nitrogen in the form of nitrite ion ($NO_2^-$). Nitrite is an intermediate in the oxidation of ammonia to nitrate, a process called nitrification. Nitrite is usually in very low concentrations unless there is active nitrification.

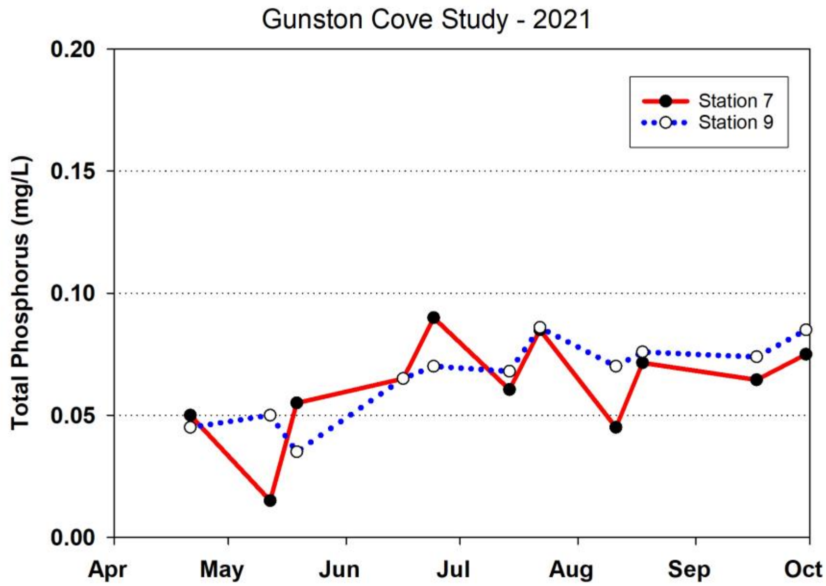
Figure 24. Nitrite Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month. (limit of detection = 0.01 mg/L).

Nitrite nitrogen was generally low and quite variable, but was consistently slightly higher in the river (Figure 24). There was an unexplained spike in early May in the river. Organic nitrogen was was consistently 0.5 to 1.0 mg/L higher in cove than the river (Figure 25). Values were generally consistent over time except for a spike in early July at Station 9.




Organic nitrogen measures the nitrogen in dissolved and particulate organic compounds in the water. Organic nitrogen comprises algal and bacterial cells, detritus (particles of decaying plant, microbial, and animal matter), amino acids, urea, and small proteins. When broken down in the environment, organic nitrogen results in ammonia nitrogen. Organic nitrogen is determined as the difference between total Kjeldahl nitrogen and ammonia nitrogen.

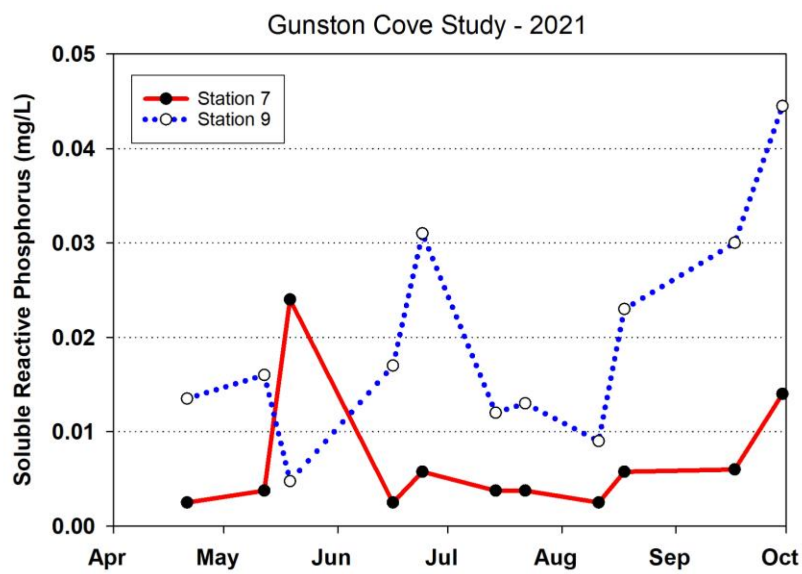
Figure 25. Organic Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.




Phosphorus (P) is often the limiting nutrient in freshwater ecosystems. As such the concentration of P can set the upper limit for algal growth. Total phosphorus is the best measure of P availability in freshwater since much of the P is tied up in biological tissue such as algal cells. Total P includes phosphate ion ($PO_4^{-3}$) as well as phosphate inside cells and phosphate bound to inorganic particles such as clays.

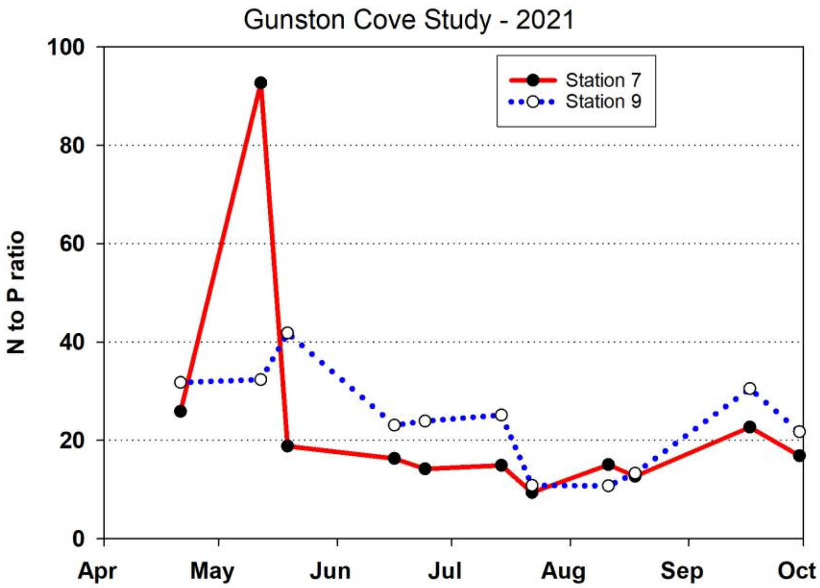
Figure 26. Total Phosphorus (mg/L). Fairfax County Lab Data. Month tick is at first day of month. (Limit of detection: 0.03 mg/L)

Total phosphorus was similar at both stations on almost all dates and showed very little trend over time at either station (Figure 26). Soluble reactive phosphorus was generally substantially higher in the river than in the cove (Figure 27).




Soluble reactive phosphorus (SRP) is a measure of phosphate ion ($PO_4^{-3}$). Phosphate ion is the form in which P is most available to primary producers such as algae and aquatic plants in freshwater. However, SRP is often inversely related to the activity of primary producers because they tend to take it up so rapidly. So, higher levels of SRP indicate either a local source of SRP to the waterbody or limitation by a factor other than P.

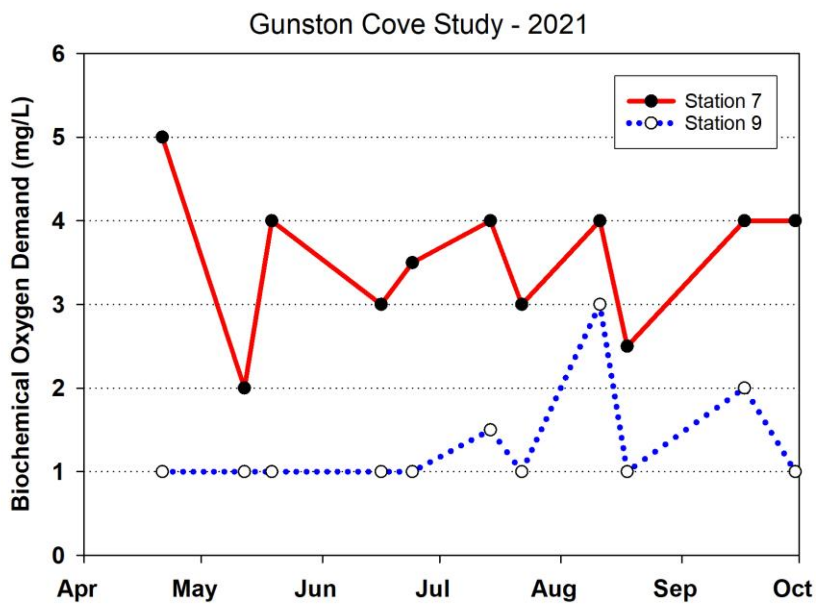
Figure 27. Soluble Reactive Phosphorus (mg/L). Fairfax County Lab Data. Month tick is at first day of month. (Limit of detection = 0.005 mg/L)




N:P ratio is determined by summing all of the components of N (ammonia, nitrate, nitrite, and organic nitrogen) and dividing by total P. This ratio gives an indication of whether N or P is more likely to be limiting primary production in a given freshwater system. Generally, values above 7.2 are considered indicative of P limitation while values below 7.2 suggest N limitation. N limitation could lead to dominance by cyanobacteria who can fix their own N from the atmosphere.

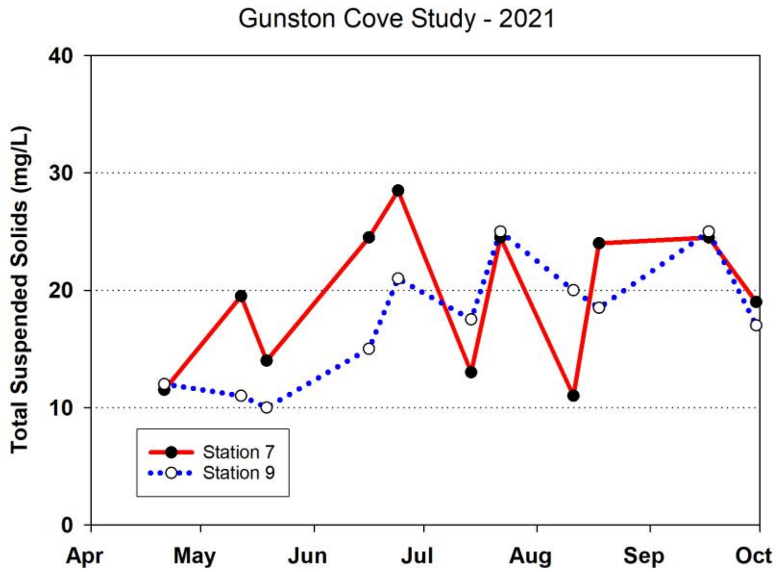
Figure 28. N/P Ratio (by mass). Fairfax County Lab Data. Month tick is at first day of month.

N/P ratio exhibited little consistent seasonal pattern at either site (Figure 28). Values bottomed out at about 12 in late July and early August approaching N limitation. Biochemical oxygen demand (BOD) was consistently higher in the cove than in the river (Figure 29).




Biochemical oxygen demand (BOD) measures the amount of decomposable organic matter in the water as a function of how much oxygen it consumes as it breaks down over a given numittlber of days. Most commonly the number of days used is 5. BOD is a good indicator of the potential for oxygen depletion in water. BOD is composed both dissolved organic compounds in the water as well as microbes such as bacteria and algae which will respire and consume oxygen during the period

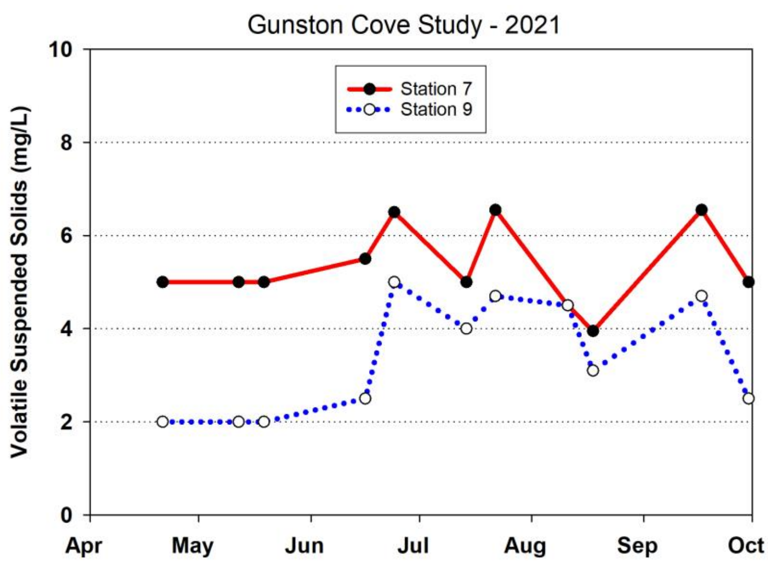
Figure 29. Biochemical Oxygen Demand (mg/L). Fairfax County Lab Data. Month tick is at first day of month.




Total suspended solids (TSS) is measured by filtering a known amount of water through a fine filter which retains all or virtually all particles in the water. This filter is then dried and the weight of particles on the filter determined by difference. TSS consists of both organic and inorganic particles. During periods of low river and tributary inflow, organic particles such as algae may dominate. During storm flow periods or heavy winds causing resuspension, inorganic particles may dominate.

Figure 30. Total Suspended Solids (mg/L). Fairfax County Lab Data. Month tick is at first day of month.

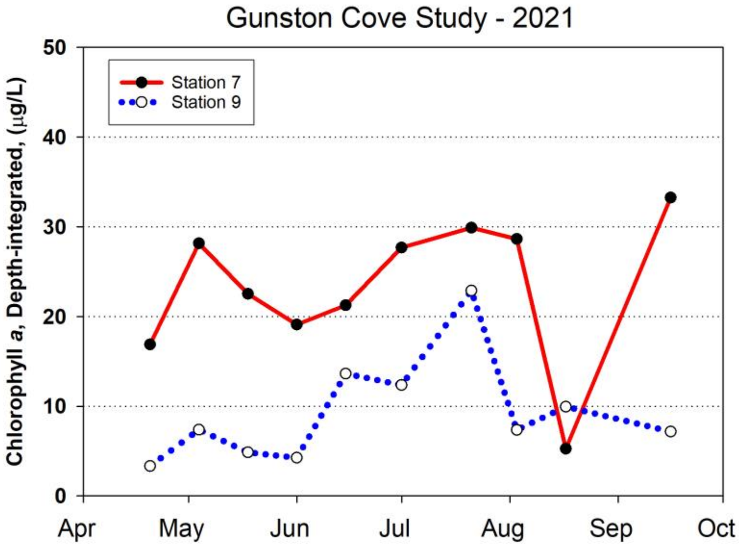
Total suspended solids increased slowly over the year in the river (Figure 30). The cove showed a more rapid increase in the spring, but varied a lot later in the year. Values were similar at both stations. Volatile suspended solids was higher in the cove throughout the year with greatest difference in the spring (Figure 31). Values did not show much of a seasonal pattern.




Volatile suspended solids (VSS) is determined by taking the filters used for TSS and then ashing them to combust (volatilize) the organic matter. The organic component is then determined by difference. VSS is a measure of organic solids in a water sample. These organic solids could be bacteria, algae, or detritus. Origins include sewage effluent, algae growth in the water column, or detritus produced within the waterbody or from tributaries. In summer in Gunston Cove a chief source is algal (phytoplankton) growth.

Figure 31. Volatile Suspended Solids (mg/L). Fairfax County Lab Data. Month tick is at first day of month.

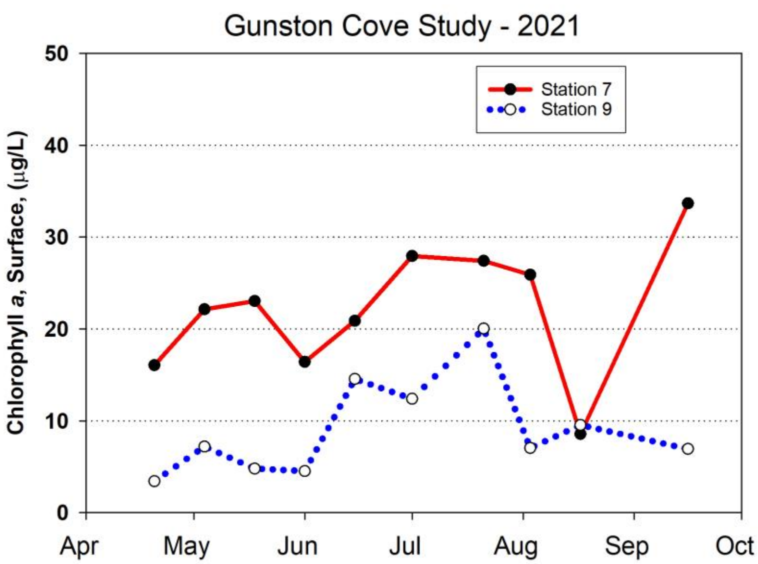
**C. Phytoplankton -2021**




Chlorophyll *a* is a measure of the amount of algae growing in the water column. These suspended algae are called phytoplankton, meaning "plant wanderers". In addition to the true algae (greens, diatoms, cryptophytes, etc.) the term phytoplankton includes cyanobacteria (sometimes known as "blue-green" algae). Both depth-integrated and surface chlorophyll values are measured due to the capacity of phytoplankton to aggregate near the surface under certain conditions.

Figure 32. Chlorophyll *a* (µg/L). Depth-integrated. GMU Lab Data. Month tick is at the first day of month. Trilogy soak procedure.

Chlorophyll *a* at in the cove exhibited two major peaks in early May and mid-July each approaching 30 µg/L (Figures 32&33). In the river, chlorophyll a exhibited a steady increase to a maximum in mid-July of about 20 µg/L. Depth-integrated and surface chlorophyll showed similar spatial and temporal patterns.




In the Gunston Cove, there is very little difference in surface and depth-integrated chlorophyll levels because tidal action keeps the water well-mixed which overcomes any potential surface aggregation by the phytoplankton. Summer chlorophyll concentrations above 30 ug/L are generally considered characteristic or eutrophic conditions.

Figure 33. Chlorophyll *a* (µg/L). Surface. GMU Lab Data. Month tick is at first day of month. Trilogy soak procedure.

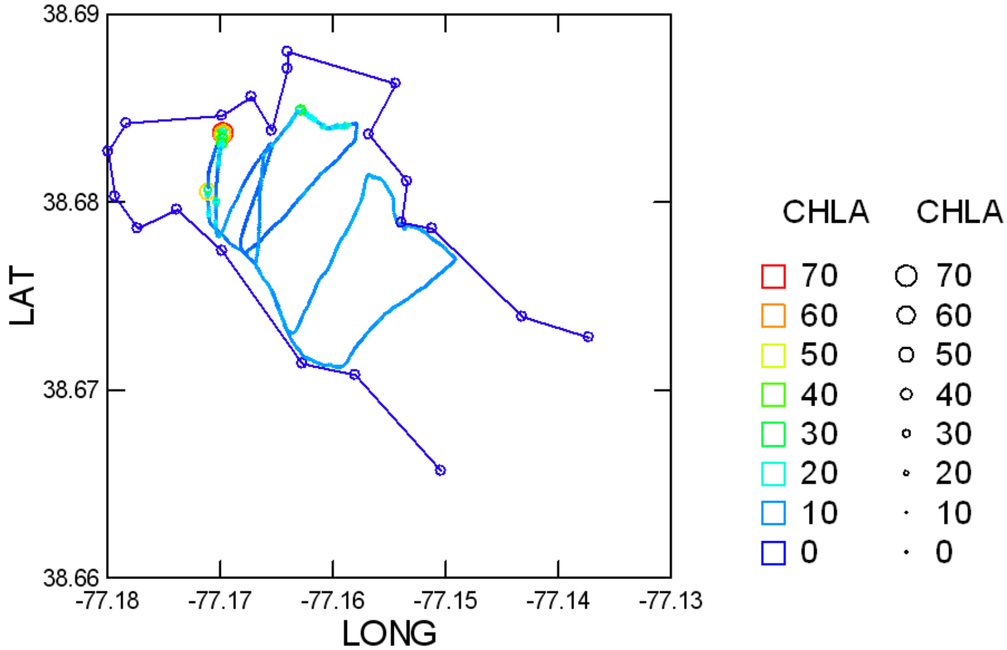



Figure 34. Chlorophyll *a* (µg/L) observed in transects across Gunston Cove during data mapping cruise on August 26, 2021.

Chlorophyll data from the datamapping cruise in 2021 showed a pattern of relatively low values over most of the study area (Figure 34). The peak in northern Pohick Bay probably resulted from algae being knocked off of SAV. A graph of dissolved oxygen (an indicator of photosynthesis) vs. phytoplankton chlorophyll showed that high values of DO (>130% saturation) occurred without much change in phytoplankton (Figure 35). The other potential driver of DO, SAV, was abundant in 2021. SAV depresses phytoplankton chlorophyll. Thus, the high DO values in 2021 can be attributed to both mainly to SAV photosynthesis.

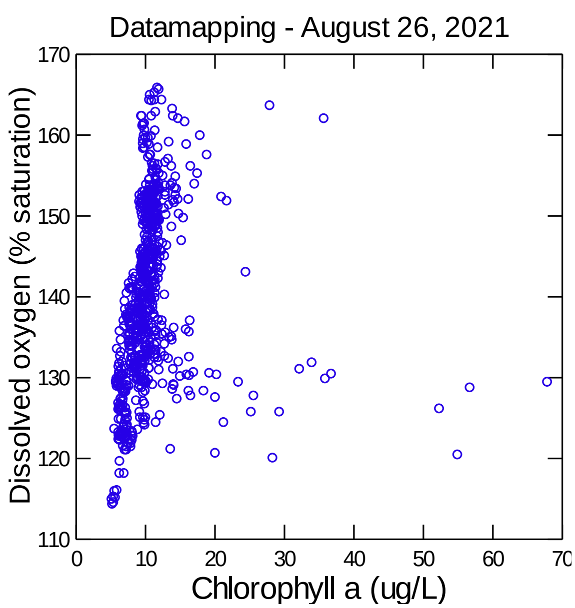
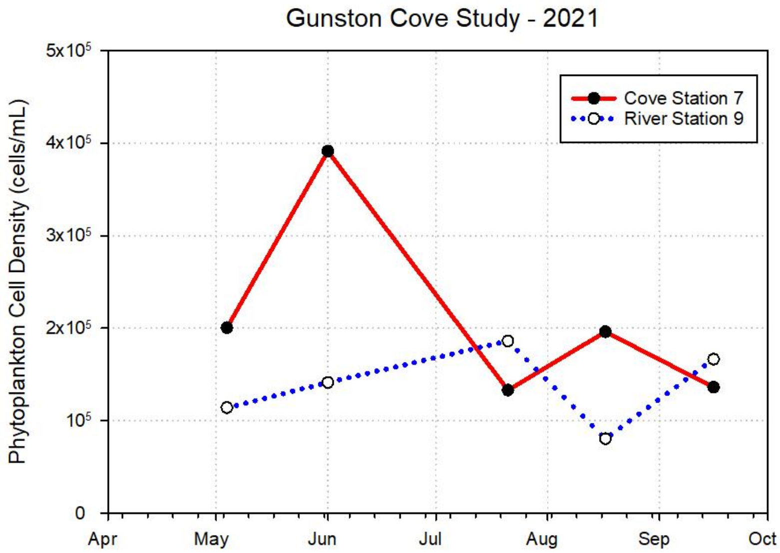



Figure 35. Dissolved Oxygen (% saturation) vs. Chlorophyll a (ug/L) as determined by YSI EXO sonde during datamapping on August 26, 2021.




Phytoplankton cell density provides a measure of the number of algal cells per unit volume. This is a rough measure of the abundance of phytoplankton, but does not discriminate between large and small cells. Therefore, a large number of small cells may actually represent less biomass (weight of living tissue) than a smaller number of large cells. However, small cells are typically more active than larger ones so cell density is probably a better indicator of activity than of biomass. The smaller cells are mostly

Figure 36. Phytoplankton Density (cells/mL)

In the cove phytoplankton density was low in April, then increased to a strong peak in May (Figure 36).. In the river the highest value for phytoplankton density was observed in July. The river peak for cell biovolume was also found in July, but the biovolume peak for the cove was observed in early June (Figure 37).

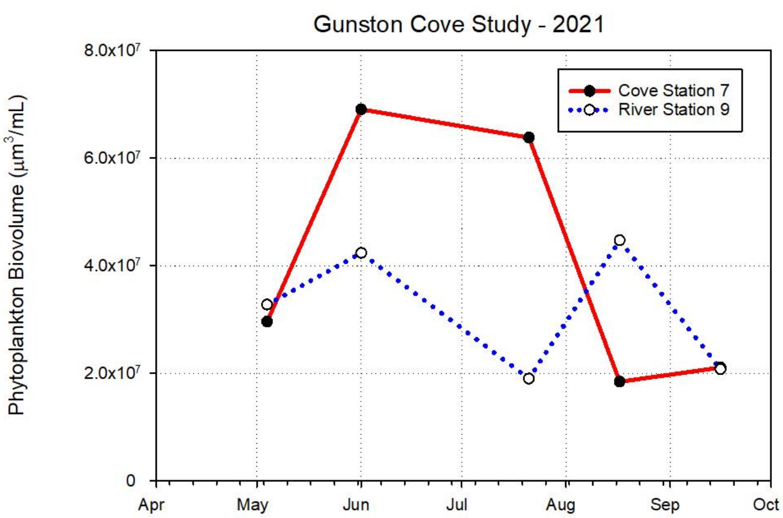
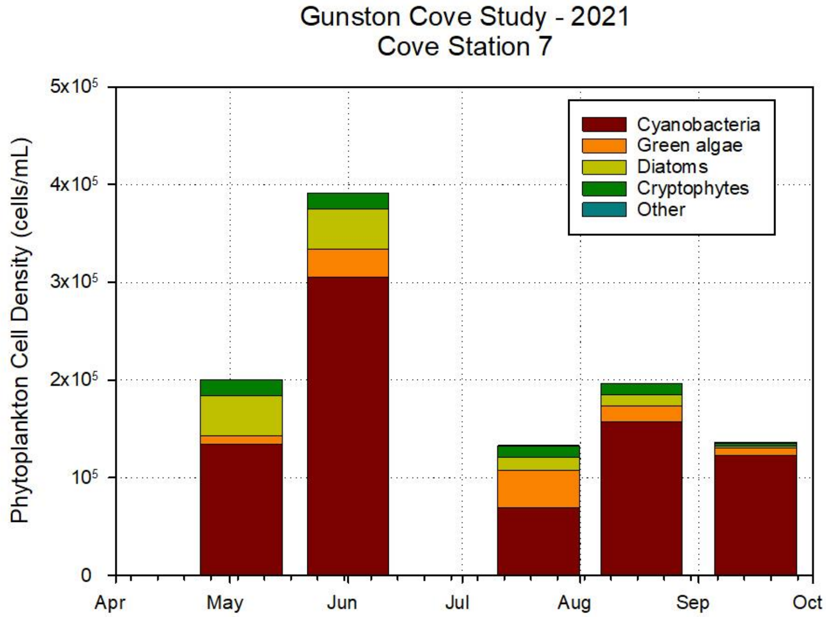



Figure 37. Phytoplankton Biovolume (um$^3$/mL).

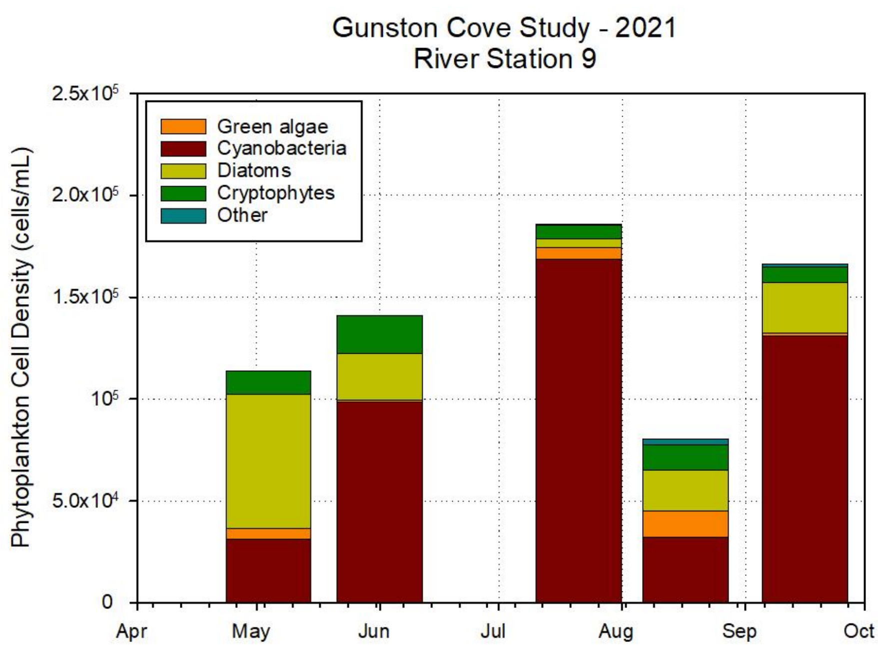
The volume of individual cells of each species is determined by approximating the cells of each species to an appropriate geometric shape (e.g. sphere, cylinder, cone, etc.) and then making the measurements of the appropriate dimensions under the microscope. Total phytoplankton biovolume (shown here) is determined by multiplying the cell density of each species by the biovolume of each cell of that species. Biovolume accounts for the differing size of various phytoplankton cells and is probably a better measure of biomass. However, it does not account for the varying amount of water and other nonliving constituents in cells.




Total phytoplankton cell density can be broken down by major group. The top four groups represent those which are generally most abundant. "Other" includes euglenoids and dinoflagellates. Due to their small size cyanobacteria typically dominate cell density numbers. Their numbers are typically highest in the late summer reflecting an accumulation of cells during favorable summer growing conditions.

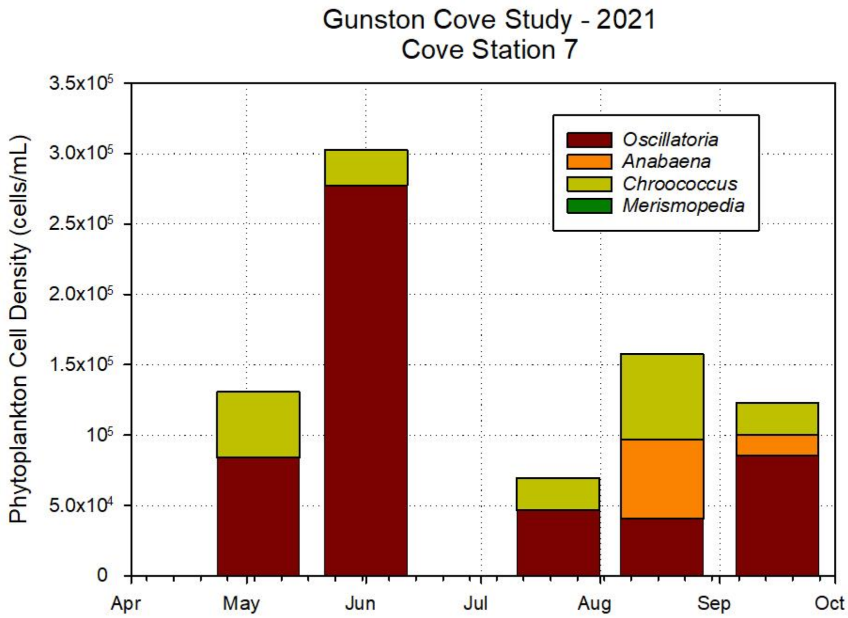
Figure 38. Phytoplankton Density by Major Group (cells/mL). Gunston Cove.

In 2021 phytoplankton density in the cove was dominated by cyanobacteria with green algae and diatoms in a secondary role (Figure 38). In June cyanobacteria were most abundant and dominant. In the river diatoms dominated in May, but otherwise cyanobacteria were most important (Figure 39).




In the river cyanobacteria normally follow similar patterns as in the cove, but attaining lower abundances. This is probably due to the deeper water column which leads to lower effective light levels and greater mixing. Other groups such as diatoms and green algae tend to be more important on a relative basis than in the

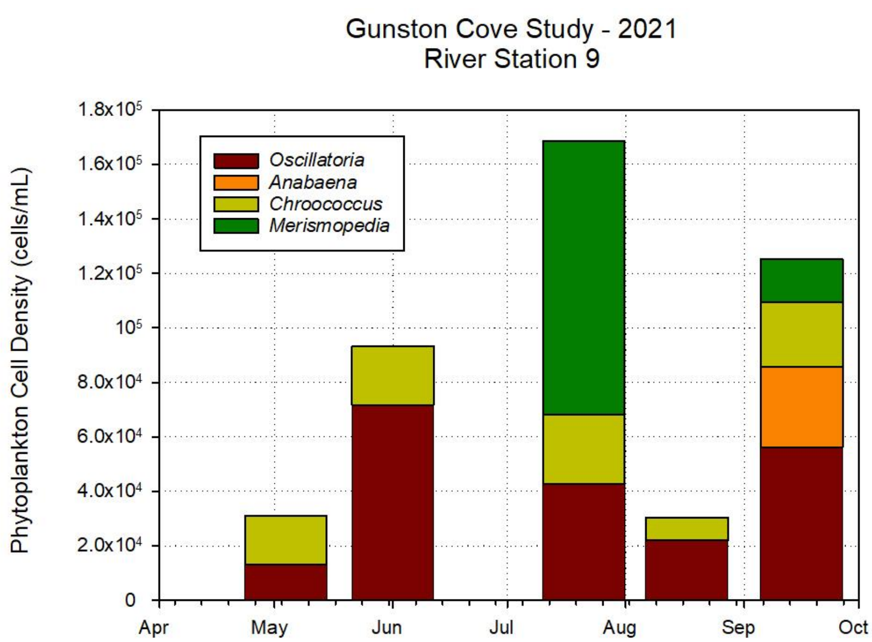
Figure 39. Phytoplankton Density by Major Group (cells/mL). River.




The dominant cyanobacteria on a numerical basis were:
- *Anabaena* – a filament with bead-like cells & heterocysts
- *Oscillatoria* – a filament with cylindrical cells
- An unknown unicellular cyanobacterium less than 2 *u*
- *Chroococcus* – individual spherical cells

Figure 40. Phytoplankton Density by Dominant Cyanobacteria (cells/mL). Gunston Cove.

*Oscillatoria* was the most abundant cyanobacterium in the during most months, sharing dominance with *Anabaena* and *Chroococcus* in August (Figure 40). In the river *Oscillatoria* was dominant in most months, but in July *Merismopedia* was dominant in cell density (Figure 41).




*Anabaena*

*Microcystis*

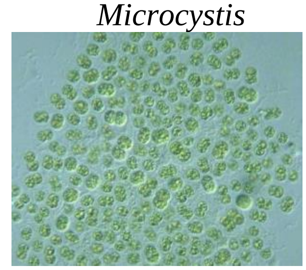
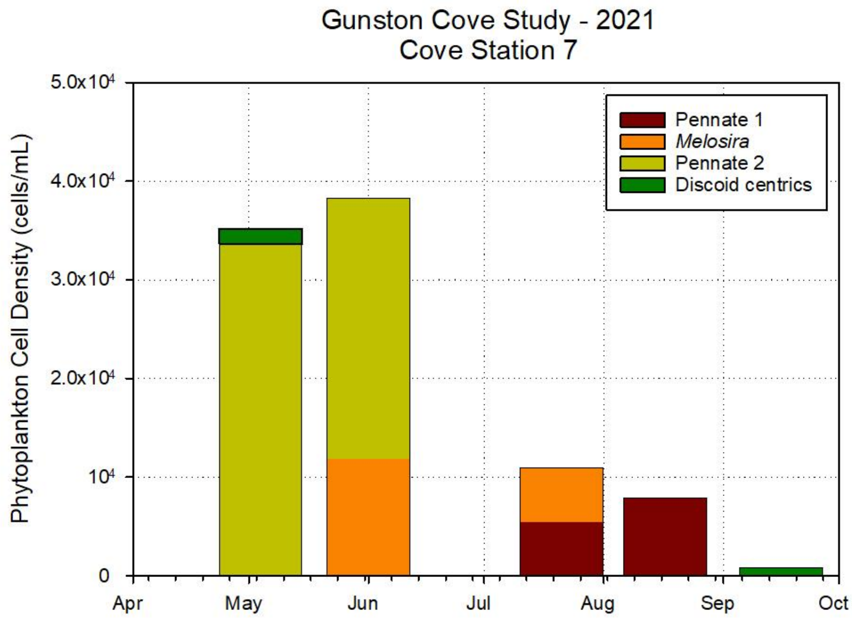


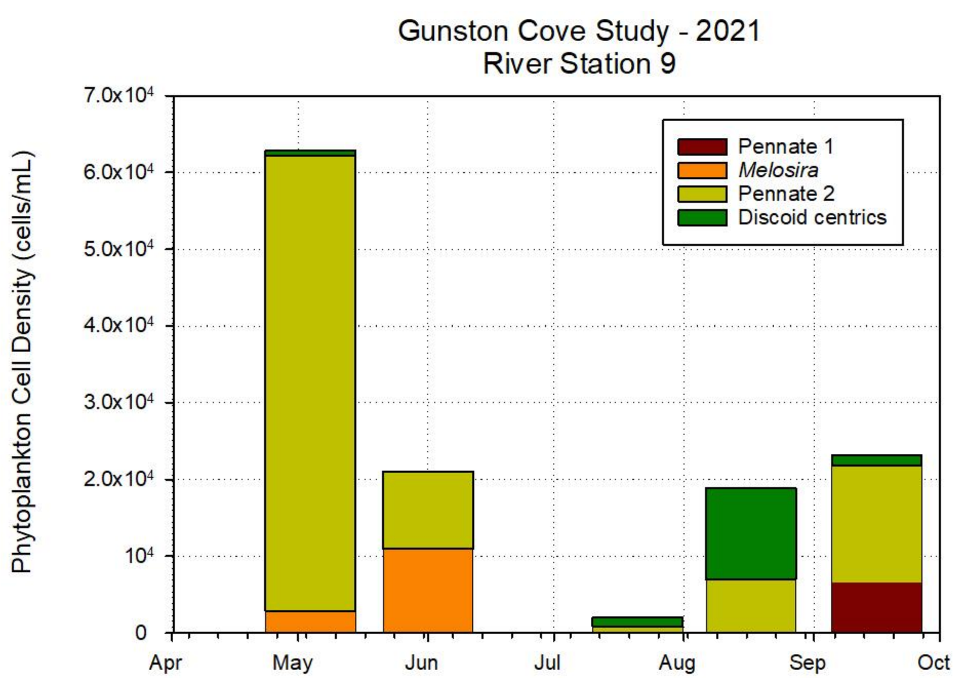
Figure 41. Phytoplankton Density by Dominant Cyanobacteria (cells/mL). River.




The most numerous diatoms in the phytoplankton were:
*Melosira* – a filamentous centric diatom
Centrics – discoid centric diatoms
Pennate 2 – a small pinnate diatom
*Syned*ra – a pinnate diatom
*Asterionella* – a small pennate diatom that forms spoked -wheel colony

Figure 42. Phytoplankton Density by Dominant Diatoms (cells/mL). Gunston Cove.

Diatom cell density in the cove was composed was dominated by Pennate 2 in May and June and by Pennate 1 in July and August (Figure 42). *Melosira* was important in June and July. In the river Pennate 2 was dominant for most of the year with discoid centrics being most importan in August (Figure 43).




*Melosira*

Discoid Centrics

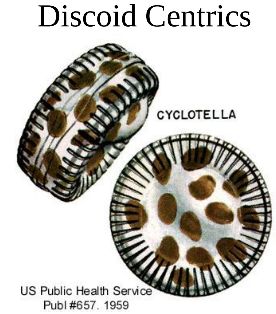
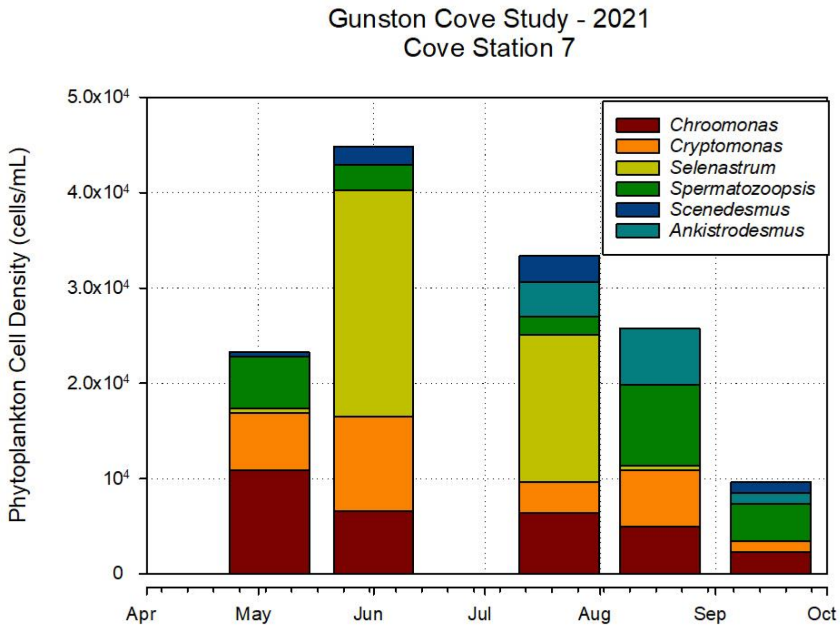


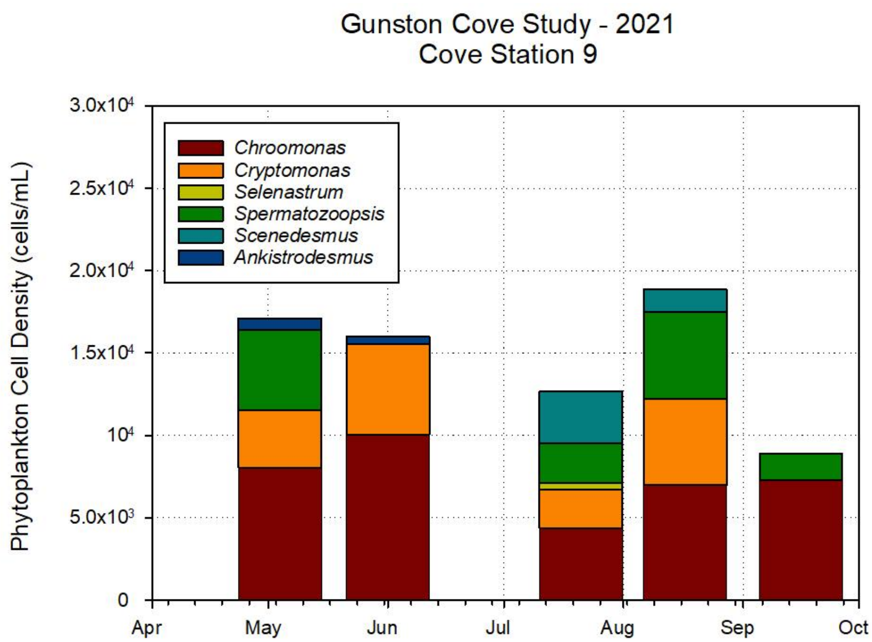

Figure 43. Phytoplankton Density by Dominant Diatoms (cells/mL). River.




The most numerous phyto-plankton among the cryptophytes, green algae and others were:
- *Cryptomonas* – an ellipsoidal, flagellated unicell
- *Chroomonas* – a flagellated cryptomonad unicell
- *Selenastrum* – single green algal cell as curved rod
- *Spermatozoopsis – a flagellated green unicell*
- *Scendesmus – a green alga composed of a 4-celled colony*
- *Ankistrodesmus* – a green alga that is long and thin

Figure 44. Phytoplankton Density (#/mL) by Dominant Other Taxa. Gunston Cove.

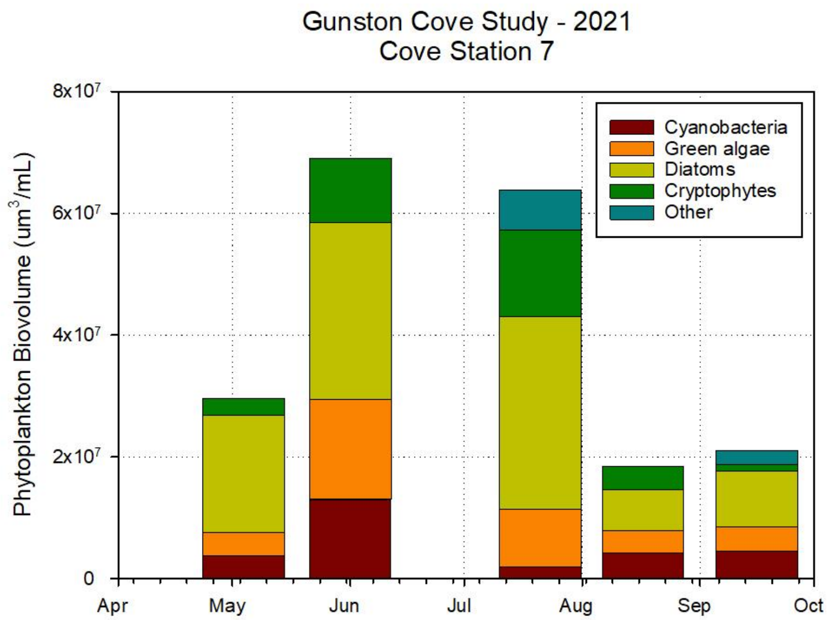
In the cove a number of other taxa were important, with the combination of *Chroomonas* and *Cryptomonas* being present at substantial levels each month (Figure 44). The green alga *Selenastrum* was dominant in June and July. The river station had a similar assemblage with *Chroomonas* and *Cryptomonas* dominant in each month (Figure 45).




*Cryptomonas*

*Scenedesmus*

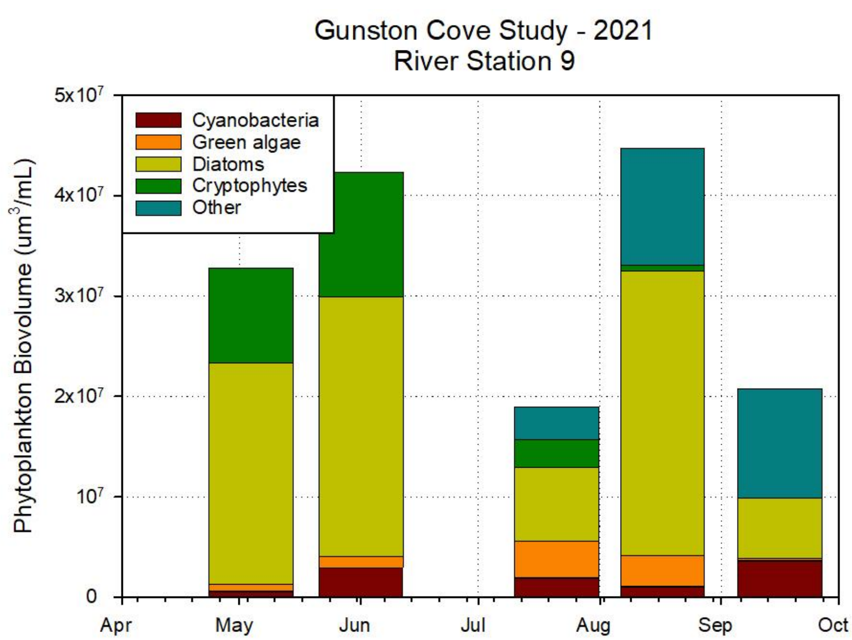
Figure 45. Phytoplankton Density (#/mL) by Dominant Other Taxa. River.




Total phytoplankton biovolume can be broken down into groups:
- **Cyanobacteria** ("blue-green" algae)
- **Green algae**
- **Diatoms** – includes both centric and pinnate
- **Cryptophytes**
- **Other** – includes euglenoids, chrysophytes, and dinoflagellates

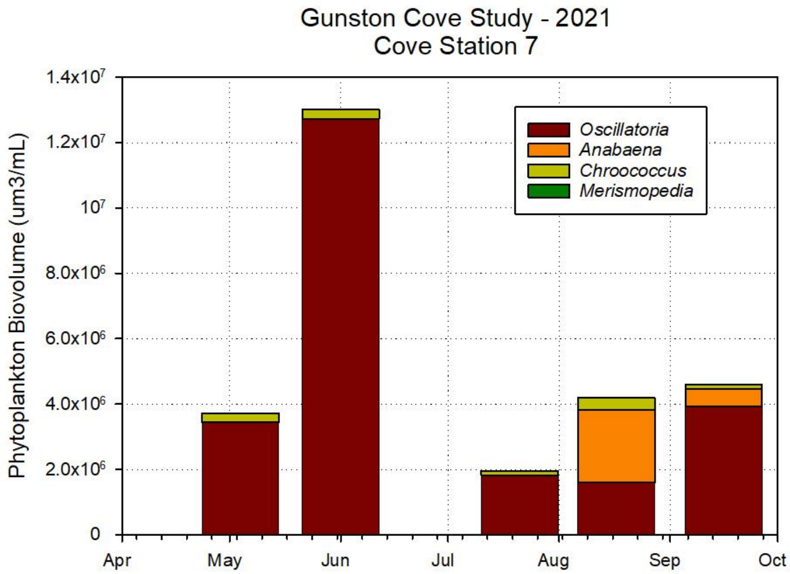
Figure 46. Phytoplankton Biovolume (um$^3$/mL) by Major Groups. Gunston Cove.

In the cove biovolume was strongly dominated by diatoms from April to July (Figure 46). Biovolume in the cove decreased in August and September with diatoms being the most important. In the river, diatoms were dominant in biovolume most of the year with cryptophytes being important in May and June and Other algae being important in August and September (Figure 47).




While dominating cell density, cyanobacteria typically make up a much smaller portion of phytoplankton biovolume. As with cell density, biovolume is generally greater in the cove.

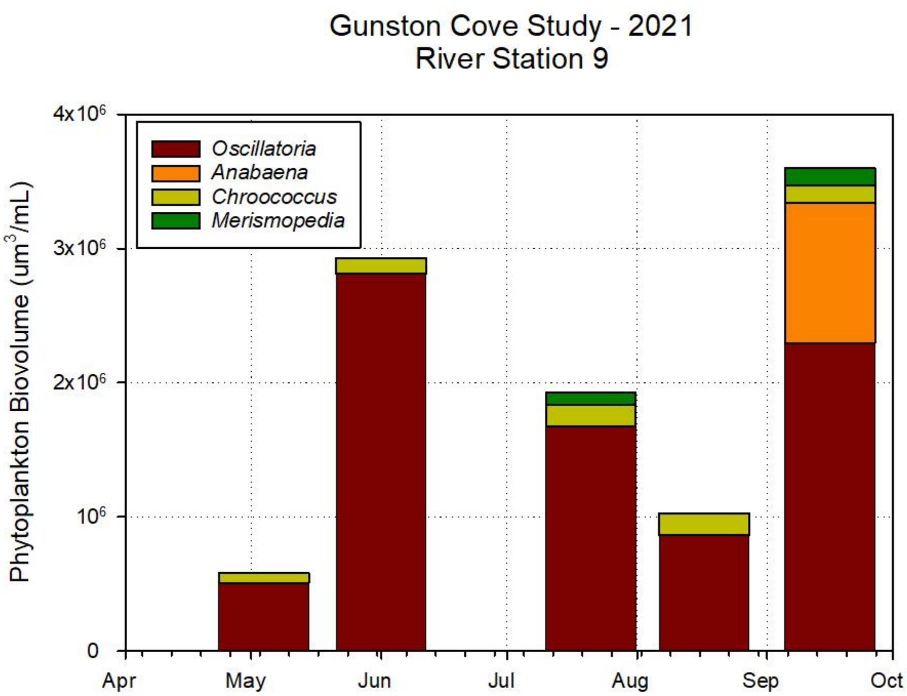
Figure 47. Phytoplankton Biovolume (um$^3$/mL) by Major Groups. River.



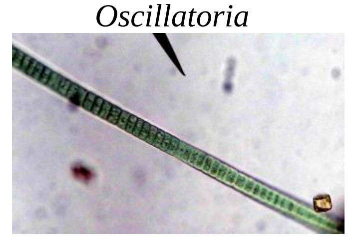

The dominant cyanobacteria on a biovolume basis were:
- *Anabaena* – a filament with bead-like cells & heterocysts
- *Rhabdoderma* – rod-shaped cells in small packets
- *Oscillatoria* – a filament with cylindrical cells
- *Chroococcus* – individual spherical cells
- *Raphidiopsis* – a filament of cylindrical cells

Figure 48. Phytoplankton Biovolume (um$^3$/mL) by Cyanobacteria Taxa. Gunston Cove.

*Oscillatoria* accounted for most of the cyanobacterial biovolume in the cove except in August when *Anabaena* was even more abundant (Figure 48). It reached a maximum in June. In the river *Oscillatoria* was usually highly dominant and had a maximum in June (Figure 49). In September *Anabaena* was also important.




*Oscillatoria*



*Chroococcus*

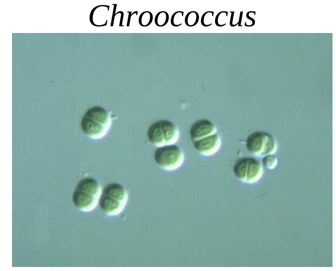
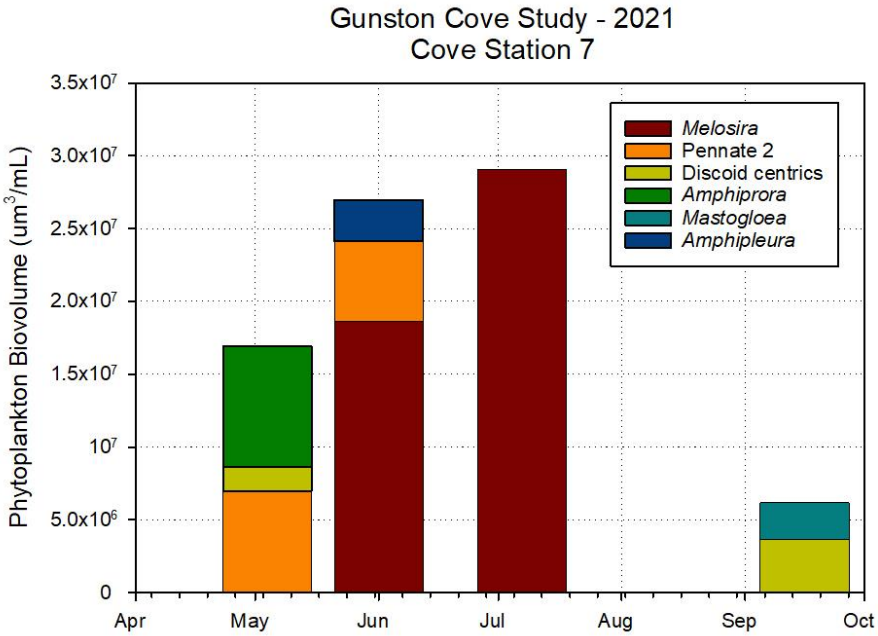


Figure 49. Phytoplankton Biovolume (um$^3$/mL) by Cyanobacterial Taxa. River.

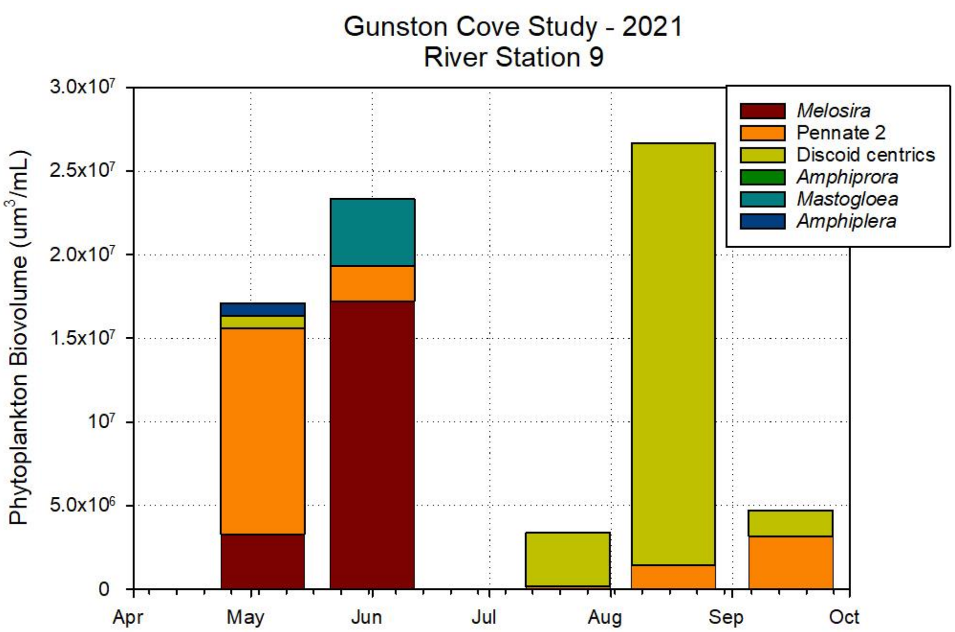



The most numerous diatoms in the phytoplankton were:

*Melosira* – a filamentous centric diatom
Centrics – discoid centric diatoms
*Stauroneis* – larger pennate diatom
Pennate 2 – a small pinnate diatom
Pennate 1 – a small pinnate diatom
*Surirella* – a larger pennate diatom
*Nitzschia* – a small pennate diatom

Figure 50. Phytoplankton Biovolume (um$^3$/mL) by Diatom Taxa. Gunston Cove.

In the cove *Melosira* was dominant and very abundant in both June and July (Figure 50). Pennate 2 was dominant in May and discoid centrics in September. In the river Pennate 2 had the highest biovolume in May and September (Figure 51). *Melosira* was very abundant in June and discoid centrics in August..




*Melosira*

*Surirella*

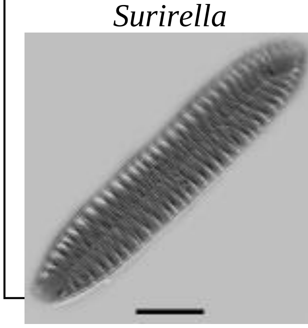
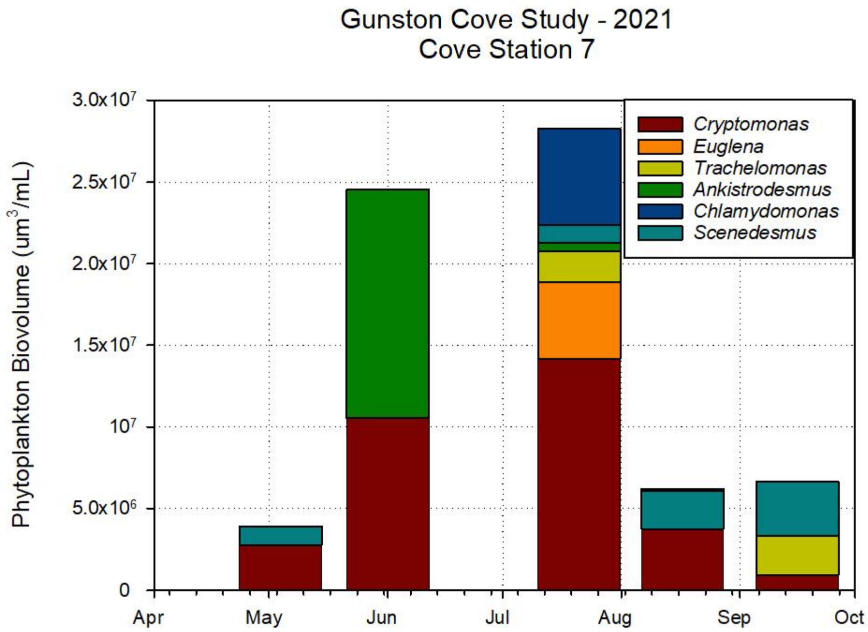


Figure 51. Phytoplankton Biovolume (um$^3$/mL) by Diatom Taxa. River.

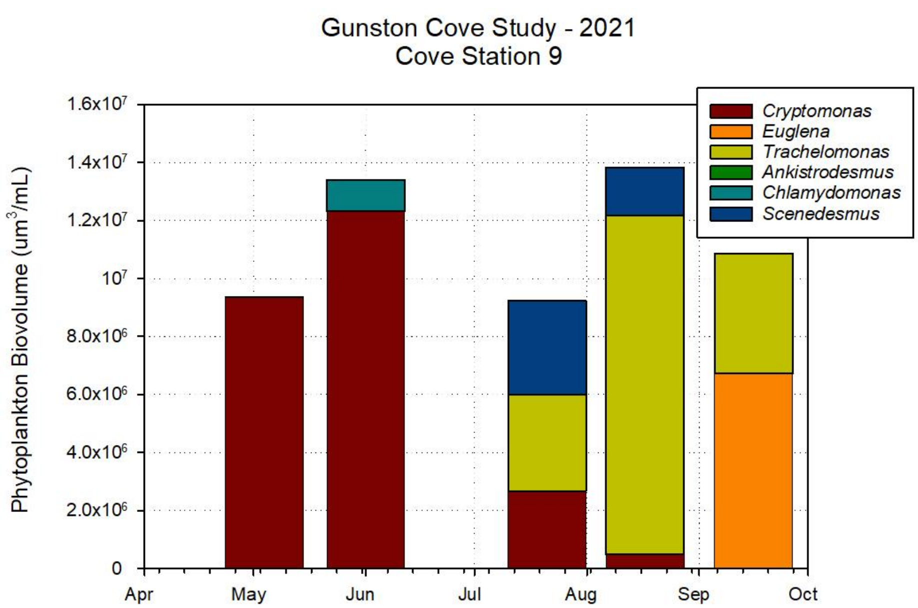



The most numerous phytoplankton among the cryptophytes, green algae and others were:

- *Euglena* – large euglenoid flagellate
- *Cryptomonas* – an ellipsoidal, flagellated unicell
- *Carteria* – flagellated green unicell
- *Mallomonas* – unicellular scaled flagellate
- *Trachelomonas* – spherical, armored euglenoid
- *Ankistrodesmus* – rod-like single celled green alga
- *Oocystis* –green unicells in small packets

Figure 52. Phytoplankton Biovolume (um$^3$/mL) by Dominant Other Taxa. Gunston Cove.

A number of other taxa contributed to biovolume in the cove in 2021 with *Cryptomonas* being dominat in May, July, and August (Figure 52). *Ankistrodesmus* was dominant in June and *Scenedesmus* in September. In the river the *Cryptomonas* was dominant in May and June and co-dominant with *Trachelomonas* and *Chlamydomonas* in July (Figure 53). In August Trachelomonas assumed overwhelming dominance and in September Euglena was most abundant.



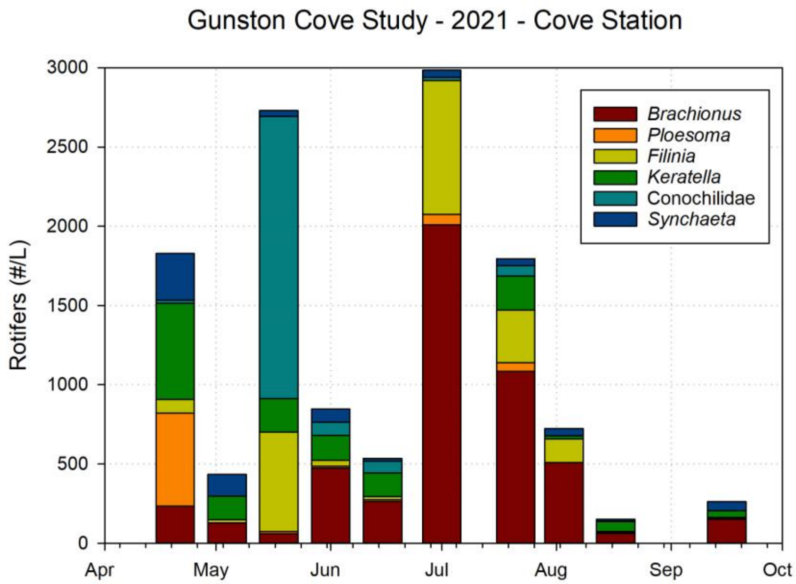


*Cryptomonas*

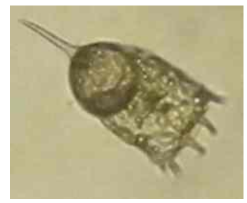
*Euglena*


Figure 53. Phytoplankton Biovolume (um$^3$/mL) by Dominant Other Taxa. River.

**D. Zooplankton – 2021**



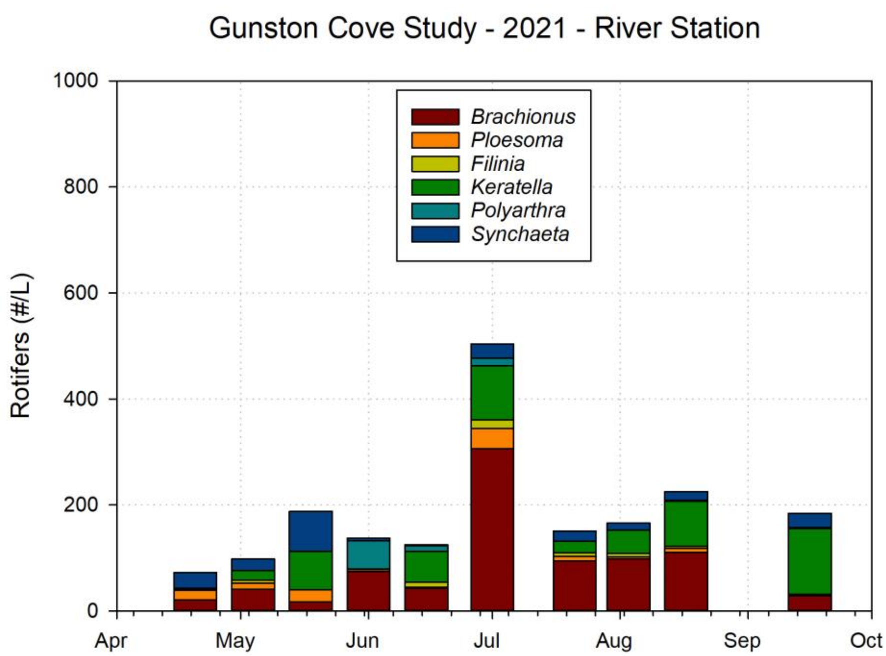

*Brachionus* (Sta 7, RCJ)



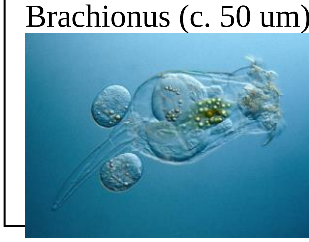
*Keratella* (Sta 7, RCJ)

Figure 54. Rotifer Density by Dominant Taxa (#/L). Cove.

In the cove, rotifers were quite variable in 2021 (Figure 54) In April there was a peak led by *Keratella* and *Ploesoma*. In late May peak values were atrributable to Conochilidae. *Brachionus* dominated a peak in early July. In the river rotifers were consistently much lower than in the cove with the highest value in early July of 500/L (Figure 55). *Brachionus* was the dominant in most samples.




Brachionus (c. 50 um)



Conochilidae

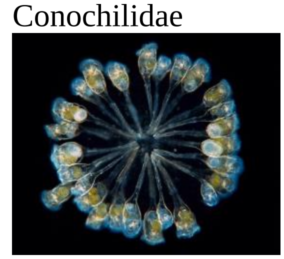


Figure 55. Rotifer Density by Dominant Taxa (#/L). River.

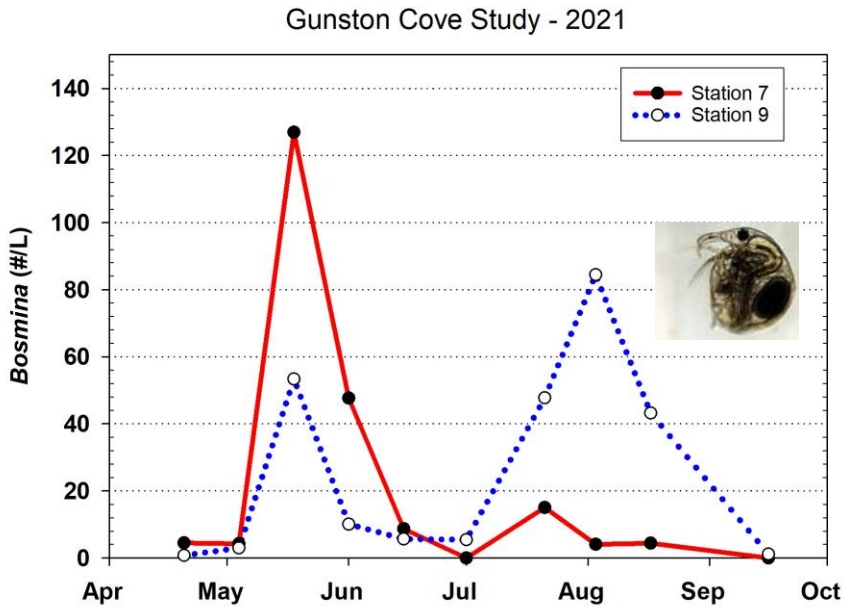



Figure 56. *Bosmina* Density by Station (#/L).

*Bosmina* is a small-bodied cladoceran, or "waterflea", which is common in lakes and freshwater tidal areas. It is typically the most abundant cladoceran with maximum numbers generally about 100-1000 animals per liter. Due to its small size and relatively high abundances, it is enumerated in the micro-zooplankton samples. *Bosmina* can graze on smaller phytoplankton cells, but can also utilize some cells from colonies by knocking them loose.

In 2021 the small cladoceran *Bosmina* exhibited peaks in both cove and river in late May (Figure 56). A second peak was observed in early August. *Diaphanosoma,* typically the most abundant larger cladoceran in the study area, was very abundant in the river in mid-June reaching over 2500/$m^3$ (Figure 57). A peak was also observed at this time in the cove of just over 1000/$m^3$. In general values in the river were higher than in the cove.

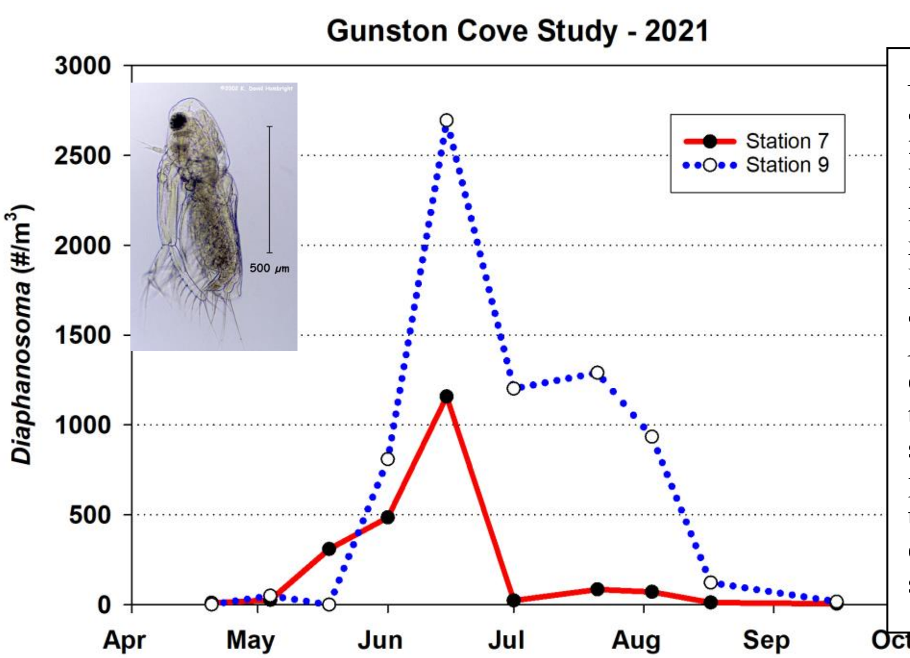
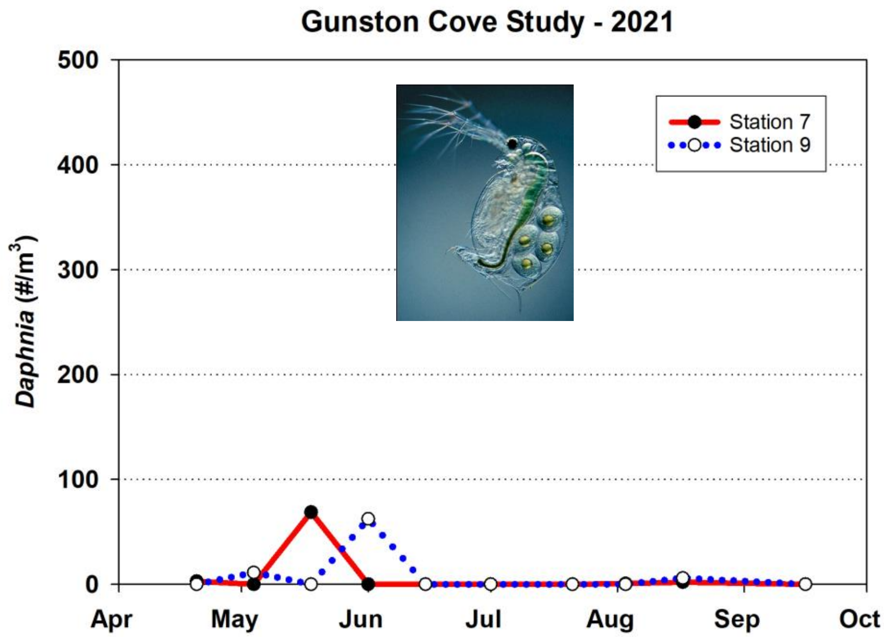



Figure 57. *Diaphanosoma* Density by Station (#/$m^3$).

*Diaphanosoma* is the most abundant larger cladoceran found in the tidal Potomac River. It generally reaches numbers of 1,000-10,000 per $m^3$ (which would be 1-10 per liter). Due to their larger size and lower abundances, *Diaphanosoma* and the other cladocera are enumerated in the macrozooplankton samples. *Diaphanosoma* prefers warmer temperatures than some cladocera and is often common in the summer.




*Daphnia*, the common waterflea, is one of the most efficient grazers of phytoplankton in freshwater ecosystems. In the tidal Potomac River it is present, but has not generally been as abundant as *Diaphanosoma*. It is typically most common in

Figure 58. *Daphnia* Density by Station (#/m$^3$).

In 2021 *Daphnia* exhibited very low values at both stations (Figure 58). *Ceriodaphnia* was also present at only low levels in 2021 (Figure 59).

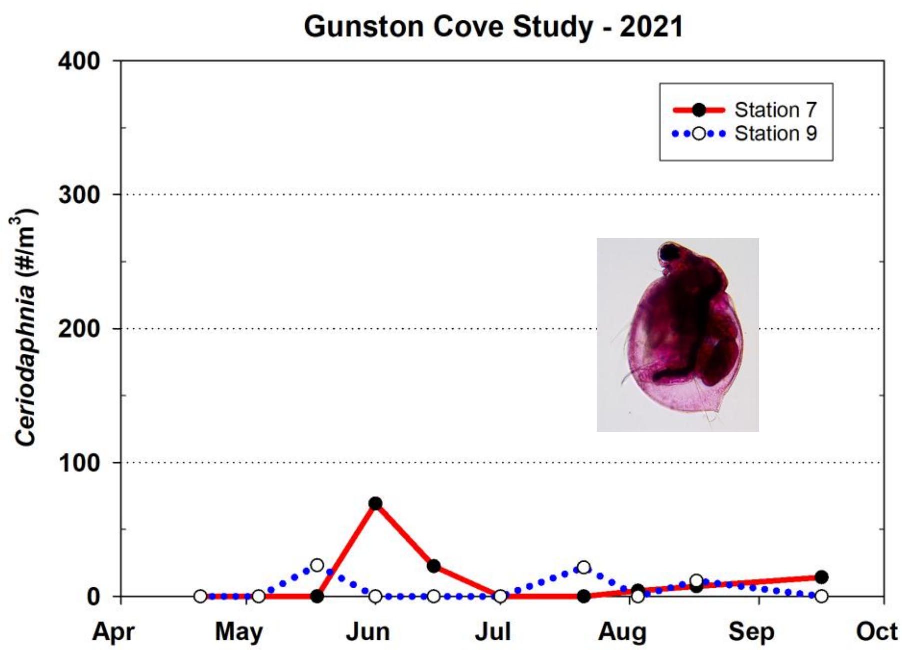
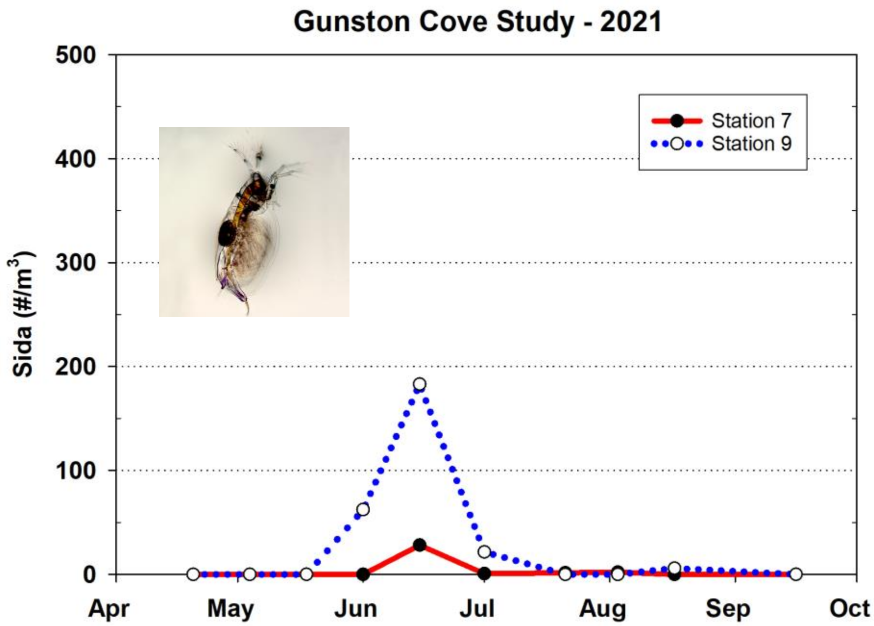


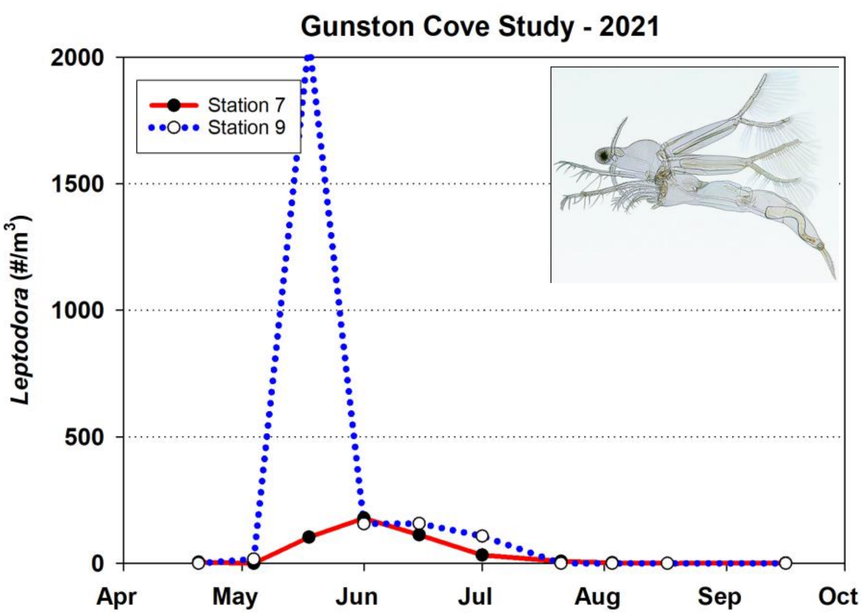

Figure 59. *Ceriodaphnia* Density by Station (#/m$^3$).




*Sida* is another waterflea that is often observed in the tidal Potomac River. Like the other cladocera mentioned so far, *Sida* grazes on phytoplankton to obtain its food supply.

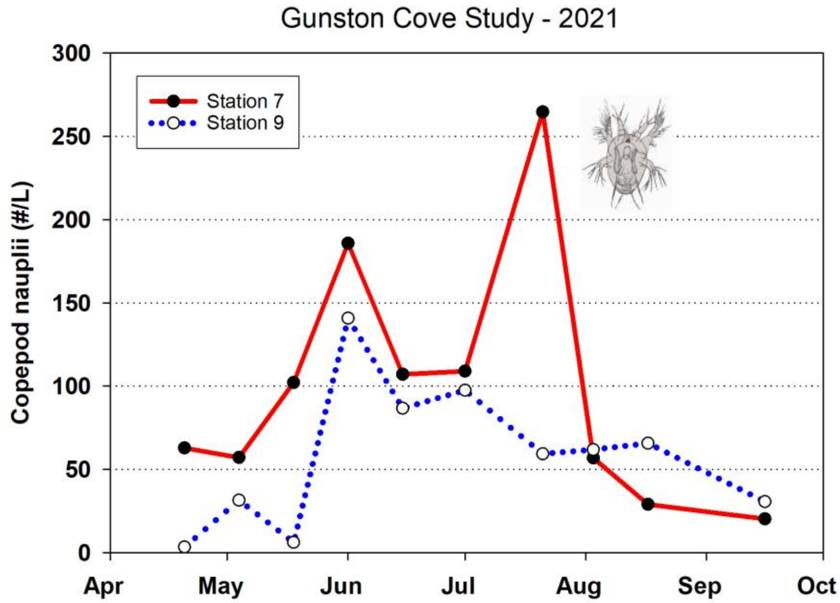
Figure 60. *Sida* Density by Station (#/m$^3$).

*Sida*, a smallish cladoceran related to *Diaphanosoma*, was present at relatively low levels for most of the year, reaching a peak of about 200/m$^3$ in June in the river (Figure 60). *Leptodora*, the large cladoceran predator, was quite abundant in in mid-May reaching a peak of nearly 2000/m$^3$ in the river. It didn't exceed a peak of 200/m$^3$ in the cove (Figure 61).




*Leptodora* is substantially larger than the other cladocera mentioned. Also different is its mode of feeding – it is a predator on other zooplankton. It normally occurs for brief periods in the late spring or early summer.

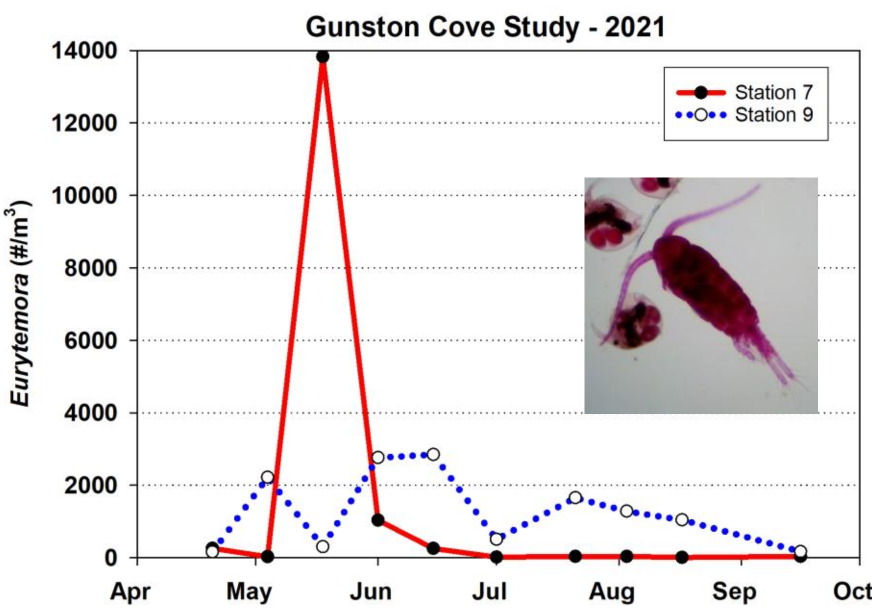
Figure 61. *Leptodora* Density by Station (#/m$^3$).




Copepod eggs hatch to form an immature stage called a nauplius. The nauplius is a larval stage that does not closely resemble the adult and the nauplii of different species of copepods are not easily distinguished so they are lumped in this study. Copepods go through 5 naupliar molts before reaching the copepodid stage which is morphologically very similar to the adult. Because of their small size and high abundance, copepod nauplii are enumerated in the micro-

Figure 62. Copepod Nauplii Density by Station (#/L).

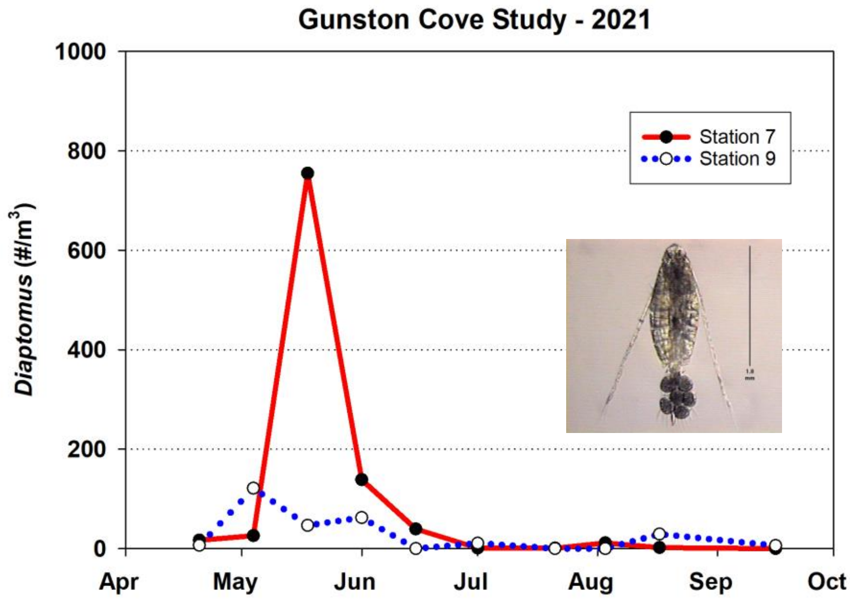
In the cove copepod nauplii showed a pattern of major increase over the period from May to June reacing a peak of about 200/L in early June (Figure 62). A second peak was found in late July at about 260/L. In the river the peak occurred in early Juneat about 150/L and a gradual decline was observed for the rest of the year. In 2021 *Eurytemora* attained high densities of over 14,000/$m^3$ in May but for most of the year values were lower than in the river (Figure 63). In the river *Eurytemora* attained about 3000/$m^3$ in June.




*Eurytemora affinis* is a large calanoid copepod characteristic of the freshwater and brackish areas of the Chesapeake Bay. *Eurytemora* is a cool water copepod which often reaches maximum abundance in the late winter or early spring. Included in this graph are adults and those copepodids that are recognizable as *Eurytemora*.

Photo credit: Laura Birsa

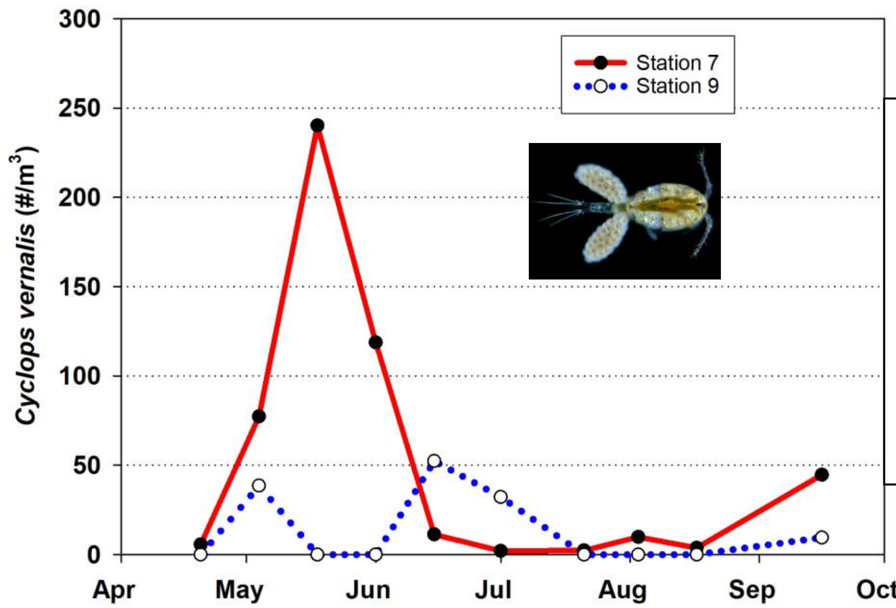
Figure 63. *Eurytemora* Density by Station (#/$m^3$).




*Diaptomus pallidus* is a calanoid copepod often found in moderate densities in the Gunston Cove area. *Diaptomus* is an efficient grazer of algae, bacteria, and detrital particles in freshwater ecosystems Included in this graph are adults and those copepodids that are recognizable as *Diaptomus*.

Figure 64. *Diaptomus* Density by Station (#/m$^3$)

*Diaptomus* was was restricted to fairly low values in 2021 (Figure 64). Peak in the cove was about 750/m$^3$ in May. Values were low in the river. *Cyclops vernalis* was at low, but increasing values in the cove in spring attaining about 250/m$^3$ (Figure 65). In the river *C. vernalis* was very low all year.




Cyclopoids are the other major group of planktonic copepods. Cyclopoids feed on individual particles suspended in the water including small zooplankton as well as phytoplankton. In this study we have lumped all copepodid and adult cyclopoids together.

Figure 65. *Cyclops vernalis* by Station (#/m$^3$)..

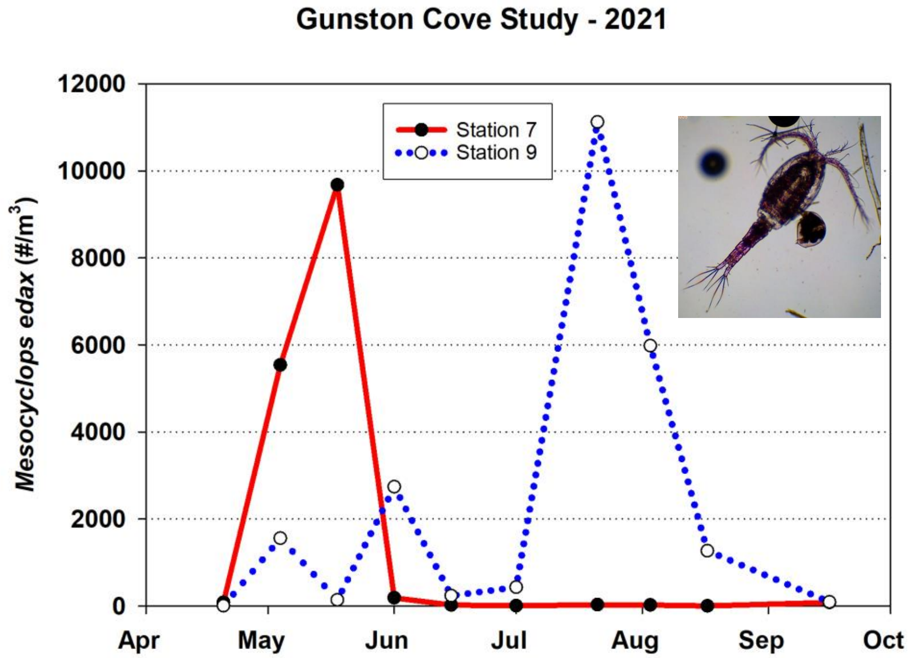



Photo credit: Laura Birsa

Figure 66. *Mesocyclops edax* by Station (#/m$^3$).

*Mesocyclops edax* was very abundant in both river and cove, but at different times of the year. It reached a peak of 10,000/m$^3$ in mid-May and attained a similar value in the river in mid July (Figure 66).

**E. Ichthyoplankton - 2021**

Larval fishes are transitional stages in the development of juvenile fishes. They range in development from newly hatched, embryonic fish to juvenile fish with morphological features similar to those of an adult. Many fishes such as clupeids (herring family), White Perch, Striped Bass, and Yellow Perch disperse their eggs and sperm into the open water. The larvae of these species are carried with the current and termed “ichthyoplankton”. Other fish species such as sunfishes and bass lay their eggs in “nests” on the bottom and their larvae are rare in the plankton.

After hatching from the egg, the larva draws nutrition from a yolk sack for a few days time. When the yolk sack diminishes to nothing, the fish begins a life of feeding on other organisms. This post yolk sack larva feeds on small planktonic organisms (mostly small zooplankton) for a period of several days. It continues to be a fragile, almost transparent, larva and suffers high mortality to predatory zooplankton and juvenile and adult fishes of many species, including its own. When it has fed enough, it changes into an opaque juvenile, with greatly enhanced swimming ability. It can no longer be caught with a slow-moving plankton net, but is soon susceptible to capture with the seine or trawl net.

In 2021, we collected 14 samples (7 at Station 7 and 7 at Station 9) during the months April through July and obtained a total of 1161 larvae (Table 4), which is on par with previous years (e.g. 1798 in 2020, 1399 in 2019, 1072 in 2018, and 1751 in 2017). The fish larvae are sometimes too damaged to distinguish at the species level, thus some of the counts are only to the genus level, family level or less (3.27% were unidentified). This year the number of fishes we identified to genus and Family levels were similar to last year and lower than historic values. Our identification to family Clupeidae (but not further) was 9.99 (9.73% last year but 35.4% in 2018). Of the Clupeidae we identified to the species level, Gizzard Shad was the dominant species representing 23.26%, closely followed by Alewife at 22.31%. All clupeids together constituted 77.7% of the catch. Other abundant clupeids were Blueback Herring at 16.45% and Hickory Shad at 4.39%. The dominant non-clupeid species in the catch was White Perch with 15.33% of the catch, similar to previous years and we identified a total of at least 8 species.

Table 4. The number of larval fishes collected in Gunston Cove and the Potomac River in 2021.

| Scientific Name | Common Name | 7 | 9 | Total | % of Total |
|---|---|---|---|---|---|
| *Alosa aestivalis* | Blueback Herring | 42 | 149 | 191 | 16.45 |
| *Alosa mediocris* | Hickory Shad | 38 | 13 | 51 | 4.39 |
| *Alosa pseudoharengus* | Alewife | 75 | 184 | 259 | 22.31 |
| *Alosa sapidissima* | American Shad | 4 | 10 | 14 | 1.21 |
| *Alosa sp.* | unk. Alosa species | 1 | 0 | 1 | 0.09 |
| Clupeidae | unk. clupeid species | 26 | 90 | 116 | 9.99 |
| *Dorosoma cepedianum* | Gizzard Shad | 173 | 97 | 270 | 23.26 |
| Eggs | eggs | 3 | 4 | 7 | 0.60 |
| *Lepomis gibbosus* | Pumpkinseed | 1 | 0 | 1 | 0.09 |
| *Lepomis sp.* | unk. sunfish | 2 | 0 | 2 | 0.17 |
| *Menidia beryllina* | Inland Silverside | 18 | 15 | 33 | 2.84 |
| *Morone americana* | White Perch | 22 | 156 | 178 | 15.33 |
| Unidentified | unidentified | 30 | 8 | 38 | 3.27 |
| **Total** | | 435 | 726 | 1161 | 100.00 |

The mean density of larvae, which takes the volume of water sampled into account over the time sampled, is shown in Figure 67 and 68. Clupeid larvae in Figure 67 include Blueback Herring, Hickory Shad, Alewife, American Shad, and Gizzard Shad. These have similar spawning patterns, so they are lumped into one group for this analysis. Clupeid larvae peak from mid-May to early June (Figure 67), which is similar to previous years. The abundance of other larvae than Clupeids was lower and had peak mid-May (Figure 68). Larval density tends to taper off as the summer progresses, as was seen in 2020. The other larvae included all other taxa listed in Table 4.

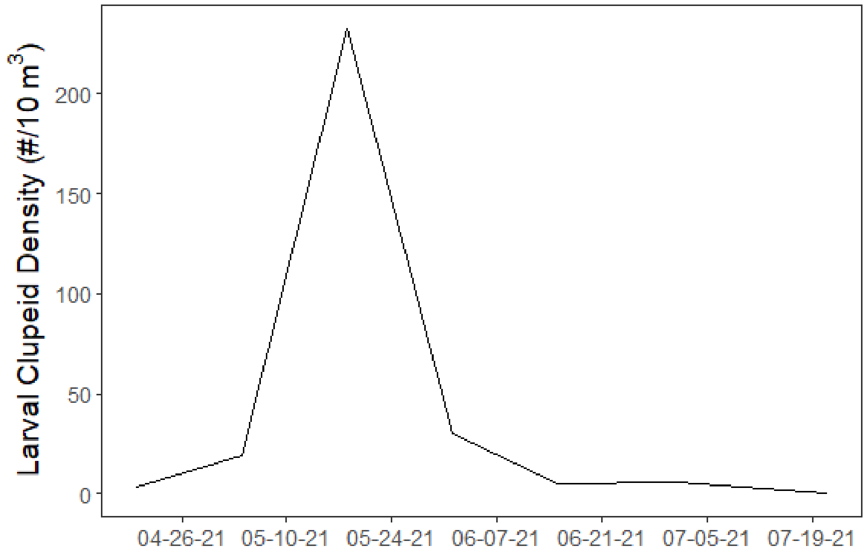



Figure 67. Clupeid larvae, mean density (abundance per 10m$^3$).

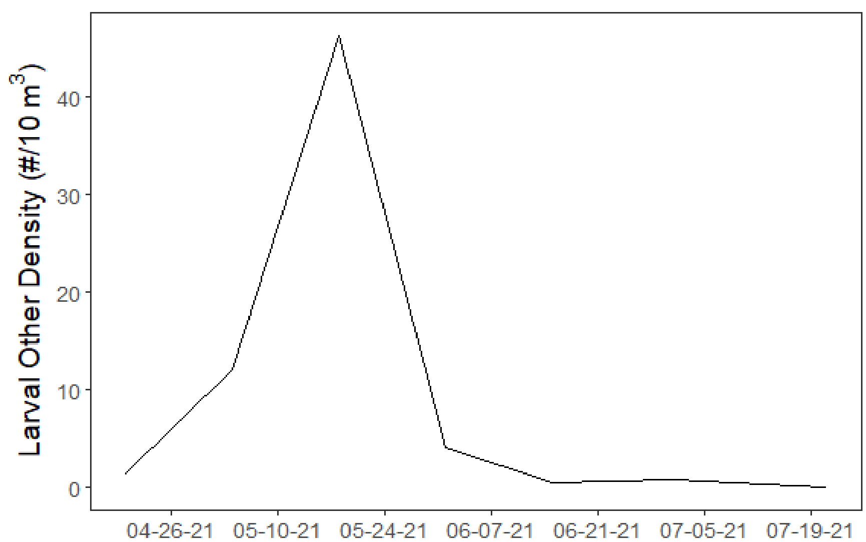



Figure 68. All other larvae, mean density (abundance per 10m$^3$)

## F. Adult and juvenile fishes – 2021

### Trawls

We sampled fishes with the trawl from April 23 - September 10 at station 7, 9, and 10. These three fixed stations have been sampled continuously since the inception of the survey. We collected a total of 3290 fishes comprising at least 21 species in all trawl samples combined (Table 5). Interestingly, this total number is less than last year's sampling, which was conducted over a shortened time frame, but our species diversity was higher. Similar to 2020, the dominant species we collected was White Perch (67.89 %). Spottail Shiner was the second most abundant species (9.85%) and we continued to collect the invasive Blue Catfish (Tables 5 and 6).

Table 5. Total adult and juvenile fish collected by trawling.

| **Scientific Name** | **Common Name** | **Abundance** | **Percent** |
|---|---|---|---|
| *Morone americana* | White Perch | 2234 | 67.89 |
| *Notropis hudsonius* | Spottail Shiner | 324 | 9.85 |
| *Lepomis microlophus* | Redear Sunfish | 159 | 4.83 |
| *Alosa pseudoharengus* | Alewife | 95 | 2.89 |
| *Alosa aestivalis* | Blueback Herring | 91 | 2.77 |
| *Lepomis sp.* | unk. sunfish | 63 | 1.91 |
| *Lepomis gibbosus* | Pumpkinseed | 54 | 1.64 |
| *Lepomis macrochirus* | Bluegill | 47 | 1.43 |
| *Alosa sp.* | unk. Alosa species | 45 | 1.37 |
| *Anchoa mitchilli* | Bay anchovy | 36 | 1.09 |
| *Etheostoma olmstedi* | Tessellated Darter | 33 | 1.00 |
| *Fundulus diaphanus* | Banded Killifish | 30 | 0.91 |
| *Menidia beryllina* | Inland Silverside | 28 | 0.85 |
| *Ictalurus furcatus* | Blue Catfish | 25 | 0.75 |
| *Carassius auratus* | Goldfish | 6 | 0.18 |
| *Ameiurus natalis* | Yellow Bullhead | 4 | 0.12 |
| *Dorosoma cepedianum* | Gizzard Shad | 4 | 0.12 |
| *Dorosoma petenense* | Threadfin Shad | 4 | 0.12 |
| *Cyprinus carpio* | Carp | 3 | 0.09 |
| *Ameiurus catus* | White Bullhead | 2 | 0.06 |
| *Perca flavescens* | Yellow Perch | 2 | 0.06 |
| *Ameiurus nebulosus* | Brown Bullhead | 1 | 0.03 |
| *Morone saxatilis* | Striped Bass | 1 | 0.03 |
| Total | | 3290 | 100.00 |

Table 6. Adult and juvenile fish collected by trawling on each sampling date

| Scientific Name | Common Name | 4-23 | 5-14 | 5-27 | 6-10 | 6-24 | 7-08 | 7-22 | 8-12 | 8-26 | 9-16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Alosa aestivalis* | Blueback Herring | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 90 | 91 |
| *Alosa pseudoharengus* | Alewife | 0 | 0 | 1 | 2 | 14 | 12 | 10 | 0 | 0 | 56 | 95 |
| *Alosa sp.* | unk. Alosa species | 0 | 0 | 0 | 10 | 4 | 0 | 9 | 9 | 0 | 13 | 45 |
| *Ameiurus catus* | White Bullhead | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| *Ameiurus natalis* | Yellow Bullhead | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 4 |
| *Ameiurus nebulosus* | Brown Bullhead | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| *Anchoa mitchilli* | Bay anchovy | 0 | 0 | 0 | 0 | 0 | 1 | 14 | 1 | 3 | 17 | 36 |
| *Carassius auratus* | Goldfish | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 6 |
| *Cyprinus carpio* | Carp | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 |
| *Dorosoma cepedianum* | Gizzard Shad | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 4 |
| *Dorosoma petenense* | Threadfin Shad | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 4 |
| *Etheostoma olmstedi* | Tessellated Darter | 1 | 0 | 1 | 8 | 6 | 5 | 5 | 3 | 3 | 1 | 33 |
| *Fundulus diaphanus* | Banded Killifish | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 8 | 3 | 16 | 30 |
| *Ictalurus furcatus* | Blue Catfish | 0 | 0 | 1 | 6 | 0 | 7 | 7 | 0 | 3 | 1 | 25 |
| *Lepomis gibbosus* | Pumpkinseed | 2 | 2 | 3 | 6 | 6 | 5 | 5 | 17 | 6 | 2 | 54 |
| *Lepomis macrochirus* | Bluegill | 2 | 0 | 17 | 3 | 2 | 7 | 3 | 7 | 3 | 3 | 47 |
| *Lepomis microlophus* | Redear Sunfish | 1 | 3 | 1 | 0 | 1 | 1 | 1 | 3 | 5 | 143 | 159 |
| *Lepomis sp.* | unk. sunfish | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 49 | 0 | 63 |
| *Menidia beryllina* | Inland Silverside | 0 | 0 | 4 | 0 | 0 | 0 | 24 | 0 | 0 | 0 | 28 |
| *Morone americana* | White Perch | 1 | 8 | 11 | 101 | 564 | 697 | 455 | 300 | 53 | 44 | 2234 |
| *Morone saxatilis* | Striped Bass | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| *Notropis hudsonius* | Spottail Shiner | 3 | 0 | 1 | 4 | 22 | 66 | 83 | 85 | 41 | 19 | 324 |
| *Perca flavescens* | Yellow Perch | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| **Total** | | **11** | **13** | **48** | **142** | **623** | **802** | **624** | **449** | **171** | **407** | **3290** |

The dominant migratory species, White Perch, was ubiquitous occurring at all stations on every sampling date (Tables 6 and 7). A peak in abundance for White Perch was late July (Table 6). Spottail Shiner, Pumpkinseed, Bluegill, and Redear Sunfish were also ubiquitous throughout the season occurring on almost all sampling dates. Although we collected 25 individuals of the Invasive Blue Catfish spread throughout the season, we also collected our native Bullhead Catfishes in lower abundances (White = 2, Yellow = 4, Brown = 1).

In total numbers and species richness of fish, station 7 dominated the other stations by far with 2618 individuals from 19 species (Table 7, Figure 69a). Station 9 had 129 individuals from 9 species and station 10 had 543 individuals from 14 species (Table 7). The relative abundance shows the dominance of White Perch at stations 7 and 9, but an equal split between White Perch and Redear Sunfish at station 10. This was driven by the high abundance of Redear duirng our last sampling event. Furthermore, this is the trend that we would expect given that station 10 is our shallow trawl through areas dominated by SAV beds. Unlike previous years, Blue Catfish were collected at all trawling stations. Although the majority of the catch was at station 9, a small portion of the catch, were collected at stations 7 and 10, consisting of one and two individuals respectively. This continues our observations of Blue Catfish inside of Gunston Cove, demonstrating that they are not restricted to the mainstem as previously thought. Furthermore, this is the first time a Blue Catfish has been collected in the interior cove site station 10. While ubiquitous, we collected most White Perch in the Cove (station 7) in July (Table 6, Figure 69a and 70a). Spottail Shiner showed a similar pattern and had highest abundance with 291 individuals at station 7 (Table 7, Figure 69a). At all stations, White Perch made up the most significant proportion of the total catch (Figure 69b). Blue Catfish was only a dominant group in trawl samples at Station 9, and Pumpkinseed at Station 10. Station 7 was by far the most productive site due to the high number of White Perch collected there.

Similar to their station catch dominance, White Perch also dominated the trawl catch during June, July, and August (Figure 70a and 70b). Spottail Shiner were also abundant comprising a large portion of the catch in July and August similar to previous years. Interestingly in September, juvenile river herring (*Alosa* spp.) were abundant in our catch, comprising roughly 30% of the trawl catch during that month. This indicates that Gunston Cove is valuable juvenile habitat for these imperiled species and we will continue to investigate this fall abundance trend in the future. The most productive month was July, which was due to the large catch of White Perch. Redear Sunfish dominated in September closely followed by Blueback Herring (*Alosa aestivalis*). In April, overall catches were low (n = 11) and consisted of Spotail Shiner, Tesselated Darter, and *Lepomis* spp and in May our catch was also low (n = 61) dominated by Bluegill and White Perch (Table 6).

White Perch (*Morone americana*), the most common fish in the open waters of Gunston Cove, continues to be an important commercial and popular game fish. Adults grow to over 30 cm long. Sexual maturity begins the second year at lengths greater than 9 cm. As juveniles, they feed on zooplankton and macrobenthos, but as they get larger they consume fish as well.

Spottail Shiner (*Notropis hudsonius*), a member of the minnow family, is moderately abundant in the open water and along the shore. Spawning occurs throughout the warmer months. It reaches sexual maturity at about 5.5 cm and may attain a length of 10 cm. They feed primarily on benthic invertebrates and occasionally on algae and plants.

Trawling collects fish that are located in the open water near the bottom. Due to the shallowness of Gunston Cove, the volume collected is a substantial part of the water column. However, in the river channel, the near bottom habitat through which the trawl moves is only a small portion of the water column. Fishes tend to concentrate near the bottom or along shorelines rather than in the upper portion of the open water.

Table 7. Adult and Juvenile Fish Collected by Trawling. Gunston Cove Study – 2021.

| **Scientific Name** | **Common Name** | **7** | **9** | **10** |
|---|---|---|---|---|
| *Alosa aestivalis* | Blueback Herring | 91 | 0 | 0 |
| *Alosa pseudoharengus* | Alewife | 95 | 0 | 0 |
| *Alosa sp.* | unk. Alosa species | 39 | 5 | 1 |
| *Ameiurus catus* | White Bullhead | 2 | 0 | 0 |
| *Ameiurus natalis* | Yellow Bullhead | 4 | 0 | 0 |
| *Ameiurus nebulosus* | Brown Bullhead | 1 | 0 | 0 |
| *Anchoa mitchilli* | Bay anchovy | 35 | 1 | 0 |
| *Carassius auratus* | Goldfish | 0 | 0 | 6 |
| *Cyprinus carpio* | Carp | 2 | 0 | 1 |
| *Dorosoma cepedianum* | Gizzard Shad | 4 | 0 | 0 |
| *Dorosoma petenense* | Threadfin Shad | 4 | 0 | 0 |
| *Etheostoma olmstedi* | Tessellated Darter | 6 | 1 | 26 |
| *Fundulus diaphanus* | Banded Killifish | 2 | 0 | 28 |
| *Ictalurus furcatus* | Blue Catfish | 1 | 22 | 2 |
| *Lepomis gibbosus* | Pumpkinseed | 39 | 0 | 15 |
| *Lepomis macrochirus* | Bluegill | 11 | 1 | 35 |
| *Lepomis microlophus* | Redear Sunfish | 13 | 1 | 145 |
| *Lepomis sp.* | unk. sunfish | 4 | 0 | 59 |
| *Menidia beryllina* | Inland Silverside | 0 | 0 | 28 |
| *Morone americana* | White Perch | 1974 | 90 | 170 |
| *Morone saxatilis* | Striped Bass | 0 | 1 | 0 |
| *Notropis hudsonius* | Spottail Shiner | 291 | 8 | 25 |
| *Perca flavescens* | Yellow Perch | 0 | 0 | 2 |
| **Total** | | **2618** | **129** | **543** |

Pumpkinseed (*Lepomis gibbosus)* is a common sunfish found in freshwater with a lot of vegetation. Feeds mostly on insects, mosquito larvae, crustaceans and worms, but also on small fishes, gastropods and small mollusks. They prefer clear water and vegetation to hide.

Blueback Herring (*Alosa aestivalis*) and Alewife (*Alosa pseudoharengus*) were formerly major commercial species, but are now depleted stocks. Adults grow to over 30 cm and are found in the coastal ocean. They are anadromous and return to freshwater creeks to spawn in March, April and May. They feed on zooplankton and may eat fish larvae.

Blue Catfish (*Ictalurus furcatus*) is an introduced species from the Mississippi River basin. They have been intentionally stocked in the James and Rappahannock rivers for food and sport. They have expanding their range and seem to replace white catfish and perhaps also Channel Catfish and bullheads. As larvae, they feed on zooplankton; juveniles and adults mostly on fishes, and on benthos, and detritus.

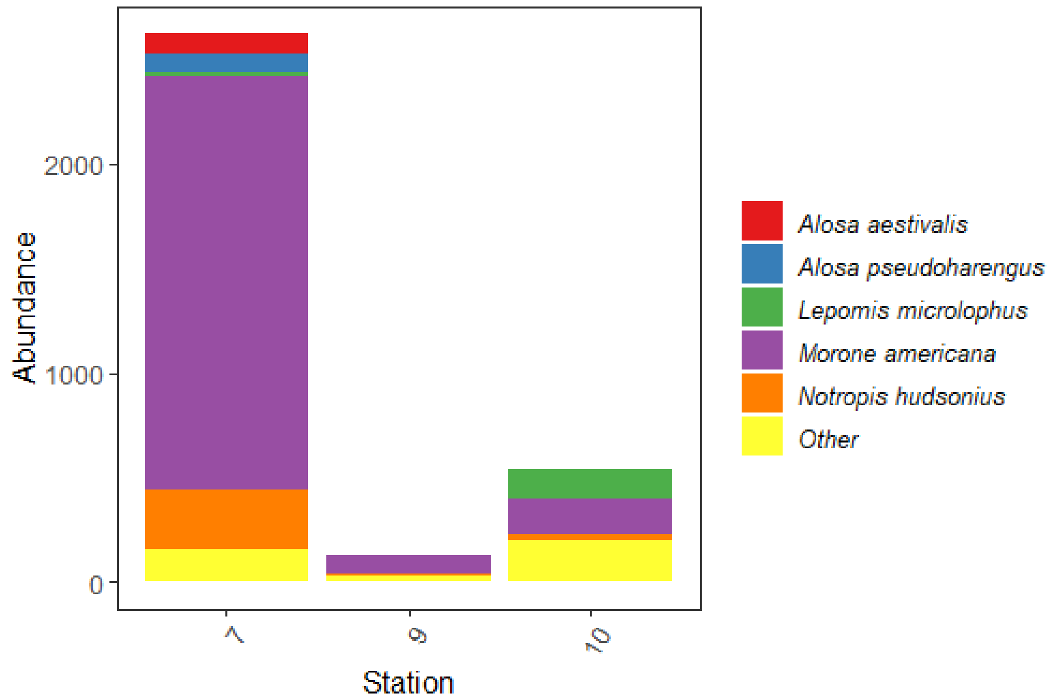



Figure 69a. Adult and Juvenile Fishes Collected by Trawling in 2021. Dominant Species by Station.

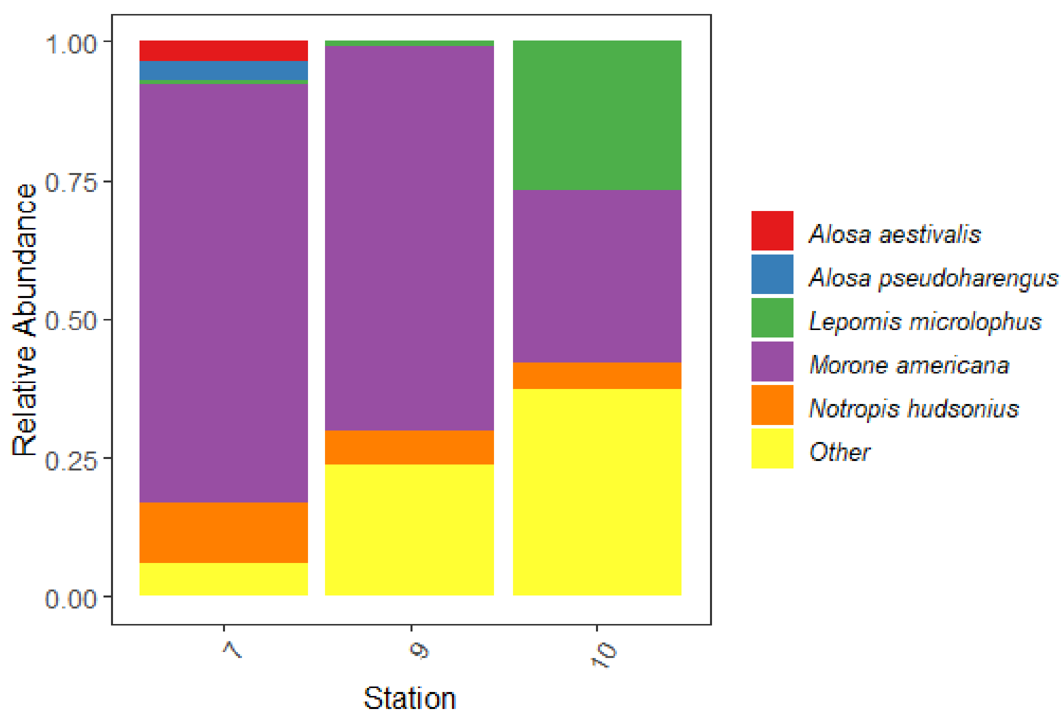



Figure 69b. Relative abundance of Adult and Juvenile Fishes Collected by Trawling in 2021.

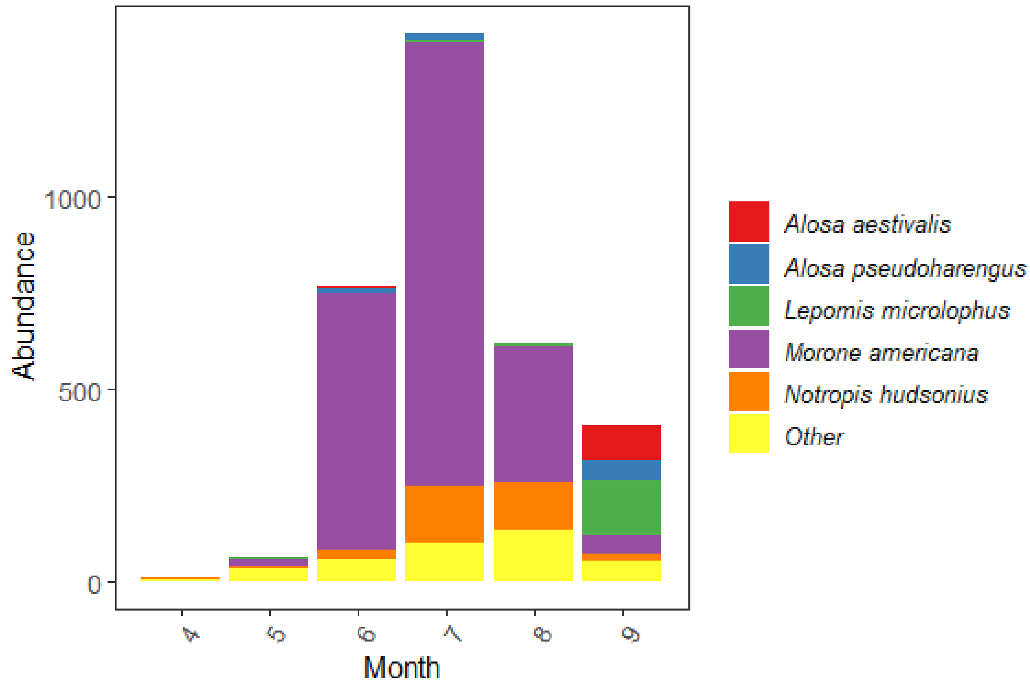



Figure 70a. Adult and Juvenile Fishes Collected by Trawling in 2021. Dominant Species by Month.

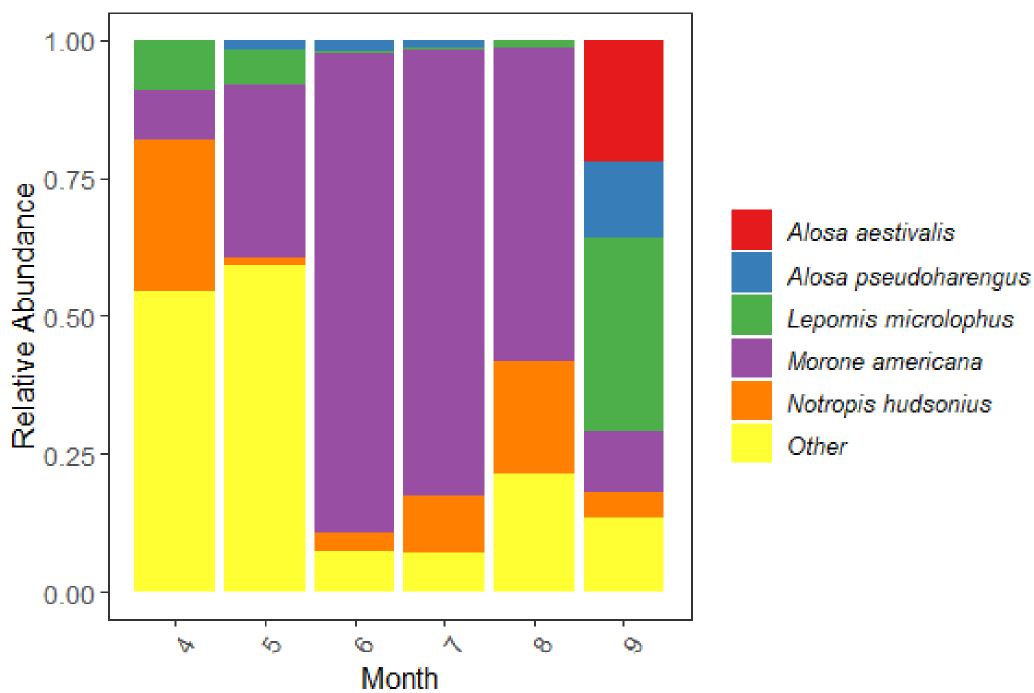



Figure 70b. Relative Abundance for Adult and Juvenile Fishes Collected by Trawling in 2021.

**Seines**

We conducted seine sampling bimonthly from mid-April to mid-September 2021. Stations 4, 6, and 11 have been sampled continuously since 1985. Station 4B was added in 2007 to have a continuous seine record when dense SAV impedes seining in 4. Station 4B is a routine station now, also when seining at 4 is possible. This allows for comparison between 4 and 4B. In 2021, SAV growth was too extensive to seine at Station 4 starting in June and SAV impeded sampling at station 6 starting in August.

We completed 32 seine tows, collecting 10,516 fishes of at least 28 species (Table 8). Similar to previous years, the dominant species in seine catches was Banded Killifish, with a relative contribution to the catch of 70.31 % (n = 7394). All other species abundances were an order of magnitude lower, Gizzard Shad and White Perch, were the next most abundant, comprising 7.73 % (n = 813) and 6.31 % (n = 664) of the catch respectively. Other taxa that contributed at least 1% to total abundance included Inland Silverside (5.34 %), Tessellated Darter (2.10 %), Bluegill (2.03%), Spottail Shiner (1.24 %), and *Alosa* sp. (1.12 %). All other species represented < 1% of the catch per species (Table 8).

Banded Killifish was abundant and present at all sampling dates, with highest abundance in May (Table 9, Figure 71). Total catch was dominated by Banded Killifish every sampling date in 2020. The other dominant species by month were Bluegill in April, Inland Silverside in May, Gizzard Shad in June, and White Perch in July – September (Table 9, Figure 71).

Banded Killifish was also dominant at all Stations (Table 10, Figure 72). At station 6, Gizzard Shad was the second most dominant, and at station 11, White Perch and Inland Silversides were the next most dominant species respectively. White Perch are pelagic species, and Station 11 is a beach closest to the mainstem.

Table 8. Adult and Juvenile Fish Collected by Seining. Gunston Cove Study - 2021.

| Scientific Name | Common Name | Abundance | Percent |
|---|---|---|---|
| *Fundulus diaphanous* | Banded Killifish | 7394 | 70.31 |
| *Dorosoma cepedianum* | Gizzard Shad | 813 | 7.73 |
| *Morone americana* | White Perch | 664 | 6.31 |
| *Menidia beryllina* | Inland Silverside | 562 | 5.34 |
| *Etheostoma olmstedi* | Tessellated Darter | 221 | 2.10 |
| *Lepomis macrochirus* | Bluegill | 214 | 2.03 |
| *Notropis hudsonius* | Spottail Shiner | 130 | 1.24 |
| *Alosa sp.* | unk. Alosa species | 118 | 1.12 |
| *Fundulus heteroclitus* | Mummichog | 76 | 0.72 |
| *Gambusia holbrooki* | Mosquitofish | 51 | 0.48 |
| *Carpiodes Cyprinus* | Quillback | 50 | 0.48 |
| *Lepomis gibbosus* | Pumpkinseed | 50 | 0.48 |
| *Alosa pseudoharengus* | Alewife | 25 | 0.24 |
| *Carassius auratus* | Goldfish | 24 | 0.23 |
| *Alosa aestivalis* | Blueback Herring | 23 | 0.22 |
| *Lepomis microlophus* | Redear Sunfish | 16 | 0.15 |
| *Erimyzon oblongus* | Creek Chubsucker | 15 | 0.14 |
| *Lepomis auratus* | Redbreast Sunfish | 15 | 0.14 |
| *Enneacanthus gloriosus* | Bluespotted Sunfish | 13 | 0.12 |
| *Micropterus salmoides* | Largemouth Bass | 12 | 0.11 |
| *Notemigonus crysoleucas* | Golden Shiner | 8 | 0.08 |
| *Morone saxatilis* | Striped Bass | 6 | 0.06 |
| *Lepisosteus osseus* | Longnose Gar | 4 | 0.04 |
| *Lepomis sp.* | unk. sunfish | 4 | 0.04 |
| *Lepomis cyanellus* | Green Sunfish | 2 | 0.02 |
| *Pomoxis annularis* | White Crappie | 2 | 0.02 |
| *Alosa sapidissima* | American Shad | 1 | 0.01 |
| *Dorosoma petenense* | Threadfin Shad | 1 | 0.01 |
| *Ictalurus punctatus* | Channel Catfish | 1 | 0.01 |
| *Notropis sp.* | unk. shiner species | 1 | 0.01 |
| **Total** | | **10516** | **100.00** |

Table 9. Adult and Juvenile Fish Collected by Seining. Gunston Cove Study - 2021.

| Scientific Name | Common Name | 4-23 | 5-14 | 5-27 | 6-10 | 6-24 | 7-08 | 7-22 | 8-12 | 8-26 | 9-16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Alosa aestivalis* | Blueback Herring | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 23 |
| *Alosa pseudoharengus* | Alewife | 0 | 0 | 2 | 0 | 8 | 0 | 0 | 14 | 1 | 0 | 25 |
| *Alosa sapidissima* | American Shad | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Alosa sp.* | unk. Alosa species | 5 | 0 | 0 | 0 | 0 | 8 | 6 | 57 | 15 | 27 | 118 |
| *Carassius auratus* | Goldfish | 0 | 0 | 0 | 0 | 1 | 10 | 4 | 1 | 0 | 8 | 24 |
| *Carpiodes cyprinus* | Quillback | 0 | 0 | 0 | 25 | 18 | 3 | 1 | 3 | 0 | 0 | 50 |
| *Dorosoma cepedianum* | Gizzard Shad | 0 | 0 | 0 | 0 | 811 | 0 | 0 | 1 | 1 | 0 | 813 |
| *Dorosoma petenense* | Threadfin Shad | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| *Enneacanthus gloriosus* | Bluespotted Sunfish | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 13 |
| *Erimyzon oblongus* | Creek Chubsucker | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 6 | 15 |
| *Etheostoma olmstedi* | Tessellated Darter | 19 | 19 | 40 | 7 | 38 | 79 | 10 | 4 | 0 | 5 | 221 |
| *Fundulus diaphanus* | Banded Killifish | 464 | 2708 | 1831 | 856 | 357 | 392 | 178 | 247 | 118 | 243 | 7394 |
| *Fundulus heteroclitus* | Mummichog | 7 | 14 | 19 | 3 | 1 | 7 | 6 | 0 | 18 | 1 | 76 |
| *Gambusia holbrooki* | Mosquitofish | 0 | 2 | 6 | 2 | 0 | 0 | 0 | 18 | 17 | 6 | 51 |
| *Ictalurus punctatus* | Channel Catfish | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| *Lepisosteus osseus* | Longnose Gar | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 4 |
| *Lepomis auritus* | Redbreast Sunfish | 0 | 0 | 3 | 0 | 5 | 1 | 0 | 6 | 0 | 0 | 15 |
| *Lepomis cyanellus* | Green Sunfish | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 2 |
| *Lepomis gibbosus* | Pumpkinseed | 31 | 2 | 2 | 2 | 1 | 2 | 0 | 8 | 1 | 1 | 50 |
| *Lepomis macrochirus* | Bluegill | 159 | 19 | 15 | 4 | 0 | 1 | 2 | 12 | 1 | 1 | 214 |
| *Lepomis microlophus* | Redear Sunfish | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 10 | 16 |
| *Lepomis sp.* | unk. sunfish | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 4 |
| *Menidia beryllina* | Inland Silverside | 19 | 46 | 373 | 56 | 26 | 10 | 2 | 5 | 1 | 24 | 562 |
| *Micropterus salmoides* | Largemouth Bass | 0 | 0 | 1 | 0 | 2 | 0 | 2 | 2 | 3 | 2 | 12 |
| *Morone americana* | White Perch | 0 | 3 | 0 | 8 | 67 | 59 | 142 | 225 | 6 | 154 | 664 |
| *Morone saxatilis* | Striped Bass | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 1 | 0 | 6 |
| *Notemigonus crysoleucas* | Golden Shiner | 4 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 8 |
| *Notropis hudsonius* | Spottail Shiner | 8 | 0 | 1 | 1 | 6 | 4 | 24 | 30 | 4 | 52 | 130 |
| *Notropis sp.* | unk. shiner species | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Pomoxis annularis* | White Crappie | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| **Total** | | **723** | **2816** | **2294** | **966** | **1345** | **581** | **378** | **637** | **198** | **578** | **10516** |

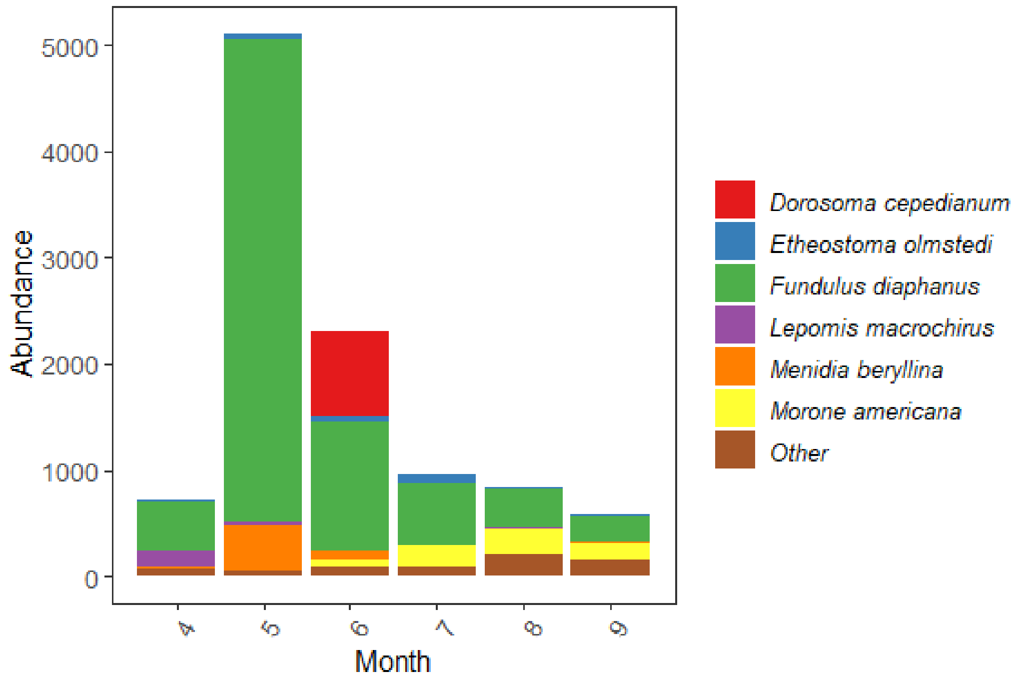



Figure 71. Adult and Juvenile Fish Collected by Seining in 2021. Dominant Species by Month.

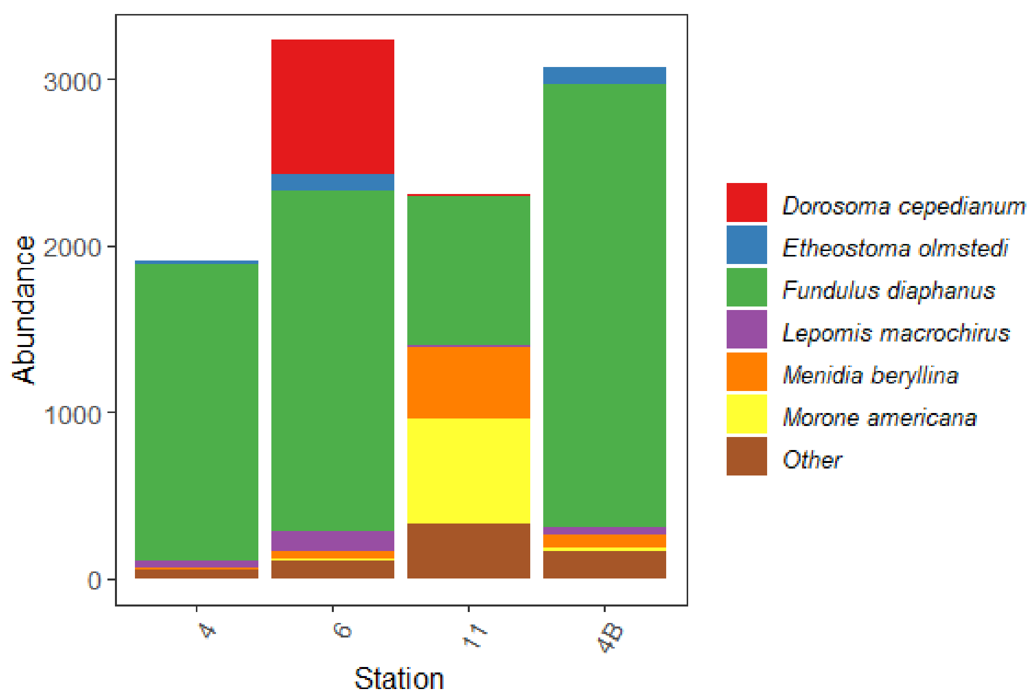



Figure 72. Adult and Juvenile Fishes Collected by Seining in 2021. Dominant Species by Station.

Table 10. Adult and Juvenile Fish Collected by Seining in 2021 per station in Gunston Cove.

| **Scientific Name** | **Common Name** | **4** | **6** | **11** | **4B** |
|---|---|---|---|---|---|
| *Alosa aestivalis* | Blueback Herring | 0 | 0 | 23 | 0 |
| *Alosa pseudoharengus* | Alewife | 0 | 7 | 16 | 2 |
| *Alosa sapidissima* | American Shad | 0 | 0 | 1 | 0 |
| *Alosa sp.* | unk. Alosa species | 0 | 4 | 93 | 21 |
| *Carassius auratus* | Goldfish | 0 | 6 | 0 | 18 |
| *Carpiodes cyprinus* | Quillback | 0 | 1 | 37 | 12 |
| *Dorosoma cepedianum* | Gizzard Shad | 0 | 801 | 12 | 0 |
| *Dorosoma petenense* | Threadfin Shad | 0 | 0 | 1 | 0 |
| *Enneacanthus gloriosus* | Bluespotted Sunfish | 0 | 0 | 0 | 13 |
| *Erimyzon oblongus* | Creek Chubsucker | 0 | 0 | 0 | 15 |
| *Etheostoma olmstedi* | Tessellated Darter | 26 | 96 | 1 | 98 |
| *Fundulus diaphanus* | Banded Killifish | 1773 | 2052 | 899 | 2670 |
| *Fundulus heteroclitus* | Mummichog | 39 | 15 | 4 | 18 |
| *Gambusia holbrooki* | Mosquitofish | 2 | 7 | 1 | 41 |
| *Ictalurus punctatus* | Channel Catfish | 0 | 0 | 1 | 0 |
| *Lepisosteus osseus* | Longnose Gar | 0 | 4 | 0 | 0 |
| *Lepomis auritus* | Redbreast Sunfish | 0 | 15 | 0 | 0 |
| *Lepomis cyanellus* | Green Sunfish | 0 | 1 | 0 | 1 |
| *Lepomis gibbosus* | Pumpkinseed | 4 | 32 | 6 | 8 |
| *Lepomis macrochirus* | Bluegill | 49 | 119 | 5 | 41 |
| *Lepomis microlophus* | Redear Sunfish | 5 | 0 | 11 | 0 |
| *Lepomis sp.* | unk. sunfish | 0 | 3 | 0 | 1 |
| *Menidia beryllina* | Inland Silverside | 7 | 45 | 431 | 79 |
| *Micropterus salmoides* | Largemouth Bass | 1 | 6 | 0 | 5 |
| *Morone americana* | White Perch | 0 | 12 | 637 | 15 |
| *Morone saxatilis* | Striped Bass | 0 | 0 | 6 | 0 |
| *Notemigonus crysoleucas* | Golden Shiner | 1 | 0 | 3 | 4 |
| *Notropis hudsonius* | Spottail Shiner | 3 | 2 | 119 | 6 |
| *Notropis sp.* | unk. shiner species | 0 | 0 | 0 | 1 |
| *Pomoxis annularis* | White Crappie | 0 | 1 | 0 | 1 |
| **Total** | | **1910** | **3229** | **2307** | **3070** |

**Fyke Nets**

We added fyke nets to the sampling regime in 2012 to better represent the fish community present within SAV beds. In 2021 we collected a total number of 821 specimens of at least 12 species in the two fyke nets (Station Fyke 1 and Station Fyke 2; Figure 74; Table 11), similar to our 2019 catches. Fykes were not sampled during 2020, because of COVID crew limitations. The dominant species in Fyke net collections were all Sunfish species (all *Lepomis* genus) combined (36.41%), followed by Inland Silversides (30.38 %) and Banded Killifish (22.36 %). Other taxa contributing more than 1% of the catch include Goldfish, Bluespotted Sunfish, and Tessellated Darters (Table 11). Similar to 2019, we only collected a single native catfish in the fyke nets this year. This lower number of native catfishes in our fykes, could be indicative of displacement by invasive Blue Catfish which we found to be encroaching further into Gunston Cove in our seine samples.

Table 11. Adult and Juvenile Fish Collected by Fyke Nets. Gunston Cove Study - 2021.

| Scientific Name | Common Name | Abundance | Percent |
|---|---|---|---|
| *Menidia beryllina* | Inland Silverside | 250 | 30.38 |
| *Fundulus diaphanus* | Banded Killifish | 184 | 22.36 |
| *Lepomis sp.* | unk. sunfish | 181 | 22.02 |
| *Lepomis macrochirus* | Bluegill | 59 | 7.19 |
| *Lepomis microlophus* | Redear Sunfish | 54 | 6.61 |
| *Carassius auratus* | Goldfish | 33 | 4.08 |
| *Enneacanthus gloriosus* | Bluespotted Sunfish | 26 | 3.17 |
| *Etheostoma olmstedi* | Tessellated Darter | 19 | 2.32 |
| *Morone americana* | White Perch | 5 | 0.60 |
| *Lepomis gibbosus* | Pumpkinseed | 5 | 0.59 |
| *Notropis hudsonius* | Spottail Shiner | 4 | 0.46 |
| *Cyprinus carpio* | Carp | 1 | 0.12 |
| *Ameiurus nebulosus* | Brown Bullhead | 1 | 0.11 |
| **Total** | | **821** | **100.00** |

Highest abundances were collected in from August - September, which was a result of high abundance of all *Lepomis* and Banded Killifish (Table 12, Figure 73). Interestingly, Inland Silversides were dominant in earlier samples, but absent in later samples. The SAV cover is highest in August, which could preclude inland silversides, given that they are an upper water column pelagic fish. Furthermore, SAV abundance is highest in August, which likely led to greater catches of the SAV associated species (*Lepomis* and Banded Killifish) during these months.

Table 12. Adult and Juvenile Fish Collected by Fyke Nets on each sampling date.

| Scientific Name | Common Name | 5-27 | 6-24 | 7-22 | 8-12 | 8-26 | 9-16 | Total |
|---|---|---|---|---|---|---|---|---|
| *Ameiurus nebulosus* | Brown Bullhead | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Carassius auratus* | Goldfish | 0 | 0 | 0 | 20 | 4 | 9 | 33 |
| *Cyprinus carpio* | Carp | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| *Enneacanthus gloriosus* | Bluespotted Sunfish | 0 | 0 | 0 | 0 | 0 | 26 | 26 |
| *Etheostoma olmstedi* | Tessellated Darter | 0 | 2 | 1 | 15 | 1 | 1 | 19 |
| *Fundulus diaphanus* | Banded Killifish | 3 | 0 | 37 | 32 | 13 | 99 | 184 |
| *Lepomis gibbosus* | Pumpkinseed | 0 | 0 | 2 | 0 | 2 | 1 | 5 |
| *Lepomis macrochirus* | Bluegill | 0 | 3 | 4 | 20 | 14 | 19 | 59 |
| *Lepomis microlophus* | Redear Sunfish | 0 | 0 | 0 | 4 | 18 | 32 | 54 |
| *Lepomis sp.* | unk. sunfish | 0 | 0 | 0 | 125 | 20 | 36 | 181 |
| *Menidia beryllina* | Inland Silverside | 105 | 130 | 14 | 0 | 0 | 1 | 250 |
| *Morone americana* | White Perch | 1 | 0 | 1 | 2 | 1 | 0 | 5 |
| *Notropis hudsonius* | Spottail Shiner | 0 | 0 | 0 | 0 | 1 | 3 | 4 |
| **Total** | | **109** | **134** | **58** | **218** | **74** | **227** | **821** |

Fyke 1 and Fyke 2 catches only differed by 1 individual (410 vs. 411 specimens; Table 13, Figure 74). Fyke 1 was dominated by *Lepomis* spp. and Banded Killifish, while Fyke 2 was dominated by Inland Silversides (Figure 74). This trend was likely driven by the fact that Fyke 2 was in an area of less dense SAV for much of the sampling season. Overall, the community structure collected with the two fyke nets similar, with more Inland Silversides collected in Fyke 2 (Figure 74).

Table 13. Adult and Juvenile Fish Collected by Fyke Nets. Gunston Cove Study - 2021.

| **Scientific Name** | **Common Name** | **Fyke1** | **Fyke2** |
|---|---|---|---|
| *Ameiurus nebulosus* | Brown Bullhead | 0 | 1 |
| *Carassius auratus* | Goldfish | 9 | 25 |
| *Cyprinus carpio* | Carp | 1 | 0 |
| *Enneacanthus gloriosus* | Bluespotted Sunfish | 10 | 16 |
| *Etheostoma olmstedi* | Tessellated Darter | 6 | 13 |
| *Fundulus diaphanus* | Banded Killifish | 123 | 60 |
| *Lepomis gibbosus* | Pumpkinseed | 2 | 3 |
| *Lepomis macrochirus* | Bluegill | 20 | 40 |
| *Lepomis microlophus* | Redear Sunfish | 29 | 25 |
| *Lepomis sp.* | unk. sunfish | 115 | 66 |
| *Menidia beryllina* | Inland Silverside | 92 | 158 |
| *Morone americana* | White Perch | 4 | 1 |
| *Notropis hudsonius* | Spottail Shiner | 0 | 4 |
| **Total** | | **410** | **411** |

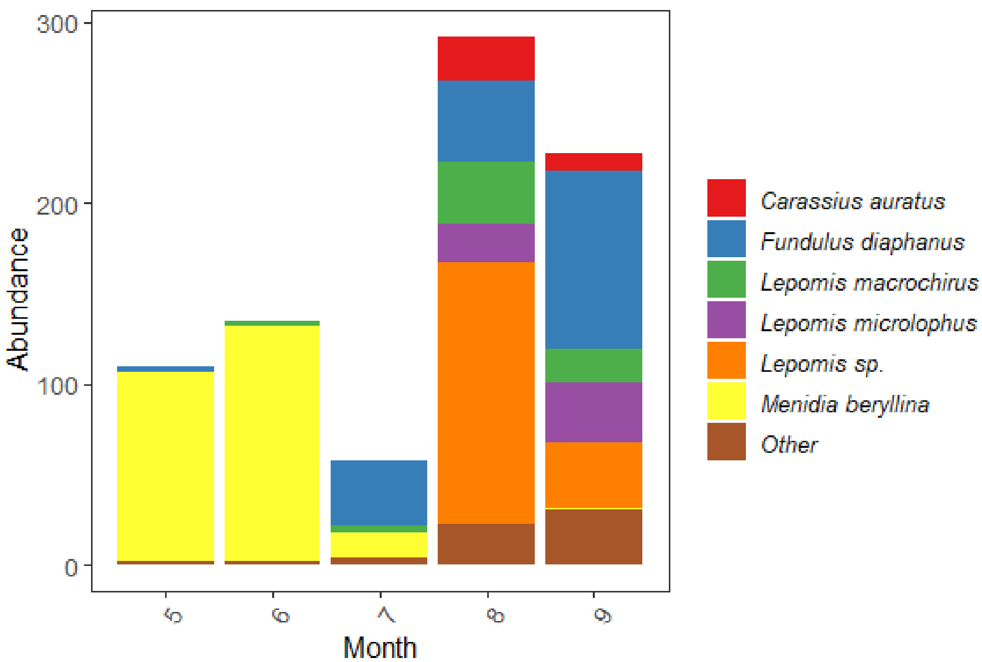



Figure 73. Adult and Juvenile Fish Collected by Fyke Nets. Dominant Species by Month. 2021.

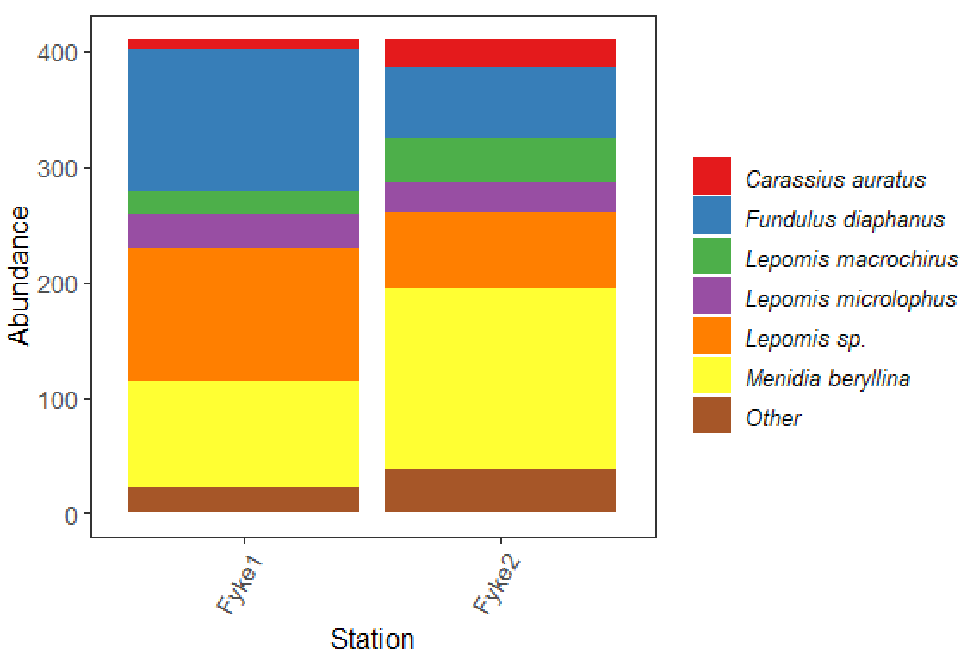



Figure 74. Adult and Juvenile Fishes Collected by Fyke Nets. Dominant Species by Station. 2021.

**G. Benthic Macroinvertebrates - 2021**

Triplicate petite ponar samples were collected from Gunston Cove proper (Station GC7) and in the Potomac River mainstem (Station GC9) monthly from May through September.

**Taxonomic Groups**: A total of 9 taxa of benthic macroinvertebrates, belonging to 5 orders and 9 families, were recorded during the survey (Table 14). One species was non-native (i.e., the Asian clam, *Corbicula fluminea*). Annelid worms, specifically Oligochaetes, were found in high numbers at both sites over all dates (Figure 75). Overall, they accounted for 72% of all benthic organisms found. Insects were the second highest group in abundance across sites and dates, accounting for 27% of all individuals accounted for. Chironomids were by far the most numerous and omnipresent insect taxon. The three other insect taxa were the families Leptophlebiidae, Ceratopogonidae and Chaoboridae. Leptophlebiidae were found at GC9 in May, while Ceratopogonidae were found at both sites in varying amounts from June through September. Chaoboridae were found at both sites in July and August. Crustaceans (including amphipods and isopods) were the third highest group in abundance across sites and dates, accounting for 1% of all individuals. Gammarid amphipods (scuds) dominated this group with the isopod *Cyathura polita* being the second most common crustacean, only found at GC9 during September (Figure 75). The remainder of the taxonomic groups accounted for minor components of the overall abundance. These included Bivalvia (0.1% of total abundance), and Nematoda (i.e., roundworms) (0.02%). The bivalve group was composed only of the invasive Asian clam, *Corbicula fluminea*, (found at both sites).

Table 14. Taxa Identified in Gunston Cove Tidal Benthic Samples.

| Taxon | Common Name | Average # / ponar | |
|---|---|---|---|
| | | GC7 | GC9 |
| Nematoda | Roundworms | 2.2 | 0 |
| Annelida-Oligochaeta* | Oligochaete worms | 81.5 | 94.7 |
| Bivalvia-Corbicula* | Asiatic clams | 0 | 1.7 |
| Crustacea-Isopoda-Cyathura | Isopods | 0 | 1 |
| Crustacea-Amphipoda-Gammarus* | Amphipods | 2 | 7.8 |
| Insecta-Diptera-Ceratopogonidae* | Biting Midges | 2 | 2.8 |
| Insecta-Diptera-Chironomidae* | Midges | 60.2 | 7.1 |
| Insecta-Diptera-Chaoboridae | Phantom Midges | 1 | 1 |
| Insecta-Ephemeroptera-Leptophlebiidae | Mayflies | 0 | 1 |
| | TOTAL | 148.9 | 117.1 |

Taxa identified with an asterisk were found on 3 or more station-dates and were included in the multivariate analysis.

**Spatial trends**: The average abundance of organisms per ponar sample was higher at GC7 within Gunston Cove as compared to the site in the Potomac mainstem (GC9), but this was entirely attributable to the large number of Chironomidae insect larvae at GC7 (Figure 75A). In

July at GC7, one replicate sample contained 336 Chironomidae insect larvae while another had 194 larvae. GC9 had a higher diversity of taxa (N=8) than GC7 (N=6), likely due to differences in sediment and flow characteristics between the sites.

Due to the high abundance of Annelida across all sites, additional analyses were conducted with non-Annelida taxa (Figure 75C). The Asian clam *Corbicula fluminea*, the isopoda *Cyathura polita*, and the Leptophlebiidae insect family were present only at GC9. However, nematodes were only found at GC7. Oligochaeta were present in about the same abundances at both sites. When examining all non-Annelida taxa, Insects were the dominant group in percent contribution at GC7 (95%) and GC9 (45%); Crustaceans were the second most dominant group at GC9 (44%) (Figure 75C). Other taxa varied in their percent contribution by site.

**Temporal trends:** Annelida, composed of only oligochaetes, were the dominant taxa recorded during all months (Figure 75B). Crustaceans, driven by Gammarid amphipods, peaked during May. Average bivalvia abundances differed monthly across the sampling period (average of 1-3 individuals/ponar) but these trends were driven by GC9 as there was no clams collected at GC7. Only a single individual of Turbellaria was found during only May and July and only at GC9.

Comparing percent contributions of all non-Annelida taxa across all of the sites, months were dominated by either Crustaceans (May – 46%) or Insecta (June – 100%, July – 95%, August – 73%, September – 74%) (Figure 75D). Overall, larger increases in abundances and relative percent contributions over the sampling period for many of the taxa described above are in direct relation to seasonal changes and recruitment.

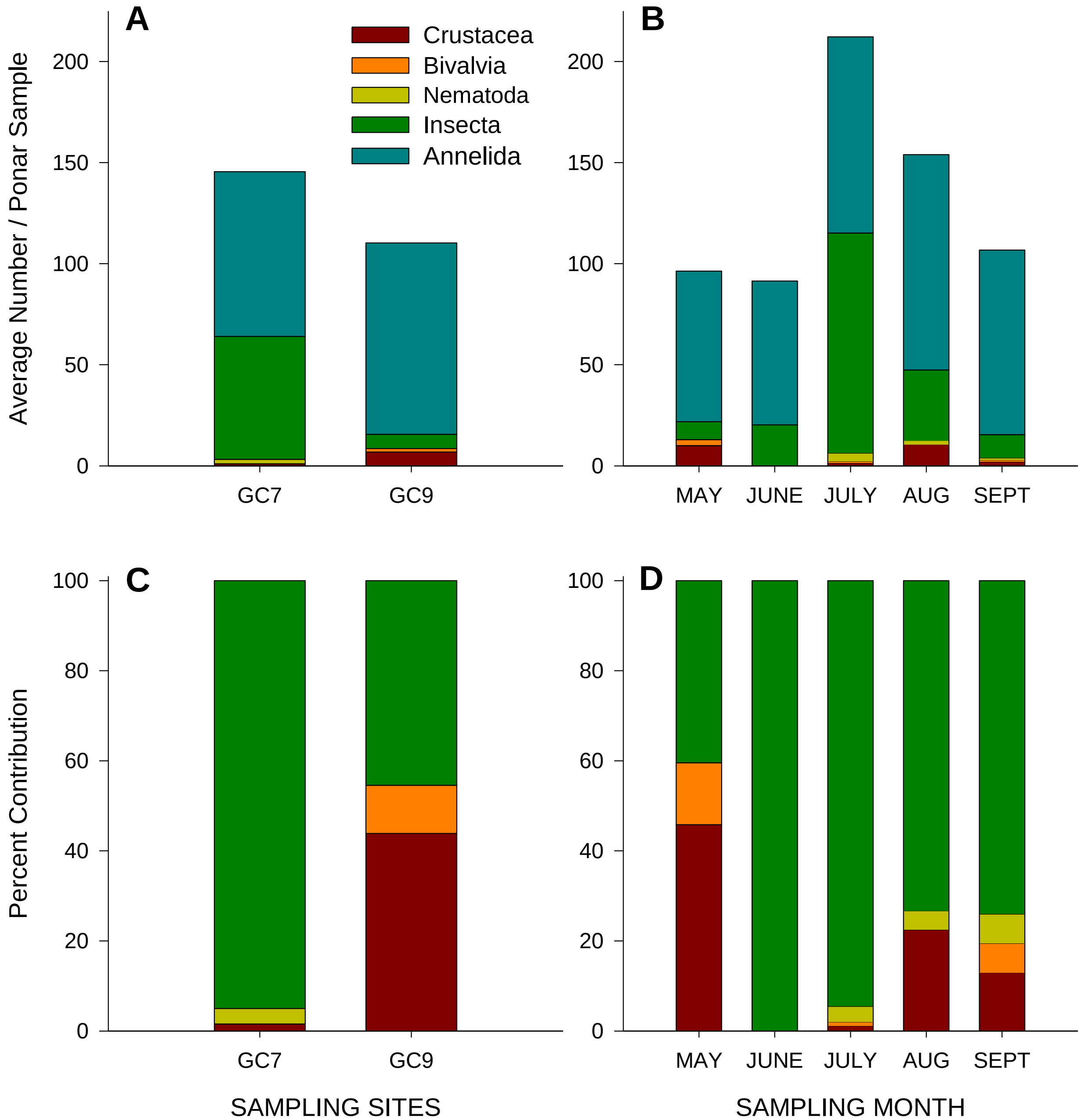



Figure 75. Average number per ponar sample of all benthic macroinvertebrate taxa (A, B) and percent contribution of all non-Annelida benthic macroinvertebrate (C, D) in petite ponar samples collected in 2021 separated by site and month.

**Multivariate analyses**: Due to the multispecies aspect of benthic communities, it is often useful to use multivariate analyses or ordination to examine relationships among samples. This allows multiple taxa to be considered simultaneously when assessing these relationships. In order to get the most meaningful relationships, the full macroinvertebrate sample/taxa matrix was condensed. Taxa that were present in less than three of the original replicate sample matrix were excluded. Then, the remaining, more consistently found taxa were used in the analysis (indicated by asterisks in Table 14) were averaged over the replicates for each date and station combination.

This resulted in one set of taxa values for each station on each date. This reduced matrix (10 samples x 5 taxa) was then subjected to an ordination using a technique called Non-metric Multidimensional Scaling (nMDS). This allows relationships among samples based on their full complement of taxa to be visualized. If successful, relationships among samples can be shown on a two-dimensional plot. The taxa differences responsible for the observed relationships can also be examined. The program PRIMER v.6 was used to conduct the ordinations.

The results of an nMDS ordination using fourth-root transformed data is shown in Figure 76. All of the GC7 samples separate from the GC9 samples, as noted by the two circles of data points. The July and August GC7 samples (blue and green symbol in the top, middle) were different from the other months because this was the only month in which Gammarid crustaceans were found in GC7 samples. May GC7 (red triangle in upper right) was different because it only contained two taxa – Oligochaeta and Chironomidae – while all other samples had at least three taxa. The GC7 samples had either 2 or 3 taxa as compared to between 2 and 5 taxa in GC9 samples. The higher richness at GC9 is probably due to better habitat conditions especially large and more heterogeneous sediment particle size. The spread of the GC9 samples represent the numbers of taxa present in the samples; July and September (green and purple symbols) both had 5 taxa present. May and August (red and blue icons) both had the most *Gammarus* amphipods among all the samples. June GC9 was different from all other samples in that there were only two taxa present.

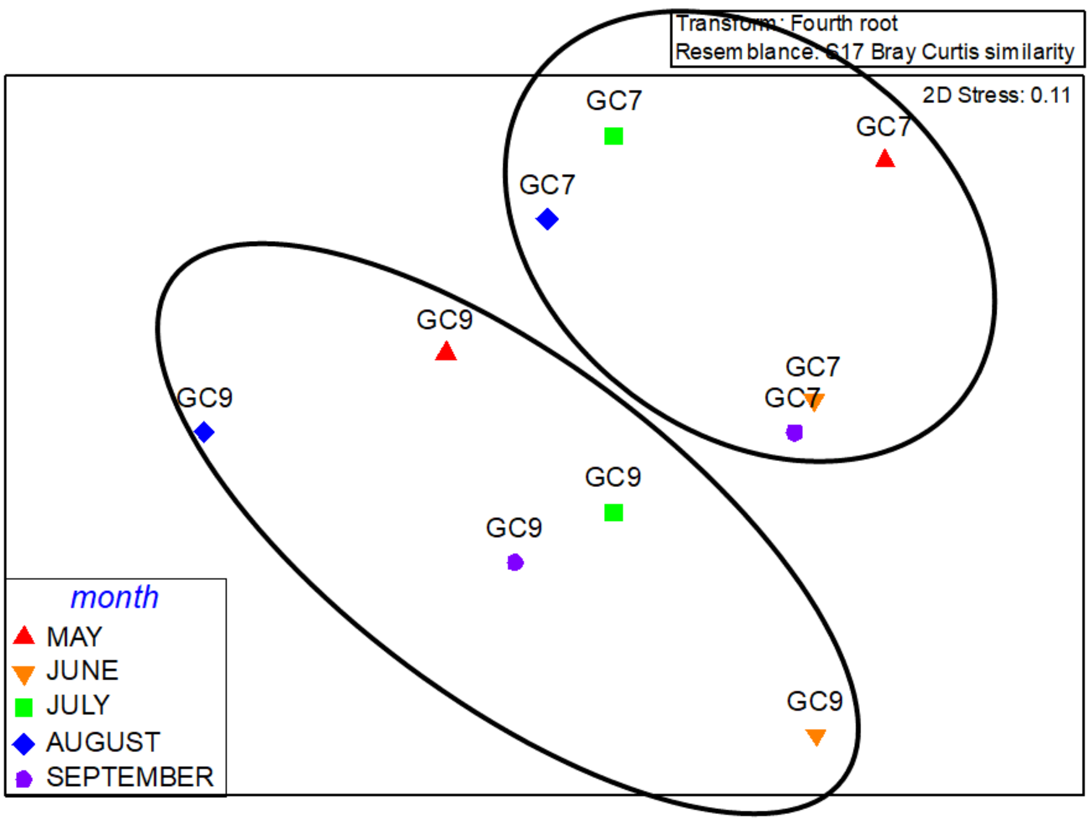



**Figure 76.** nMDS ordination of benthic samples from tidal stations. The station names are placed above each symbol. Colors represent month. Triplicates were averaged to get a single value for each month-station combination. Data was fourth root transformed, and the distance measure was S17 Bray Curtis similarity.

**Influence of Habitat on Community Composition**: We assigned all materials greater than 5 mm in the petite ponar sample to one of three categories: leaves/woody debris, mollusc shells, or submerged aquatic vegetation and calculated the percent contribution of each category to the overall habitat (Table xx). There was no correlation between macroinvertebrate abundance and the type of large particles available at either site (Table xx). Both stations had variable amounts of large particles present (GC7: range of 0 – 94.9% shell and 5.1 – 100% leaves or woody debris; GC9: range of 0 – 97% shell and 3 – 100% leaves or woody debris). There was only one sampling date in which SAV was recovered – July at GC7. GC7, on average, had a higher percent of leaves and wood (45%) than GC9 (21.7%), while GC9 was dominated by shells more so than GC7 (78.3% and 54.8%, respectively).

Table 15. Large substrate composition vs. total abundance and taxa richness of benthic macroinvertebrates in individual replicate samples.

| Site | Replicate | Month | % Leaves/Wood | % Shell | % SAV | Total Abundance | Total Richness |
|---|---|---|---|---|---|---|---|
| GC7 | A | May | 14.7 | 85.3 | 0.0 | 67 | 2 |
| | B | | 59.6 | 40.4 | 0.0 | 38 | 2 |
| | C | | 100.0 | 0.0 | 0.0 | 31 | 2 |
| | A | June | 38.8 | 61.2 | 0.0 | 117 | 3 |
| | B | | 24.8 | 75.2 | 0.0 | 88 | 2 |
| | C | | 10.9 | 89.1 | 0.0 | 82 | 2 |
| | A | July | 12.2 | 87.8 | 0.0 | 273 | 2 |
| | B | | 19.6 | 80.4 | 0.0 | 143 | 3 |
| | C | | 60.9 | 34.8 | 4.3 | 445 | 3 |
| | A | August | 5.4 | 94.6 | 0.0 | 205 | 3 |
| | B | | 100.0 | 0.0 | 0.0 | 153 | 4 |
| | C | | 97.8 | 2.2 | 0.0 | 154 | 4 |
| | A | September | 24.4 | 75.6 | 0.0 | 241 | 4 |
| | B | | 100.0 | 0.0 | 0.0 | 70 | 3 |
| | C | | 5.1 | 94.9 | 0.0 | 41 | 3 |
| GC9 | A | May | 14.7 | 85.3 | 0.0 | 67 | 2 |
| | B | | 5.1 | 94.9 | 0.0 | 36 | 5 |
| | C | | 10.5 | 89.5 | 0.0 | 59 | 2 |
| | A | June | 3.5 | 96.5 | 0.0 | 135 | 2 |
| | B | | 17.6 | 82.4 | 0.0 | 47 | 1 |
| | C | | 67.3 | 32.7 | 0.0 | 85 | 1 |
| | A | July | 10.4 | 89.6 | 0.0 | 89 | 2 |
| | B | | 8.8 | 91.2 | 0.0 | 93 | 2 |
| | C | | 3.0 | 97.0 | 0.0 | 183 | 6 |
| | A | August | 27.7 | 72.3 | 0.0 | 107 | 4 |
| | B | | 9.8 | 90.2 | 0.0 | 144 | 2 |
| | C | | 9.0 | 91.0 | 0.0 | 98 | 2 |
| | A | September | 13.8 | 86.2 | 0.0 | 79 | 2 |
| | B | | 29.7 | 70.3 | 0.0 | 201 | 4 |
| | C | | 100.0 | 0.0 | 0.0 | 33 | 4 |

**Summary:** Similar to previous years, the macroinvertebrate community was dominated by Oligochaetes (Annelids) across sites. Outside of the Annelids, Crustaceans (dominated by gammarid amphipods) were the most abundant group in the Potomac River mainstem (Station GC9), while Gunston Cove proper (Station GC7) was dominated by Insect larvae from the Chironomidae family (midges). GC9 had the highest number of unique taxa (N=3; Insecta-Ephemeroptera-Leptophlebiidae, Crustacea-Isopoda-*Cyathura polita*, and the Asian clam *Corbicula fluminea*). Comparing percent contributions of all non-Annelida taxa across both sites, months were dominated by Crustaeans in May (gammarid amphipods) and Insecta (Chironomidae midges) in all other months (Figure 64C,D).

Ordination analyses of the community indicated a clear separation between communities sampled at the two sites for all months. There was no relationship between large particle type and total macroinvertebrate abundance or richness at either site, although GC7 had a higher % leaves and woody debris while GC9 had higher % mollusc shells. There was also a change of the community composition throughout the months, as common for aquatic communities experiencing changes in abiotic conditions and recruitment during the summer months.

### H. Submersed Aquatic Vegetation – 2021

The Virginia Institute of Marine Science annual aerial SAV survey indicate a return to aerial coverage over most of the inner Cove area similar to that observed in most years since 2005 (Figure 77). For 2021, the total SAV coverage in the cove was 134 hectares, lower than in 2020, but still substantial.

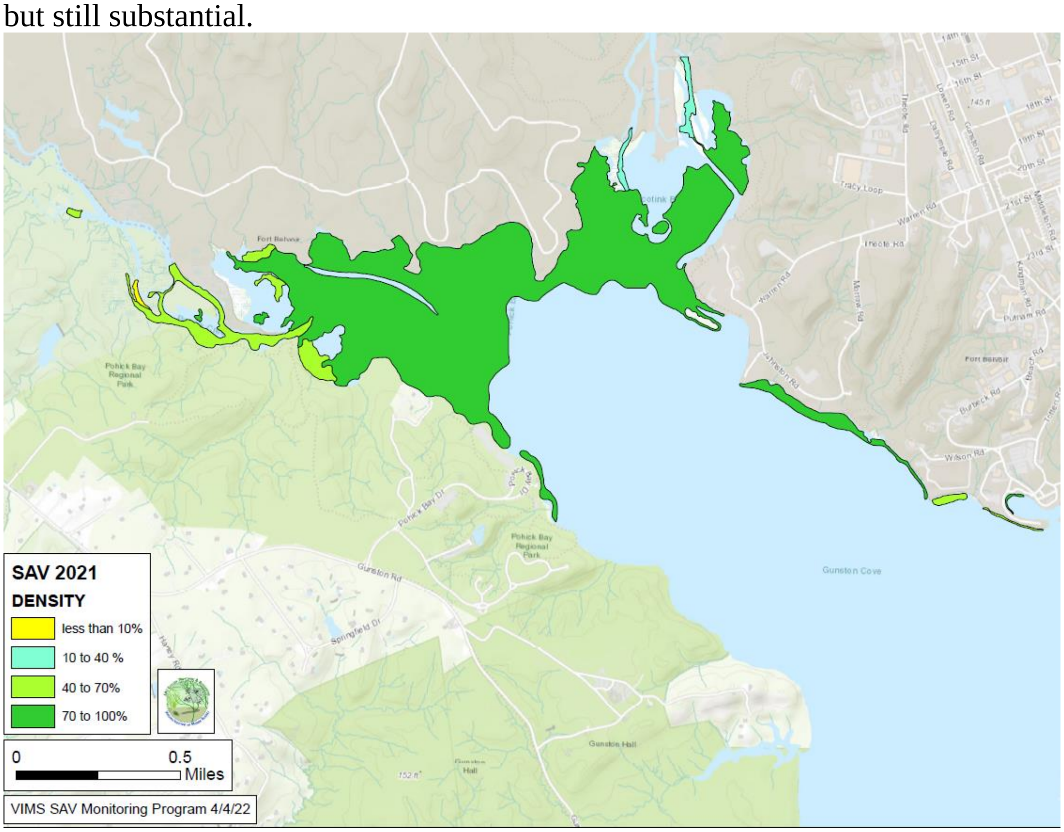



Figure 77. Coverage of Submersed Aquatic Vegetation in Gunston Cove.

VIMS SAV program. Interactive SAV map for 2021. Courtesy: David Wilcox, VIMS.

During the data mapping cruise, the distribution of dominant SAV taxa was determined at 15 points in the inner portion of Gunston Cove during the datamapping cruise on August 26, 2021 by inserting a garden rake to the bottom, twisting it to collect plants and pulling it on board. The results are summarized in Table 16. *Hydrilla verticillata* was found at about half of the shallow water sites and its coverage at those sites was fairly high. *Certatophyllum demersum* was also found at about half of the shallow water sites with somewhat less average coverage. *Najas minor* was found at about 1/3 of these sites at moderate coverage. *Zosterella dubia* was present at about half of the sampled points at low to moderate density. *Vallisneria america* and *Zosterella dubia* were present, but scarce in the rake samples. These results demonstrate that SAV continued to make a partial recovery in 2021 from the very low coverage and density observed in 2018. Note that some of the datamapping cruise occurred outside of the area of SAV coverage (Figure 6).

Table 16. Relative abundance of dominant SAV species determined during data mapping cruise.

| | | **Freq** | **Freq** | **Avg.** |
|---|---|---|---|---|
| **Scientific Name** | **Common Name** | **(#)** | **(%)** | **Density** |
| *Hydrilla verticillate* | hydrilla | 15 | 48.4 | 2.73 |
| *Ceratophyllum demersum* | coontail | 14 | 45.2 | 1.93 |
| *Najas minor* | minor/spiny naiad | 11 | 35.5 | 2.27 |
| *Vallisneria americana* | water celery | 2 | 6.5 | 1.0 |
| *Zosterella dubia* | water stargrass | 1 | 3.2 | 1.0 |

A total of 31 points were sampled for SAV with a water depth of 1.7 m or less. Frequency (#) is the number of points that contained a particular species of SAV. Frequency (%) is the proportion of points that contained that species. Average density is the average coverage value at those points that contained a particular species. Coverage values ranged from 0.5 (present) to 4 (very abundant).

# DISCUSSION

## A. 2021 Data

In 2021 temperature was above normal in all months (Table 3). There were 38 days with maximum temperature above 32.2ºC (90ºF) in 2021 as in 2020 which is well above the median number over the past decade. Precipitation was closer to normal in 2021 than in the extremely wet year 2018. However, it was again well above normal in 2021, especially in June and mid-August. Rainfall and runoff patterns relative to sampling dates are shown in Figure 78. Sample dates in June and particularly in mid-August could have been impacted by rainfall producing tributary flows. River flows which could impact the study area did not occur until September.

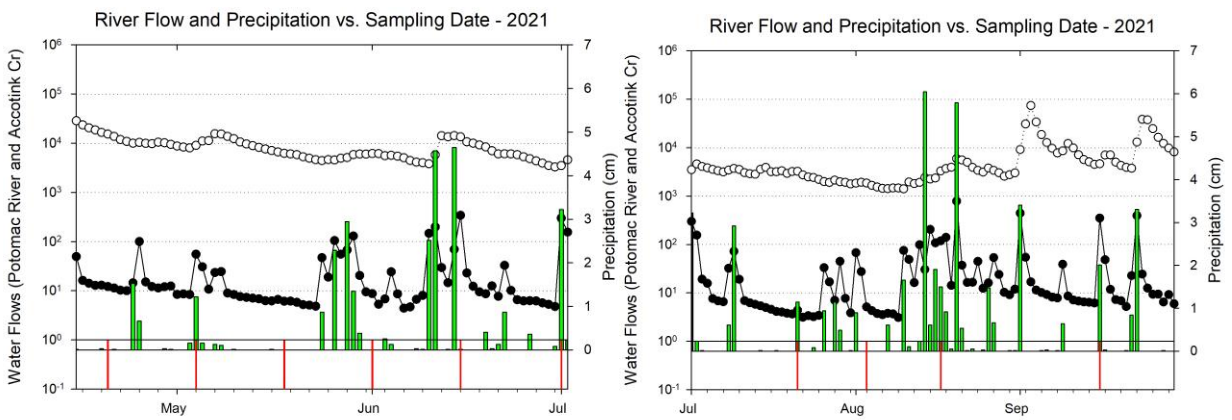



Figure 78. Precipitation (green bars), Accotink Creek flows (solid circles), Potomac River flows (open circles) and water quality/plankton sampling events (red lines at bottom).

Mean water temperature was similar at the two stations with a pronounced dip in early June and a peak of about 30° in July. Specific conductance was mostly in the 250-400 range. Station 7 showed a general downward trend with much variability while Station 9 exhibited a slight upward trend and less variability. Dissolved oxygen saturation and concentration (DO) were consistently higher in the cove and there was a general decline through the year. Field pH patterns mirrored those in DO. Total alkalinity was generally higher in the river than in the cove. Water clarity as measured by Secchi disk transparency and light attenuation coefficient was generally better in the river than in the cove. Values indicated only moderately good water clarity.

Ammonia nitrogen rarely exceeded the rather high detection limit of 0.1 mg/L making analysis of any temporal or spatial trends impossible. Nitrate values declined steadily through August at both stations with river values consistently about 0.5 mg/L than those in the cove. Nitrite was much lower overall. Organic nitrogen was generally fairly consistent through the year and about 0.1 mg/L higher in the cove than in the river. Total phosphorus showed a little seasonal or spatial trend hovering between 0.05 and 0.10 mg/L. Soluble reactive phosphorus was generally somewhat higher in the river, but showed little consistent seasonal trend. N to P ratio declined at both stations through July and August and then increased slightly in September. with most values between 10 and 30, a range which is still indicative of P limitation of phytoplankton and SAV. BOD was generally higher in the cove than in the river. TSS was consistently between

10 and 30 and varied a lot from week to week. VSS did not show strong spatial and temporal patterns.

In the cove algal populations as measured by chlorophyll *a* were consistently higher in the cove than in the river except in August when there may have been flushing from tributary runoff. There were two peaks in the cove, early May and mid-July, reaching 30 µg/L. In the river there was a steady increase through the year reaching about 20 ug/L in late July. In 2021 phytoplankton density in the cove was dominated by cyanobacteria. *Oscillatoria* was the dominant cyanobacterial taxon on most dates reaching a peak in early June. In terms of biovolume the dominant group were the diatoms with the most abundant species being the filamentous diatom *Melosira*. The dominant group in terms of cell density in the river was again the cyanobacteria and the dominant taxon on many dates was *Oscillatoria*, but *Chroococcus* and *Merismopedia* made significant contributions. The peak in cell density in the river occurred in early July. In terms of biovolume diatoms were again were the dominant group on most dates as in the cove. In the spring and early summer *Melosira* was the dominant diatom whereas in late summer discoid centrics assumed dominance.

Rotifers continued to be the most numerous microzooplankton in 2021. Rotifer densities in the cove were quite variable in 2021 with three distinct peaks each dominated by a different genus. Rotifer densities were consistently lower in the river than in the cove with *Brachionus a*s the dominant. *Bosmina*, a small cladoceran exhibited two distinct peaks in the river and one in the cove, but values were modest. *Diaphanosoma*, a larger cladoceran, was very abundant in the river in mid-June exceeding $2500/m^3$. At the same time there was a smaller peak in the cove. *Daphnia* was only found at very low values again in 2021. *Leptodora* exhibited a very strong peak in mid-May at over $2000/m^3$. Copepod nauplii had a distinct bimodal seasonal pattern in the cove reaching 250/L in mid-July. In the river the peak was somewhat lower. The calanoid copepod *Eurytemora* was very abundant in the cove in mid-May attaining $14{,}500/m^3$, but was much lower for the rest of the year. A second calanoid *Diaptomus* was found at much lower levels. *Mesocyclops edax* had a strong maximum in the cove in mid-May of almost $10{,}000/m^3$ and in the river of $11{,}000/m^3$.

Several water quality and plankton variables exhibited a strong decline in mid-August including specific conductance, chloride, dissolved oxygen, pH, total alkalinity, turbidity, secchi depth, and chlorophyll *a*. These declines were probably due to the impact of runoff from the 4 cm of precipitation in the three days preceding this sampling and the more than double the average precipitation during the month of August.

In 2021 ichthyoplankton was dominated by clupeids, most of which were Gizzard Shad (23%), Alewife (22%), and Blueback Herring (16%). and to a much lesser extent Hickory Shad and American Shad. White Perch was found in relatively high densities (15%), mostly found in the Potomac mainstem, confirming its affinity for open water. Inland Silverside was also relatively abundant (6.4%) and found more in the mainstem. The highest density of fish larvae occurred late May, which was driven by a high density of Clupeid larvae. White perch larvae also reached a maximum in late May.

Submerged aquatic vegetation continued to be abundant in 2021 after 2018's very low cover, which resulted in fish abundances and gear efficiency that was similar to the years before

2018. In trawls White Perch dominated at 68%, followed by Spottail Shiner at 10%. No other species exceeded 5%. White Perch was by far the most abundant species and was found in all months at all stations. We collected a lot less Blue Catfish than in 2018, but still found 22 in the mainstem and 1 in the cove. We continue to find a disparity between catches of Blue Catfish in the mainstem versus the cove, which supports the theory that Blue Catfish has an affinity for the mainstem, potentially leaving embayments like Gunston Cove to serve as a refuge for native catfishes. We collected 7 native bullhead catfish in the cove and none in the mainstem.

In seines, the most abundant species in 2021 was Banded Killifish comprising 70% of the catch. Banded Killifish was far more abundant in seines than in trawls, which emphasizes the preference of Banded Killifish for the shallow littoral zone (which is the area sampled with a seine, while trawls sample the open water). Other taxa with high abundances were Gizzard Shad (8%), White Perch (6%) and Inland Silverside (5%). Abundances remained substantial throughout the sampling season.

In fyke nets Inland Silverside was the dominant species in 2021 with 30% of the total catch. Sunfish (*Lepomis* species lumped together) were also abundant at 36% and Banded Killifish at 22%. White perch were rare in the fyke nets.

As in most previous years, oligochaetes were the most common invertebrates collected in ponar samples in 2021. Chironomids (midge larvae) were second most dominant in the cove and third most dominant in the river. The second most numerous taxa in the river was Amphipoda. Multivariate analysis showed a clear and consistent difference between cove benthic communities and those in the river. Shells were consistently the most abundant large substrate in river benthic samples. In the cove both shells and plant debris were abundant.

Coverage of submersed aquatic vegetation (SAV) in 2021 was down from the higher 2019 levels, but still within the range of post 2004 values. As in 2020 *Hydrilla*, coontail, and spiny naiad were the most abundant SAV taxa..

B. Water Quality Trends: 1983-2021

To assess long-term trends in water quality, data from 1983 to 2021 were pooled into two data files: one for Mason data and one for Noman Cole laboratory data. Then, subgroups were selected based on season and station. For water quality parameters, we focused on summer (June-September) data as this period is the most stable and often presents the greatest water quality challenges and the highest biological activity and abundances. We examined the cove and river separately with the cove represented by Station 7 and the river by Station 9. We tried several methods for tracking long-term trends, settling on a scatterplot with LOWESS trend line. Each observation in a particular year is plotted as an open circle on the scatterplot. The LOWESS (locally weighted sum of squares) line is drawn by a series of linear regressions moving through the years. We also calculated the Pearson correlation coefficient and performed linear regressions to test for statistical significance of a linear relationship over the entire period of record (Tables 16 and 17). This was similar to the analysis performed in previous reports.

Table 17
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1984-2021
GMU Water Quality Data
June-September

| | Station 7 | | | Station 9 | | |
|---|---|---|---|---|---|---|
| Parameter | Corr. Coeff. | Reg. Coeff. | Signif. | Corr. Coeff. | Reg. Coeff. | Signif. |
| Temperature | 0.176 | 0.046 | 0.001 | 0.103 | ----- | 0.040 |
| Conductivity, standardized to 25°C | 0.119 | 1.288 | 0.030 | 0.011 | ----- | NS |
| Dissolved oxygen, mg/L | 0.107 | -0.021 | 0.050 | 0.150 | 0.017 | 0.010 |
| Dissolved oxygen, percent saturation | 0.033 | ----- | NS | 0.178 | 0.205 | 0.002 |
| Secchi disk depth | 0.652 | 1.56 | <0.001 | 0.313 | 0.462 | <0.001 |
| Light attenuation coefficient | 0.620 | 0.076 | <0.001 | 0.087 | ----- | NS |
| pH, Field | 0.239 | -0.014 | <0.001 | 0.171 | 0.007 | 0.007 |
| Chlorophyll, depth-integrated | 0.623 | -3.54 | <0.001 | 0.329 | -0.784 | <0.001 |
| Chlorophyll, surface | 0.611 | -3.57 | <0.001 | 0.312 | -0.862 | <0.001 |

For Station 7, n=327-346 except pH, Field where n=280 and Light attenuation coefficient where n=263.
For Station 9, n=278-292 except pH, Field where n=247 and Light attenuation coefficient where n=233.

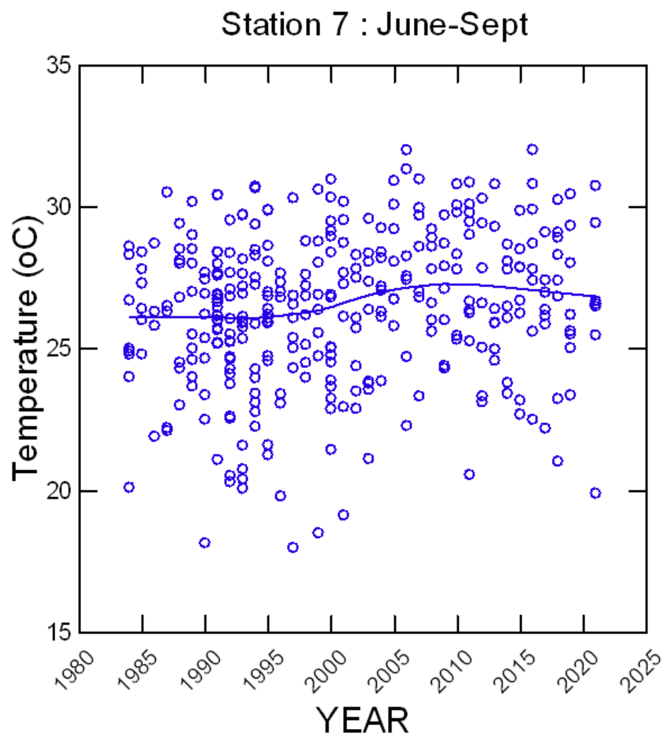
Significance column indicates the probability that a correlation coefficient this large could be due to chance alone. If this probability is greater than 0.05, then NS (not significant) is indicated. Both near surface and near bottom samples included.

Table 18
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1983-2021
Fairfax County Environmental Laboratory Data
June-September

| | Station 7 | | | Station 9 | | |
|---|---|---|---|---|---|---|
| Parameter | Corr. Coeff. | Reg. Coeff. | Signif. | Corr. Coeff. | Reg. Coeff. | Signif. |
| Chloride | 0.075 | ----- | NS | 0.066 | ----- | NS |
| Lab pH | 0.562 | -0.035 | <0.001 | 0.383 | -0.018 | <0.001 |
| Alkalinity | 0.095 | 0.108 | 0.029 | 0.387 | 0.460 | <0.001 |
| BOD | 0.644 | -0.143 | <0.001 | 0.422 | -0.042 | <0.001 |
| Total Suspended Solids | 0.369 | -0.817 | <0.001 | 0.195 | -0.100 | 0.002 |
| Volatile Suspended Solids | 0.412 | -0.522 | <0.001 | 0.399 | -0.168 | <0.001 |
| Total Phosphorus | 0.582 | -0.003 | <0.001 | 0.351 | -0.001 | <0.001 |
| Soluble Reactive Phosphorus | 0.128 | -0.0001 | 0.003 | 0.058 | ----- | NS |
| Ammonia Nitrogen | 0.324 | -0.015 | <0.001 | 0.268 | -0.002 | <0.001 |
| Nitrite Nitrogen | 0.452 | -0.003 | <0.001 | 0.169 | -0.001 | 0.010 |
| Nitrate Nitrogen | 0.595 | -0.030 | <0.001 | 0.618 | -0.029 | <0.001 |
| Organic Nitrogen | 0.607 | -0.043 | <0.001 | 0.394 | -0.012 | <0.001 |
| N to P Ratio | 0.262 | -0.273 | <0.001 | 0.340 | -0.336 | <0.001 |

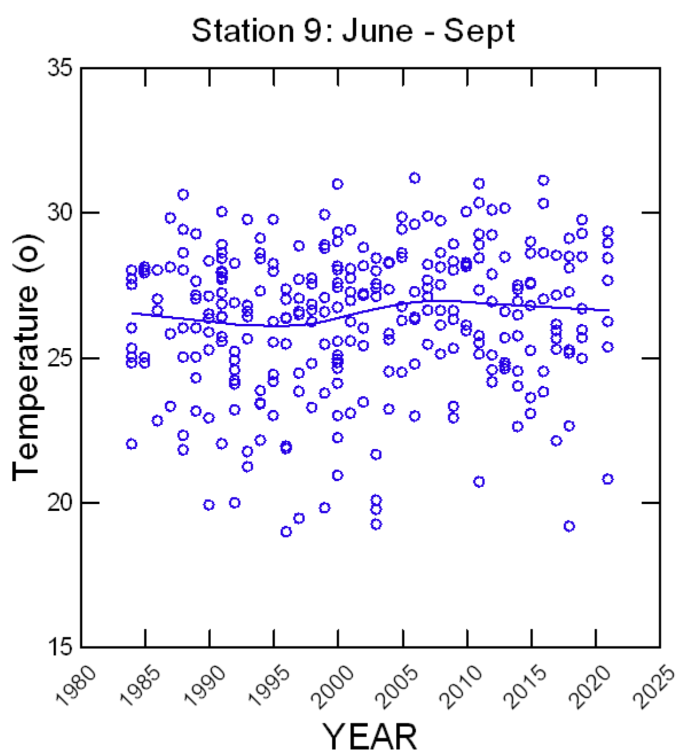
For Station 7, both surface and bottom samples used, n=509-546 except Nitrite Nitrogen where n=468
For Station 9, only surface samples used, n=250-274 except Nitrite Nitrogen where n =235.

Significance column indicates the probability that a correlation coefficient this large could be due to chance alone. If this probability is greater than 0.05, then NS (not significant) is indicated.



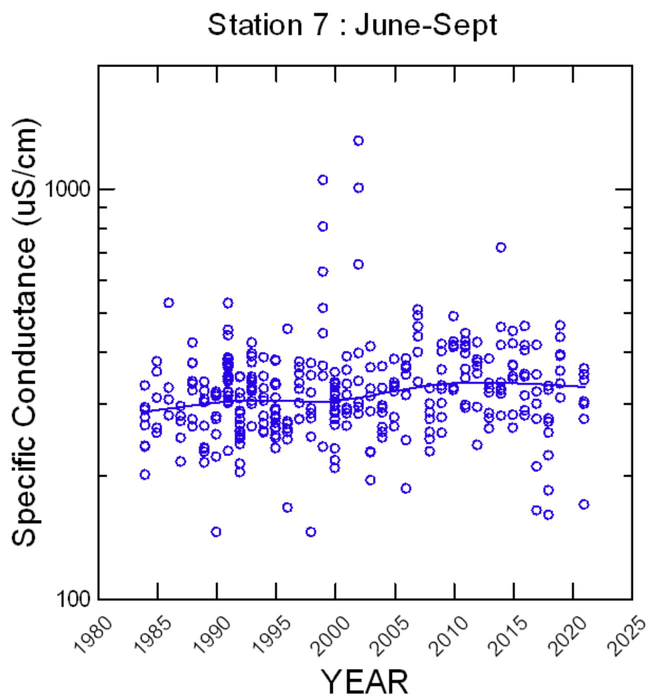

Water temperatures during the summer months generally varied between 20ºC and 30ºC over the study period (Figure 79). The LOWESS curve indicated an average of about 26°C during the period 1984-2001 with a slight upward trend in the last few years to about 27ºC. Linear regression analysis indicated a significant linear trend in water temperature in the cove when the entire period of record is considered (Table 17). The slope of this relationship is 0.05°C/year.

Figure 79. Long term trend in Water Temperature (GMU Field Data). Station 7. Gunston Cove.



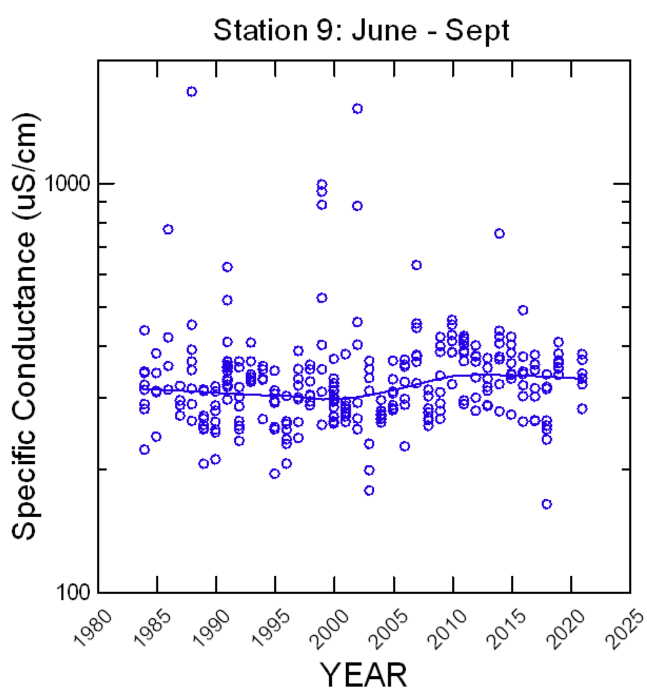

In the river summer temperatures have been similar to those in the cove with fewer readings above 30°C in the river (Figure 80). The long term trend became significant in 2021 (Table 17).

Figure 80. Long term trend in Water Temperature (GMU Field Data). Station 9. Gunston Cove.



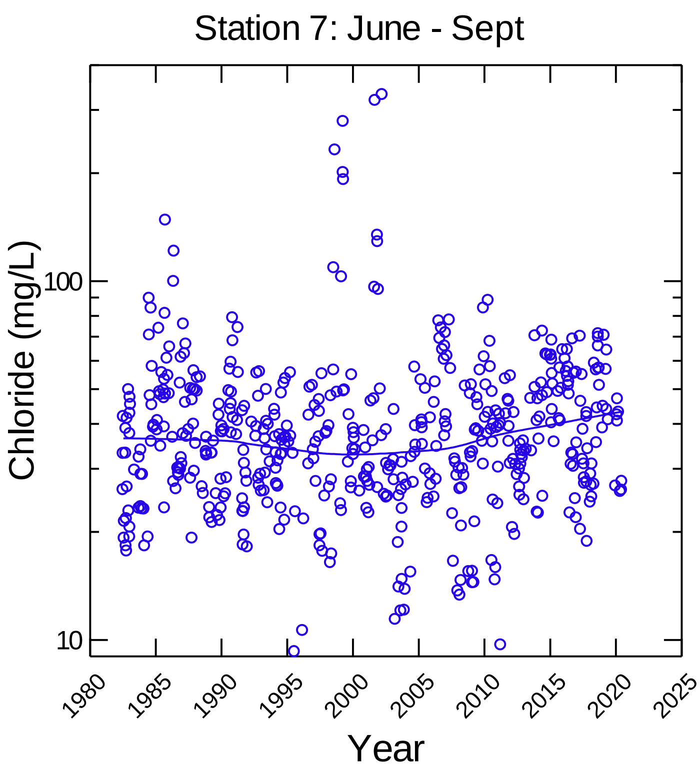

Specific conductance was generally in the range 200-500 µS/cm over the study period (Figure 81). Some significantly higher readings have been observed sporadically. A slight increase in specific conductance was suggested by the LOWESS line over the study period. This was significant over the study period with a slope of 1.3uS/cm/yr (Table 17).

Figure 81. Long term trend in Specific Conductance (GMU Field Data). Station 7. Gunston Cove.



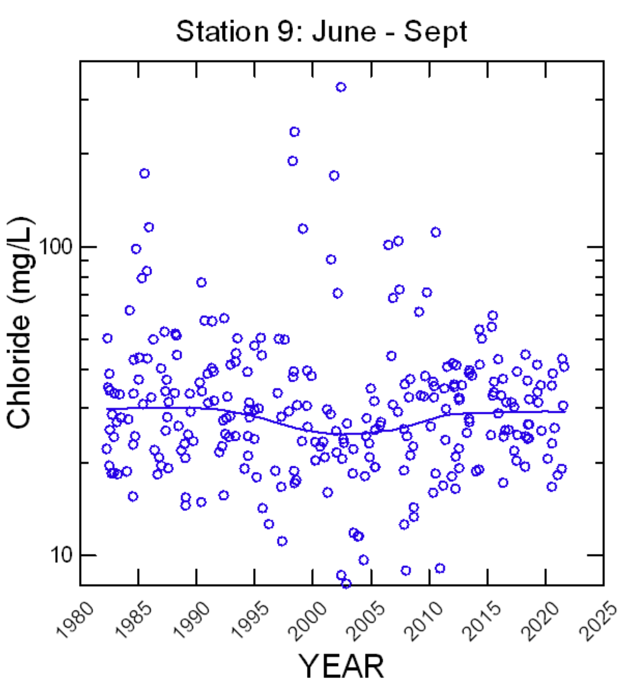

Conductivity values in the river were in the same general range as in the cove (Figure 82). Most values were between 200 and 500 µS/cm with a few much higher values. These higher values are probably attributable to intrusions of brackish water from downstream during years of low river flow. Linear regression did not reveal a significant trend in river conductivity (Table 17).

Figure 82. Long term trend in Specific Conductance (GMU Field Data). Station 9. River mainstem.



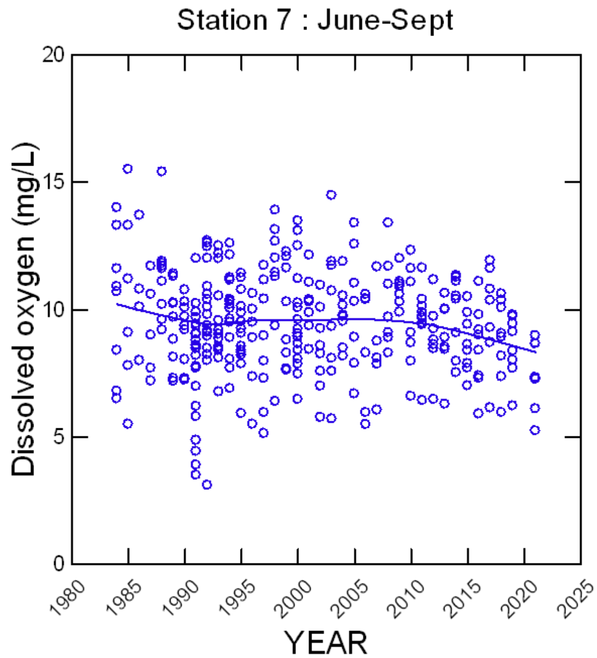

Chloride levels were clustered in a relatively narrow range of 20-70 mg/L for the entire study period (Figure 83). Higher values observed in some years were probably due to the estuarine water intrusions that occur in dry years. The trend line is nearly flat and a linear regression was not statistically significant (Table 18).

Figure 83. Long term trend in Chloride (Fairfax County Lab Data). Station 7. Gunston Cove.



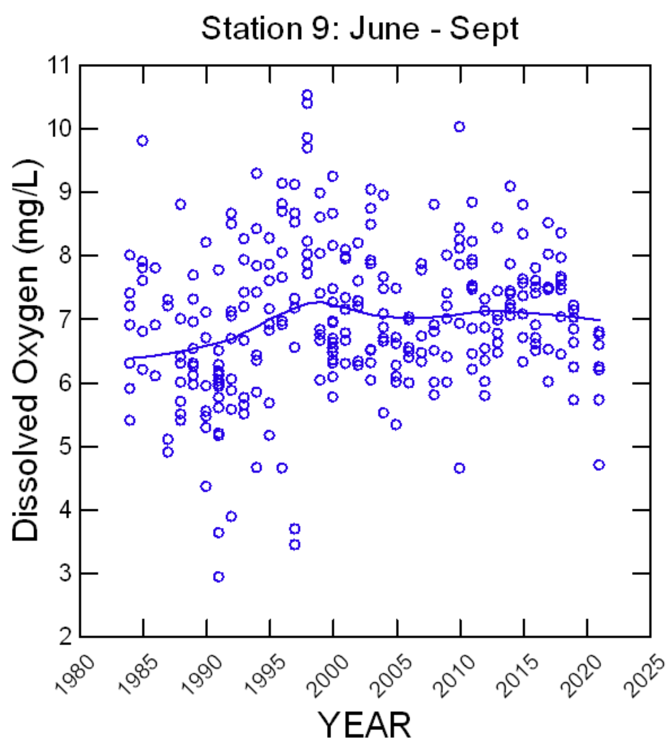

Chloride in the river has been slightly more variable than that in the cove, but in the same general range (Figure 84). The higher readings are again due to brackish water intrusions in dry years. A slight trend of increasing values in the 1980's followed by decreases in the 1990's and increases since 2005 was suggested by the LOWESS trend line. However, temporal linear regression analysis was not statistically significant (Table 18).

Figure 84. Long term trend in Chloride (Fairfax County Lab Data). Station 9. River mainstem.



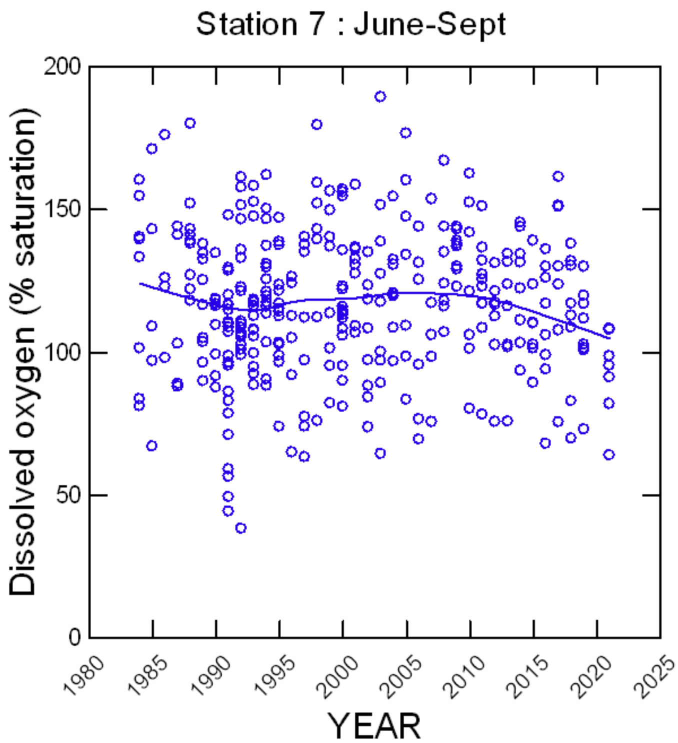

Dissolved oxygen in the cove has generally been in the range 7-13 mg/L during the summer months (Figure 85). A slight downward trend was observed through 1990, but since then the trend line has flattened, suggesting little consistent change and a mean of about 9 mg/L. In the cove dissolved oxygen (mg/L) exhibited a marginally significant downward trend -0.02 mg/L/yr (Table 17).

Figure 85. Long term trend in Dissolved Oxygen, mg/L (GMU Data). Station 7. Gunston Cove.



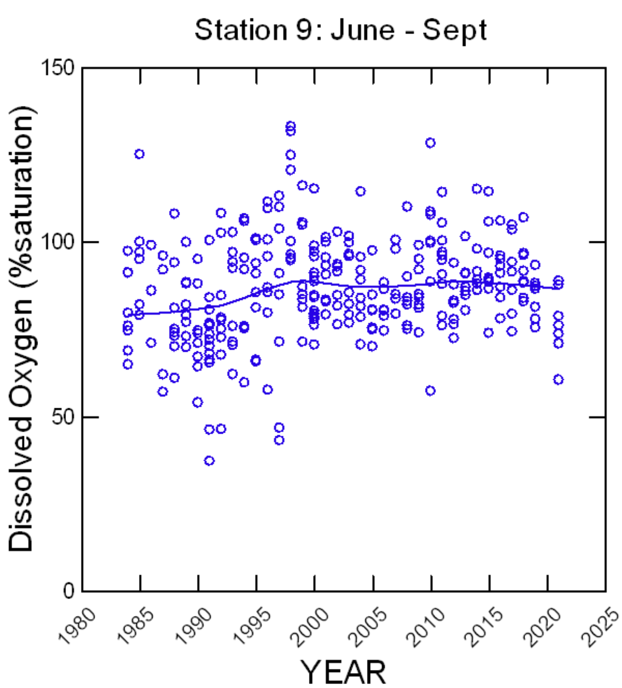

In the river dissolved oxygen values generally were in the range 5-9 mg/L over the long term study period (Figure 86). The LOWESS trend line some subtle changes from year to year, but little consistent pattern. The linear regression analysis over the entire period indicated a significant positive trend with slope of 0.02 mg/L per year or 0.72 mg/L over the period of record (Table 17).

Figure 86. Long term trend in Dissolved Oxygen, mg/L (GMU Data). Station 9. River mainstem.



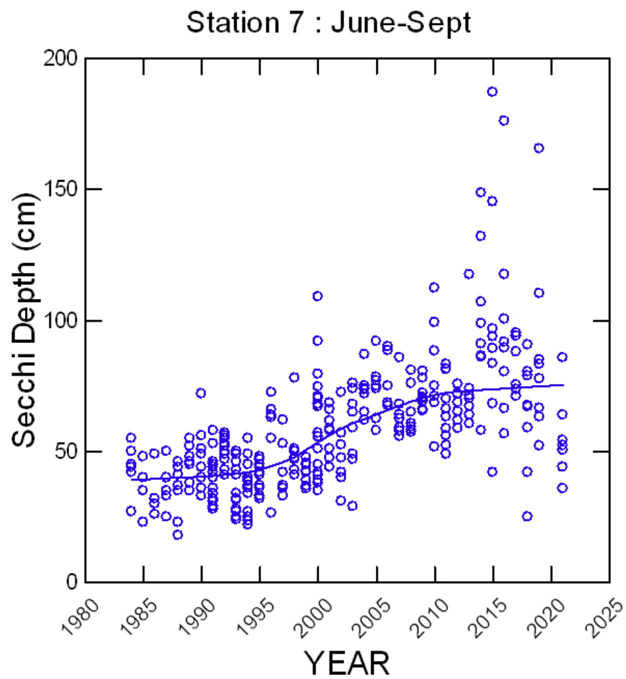

Dissolved oxygen was generally in the range 100-150% saturation in the cove over the long-term study period indicating the importance of photosynthesis in the cove (Figure 87). A decline was indicated by the trend line through 1990 followed by a slight recovery in subsequent years. Recently it has started to decrease again. Percent saturation DO did not exhibit a significant linear trend over the long-term study period (Table 17). 2021 values were generally below the trend line at less than 100% saturation.

Figure 87. Long term trend in Dissolved Oxygen, % saturation (GMU Data). Station 7. Gunston Cove.



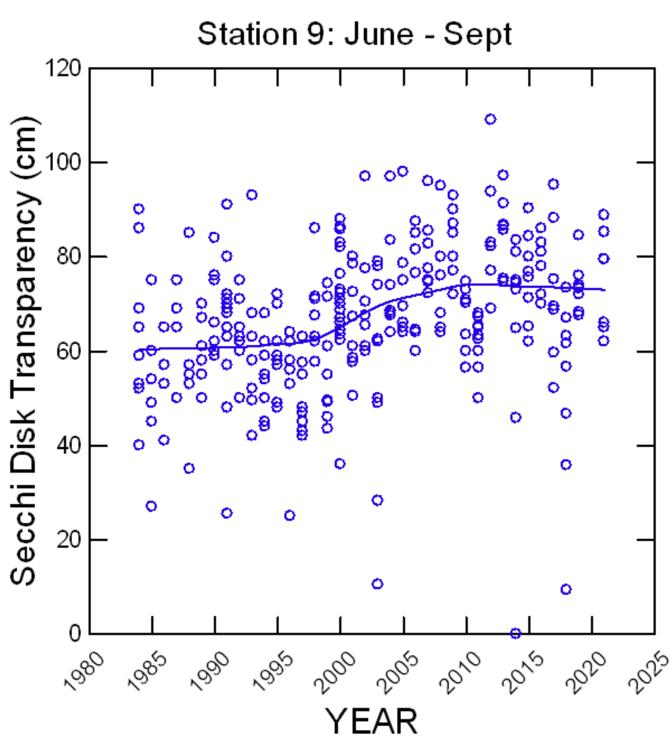

In the river dissolved oxygen was generally less than 100% indicating that photosynthesis was much less important in the river than in the cove and that respiration dominated (Figure 88). The trend line showed a very gradual increase which was statistically significant as indicated by regression analysis with a slope of 0.20% per year or about 11% over the course of the study (Table 17). 2021 readings were generally below the trend line. Despite this increase river DO was still below cove DO in general.

Figure 88. Long term trend in Dissolved Oxygen, % saturation (GMU Data). Station 9. River Mainstem.



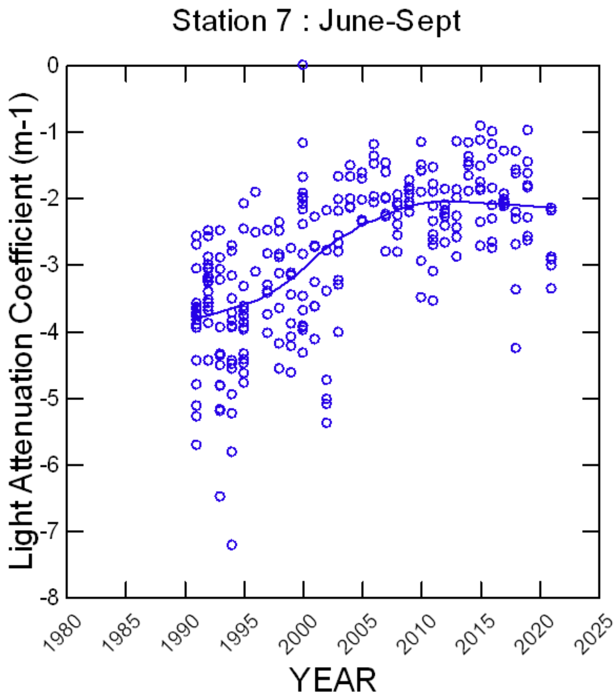

Secchi disk transparency is a measure of water clarity. Secchi disk was fairly constant from 1984 through 1995 with the trend line at about 40 cm (Figure 89). Since 1995 there has been a steady increase in the trend line from 40 cm to 80 cm in 2021. Linear regression was highly significant with a predicted increase of 1.6 cm per year or a increase of 61 cm over the study period (Table 17).

Figure 89. Long term trend in Secchi Disk Transparency (GMU Data). Station 7. Gunston Cove.



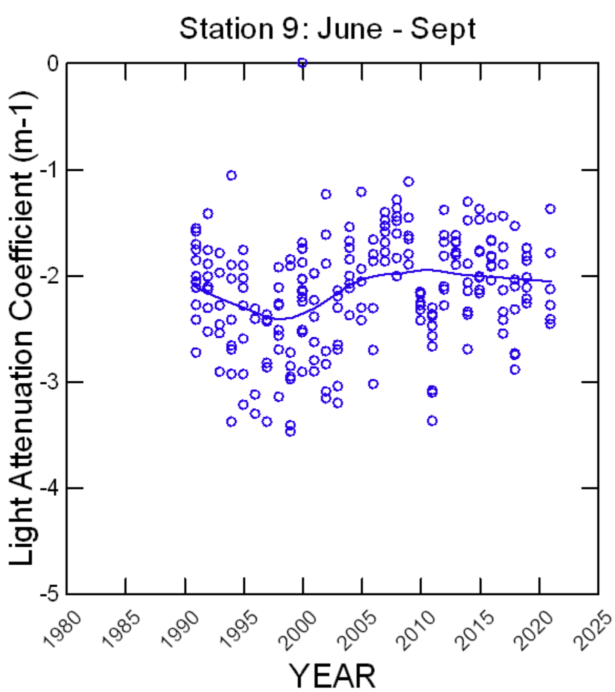

In the river Secchi depth was somewhat greater than in the cove in the 1980's (Figure 90). The trend line was fairly constant at about 60 cm until about 2000. A rise to about 75 cm was observed by 2005 where it has remained. Linear regression revealed a significant increase of 0.46 cm per year with total increase of 17 cm predicted over of the study period (Table 17). Observations in 2021 were near the trend line.

Figure 90. Long term trend in Secchi Disk Transparency (GMU Data). Station 9. River mainstem.



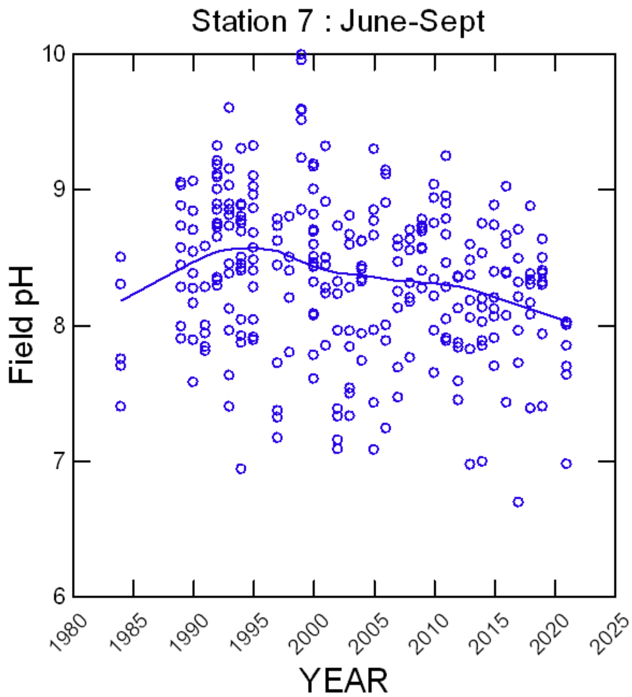

Light attenuation coefficient, another measure of water clarity, reinforces the conclusion that water clarity has been improving in the cove since 1995 (Figure 91). Trend line for the coefficient rose from about -4 to -2 $m^{-1}$ during this time. Regression analysis revealed a significant linear increase in light attenuation coefficient over the period 1991-2021 with a slope of 0.076 per year yielding a prediction that light attenuation improved by about 2.3 units over this period (Table 17).

Figure 91. Long term trend in Light Attenuation Coefficient (GMU Data). Station 7. Gunston Cove.



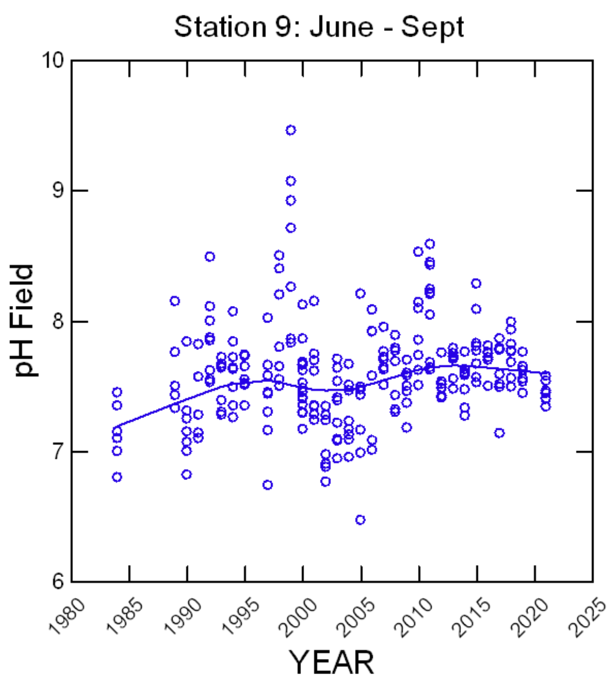

In the river light attenuation coefficient suggested a decline in light transparency between 1991 and 1997 followed by an increase through about 2008 (Figure 92). Between 2008 and 2021 the trend line indicates that light transparency has held fairly constant. Regression did not produce a significant slope over the period (Table 17).

Figure 92. Long term trend in Light Attenuation Coefficient (GMU Data). Station 9. River mainstem.



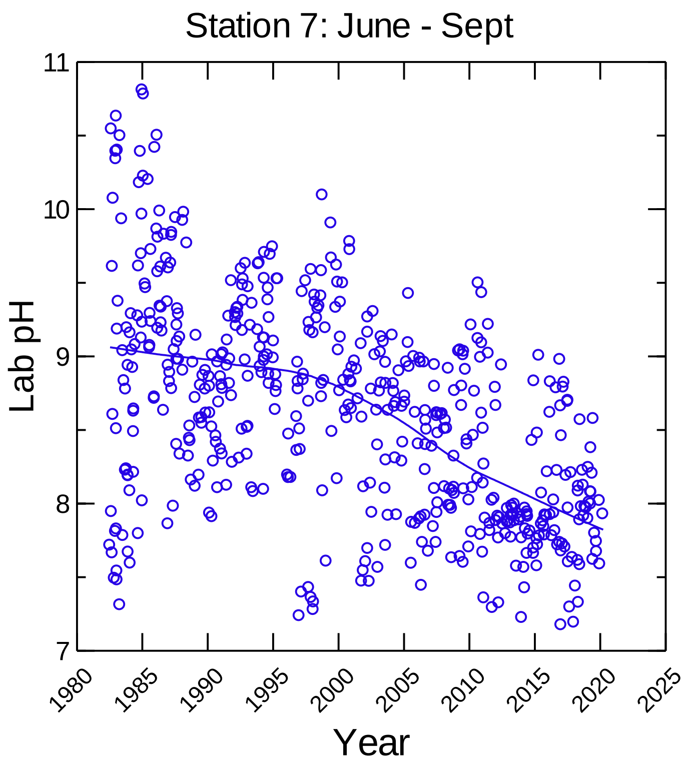

Field pH has not been measured as consistently over the entire study period as other parameters. Cove values have generally been in the 8-9 range. There is a clear trend of decreasing values since 1995 (Figure 93). Linear regression analysis now gives some evidence of a declining linear trend with a slope of -0.014 units per year when the entire study period was considered (Table 17).

Figure 93. Long term trend in Field pH (GMU Data). Station 7. Gunston Cove.



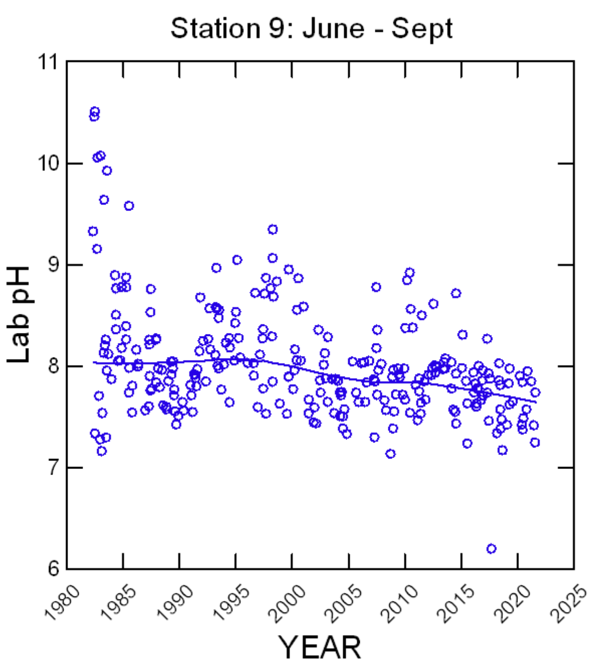

In the river a different pattern has been observed over this period (Figure 94). pH in the river has been consistently lower by about 1 pH unit than in the cove. If anything, the trend line has shown a tendency to increase. When all years were considered, field pH in the river shows a significant increase at a rate of 0.007 units per year (Table 17).

Figure 94. Long term trend in Field pH (GMU Data). Station 9. River mainstem.



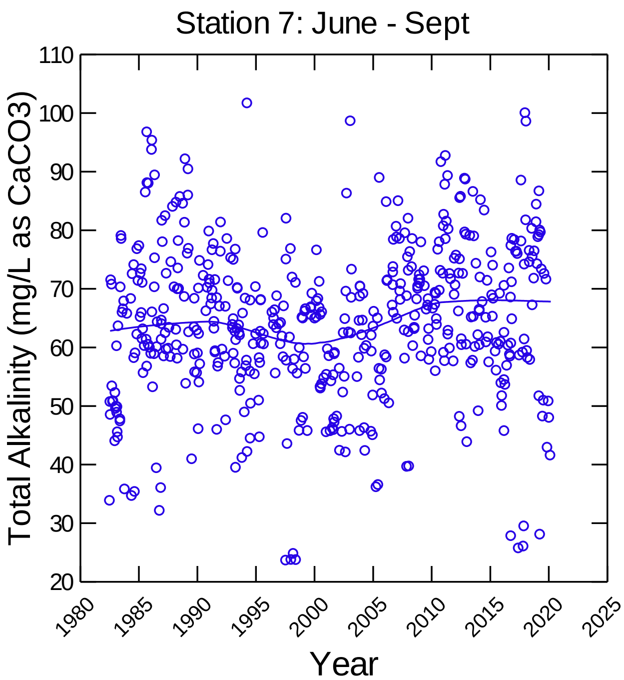

Lab pH as measured by Fairfax County personnel has shown a clear decline, especially since 2000 (Figure 95) with the trend line decreasing from about 9.0 to about 7.8. Linear regression indicates a significant decline in lab pH over the study period at a rate of about 0.035 pH units per year or a total of 1.3 units over the study period (Table 18). 2021 data were generally near the trend line.

Figure 95. Long term trend in Lab pH (Fairfax County Lab Data). Station 7. Gunston Cove.



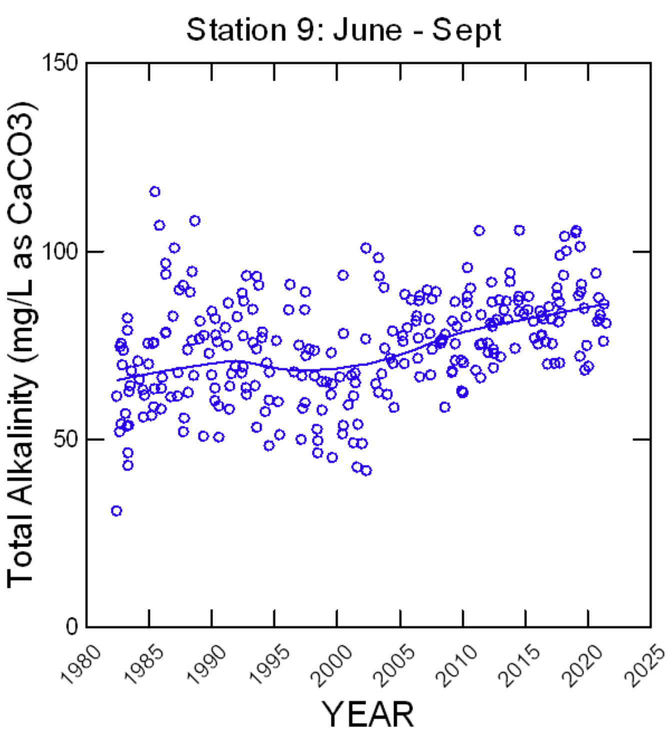

In the river, long term pH trends as measured by Fairfax County lab personnel indicate that most values fell between 7.2 and 8.2 (Figure 96). The trend line has increased and decreased slightly over the years. pH in the river showed a significant linear decline with a rate of 0.017 per year yielding a total decline of 0.65 units over the long-term study period (Table 18).

Figure 96. Long term trend in Lab pH (Fairfax County Lab Data). Station 9. Potomac mainstem.



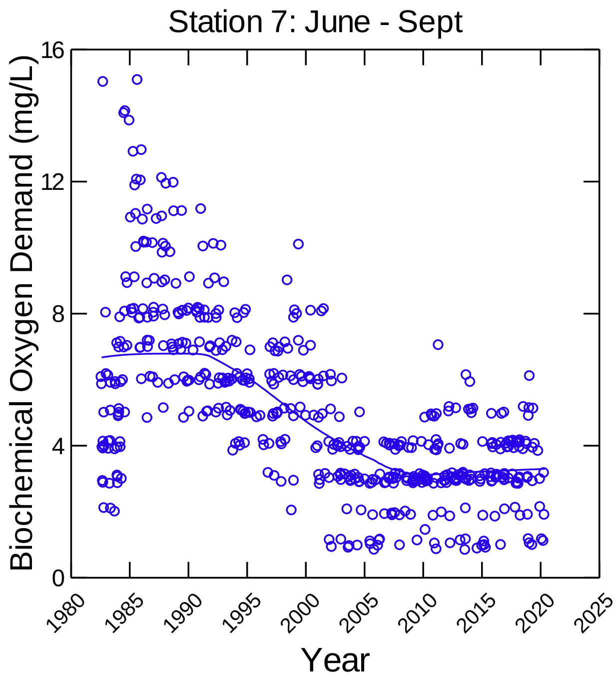

Total alkalinity as measured by Fairfax County personnel exhibited little variation early on, a slow increase until 2010 and little change since (Figure 97). The trend line at 2021 was slightly higher than it was in 1983. Overall, a very weak statistically significant linear trend has developed in total alkalinity in the cove over this period with a slope of 0.11 mg/L per year yielding a projected increase of about 4.2 mg/L over the entire study period (Table 18).

Figure 97. Long term trend in Total Alkalinity (Fairfax County Lab Data). Station 7. Gunston Cove.



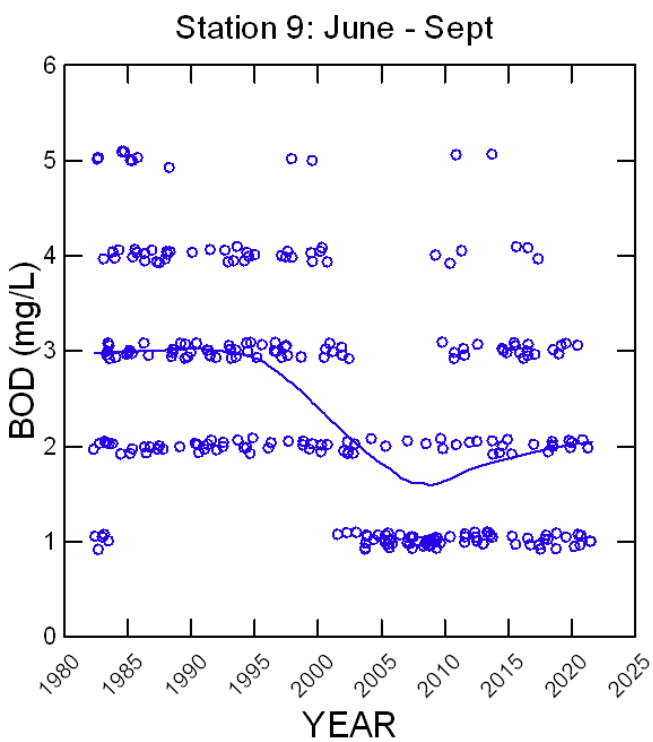

In the river a similar pattern has been observed over the three decades with an even clearer recent increase (Figure 98). There is a significant linear trend over the period with a slope of 0.46 mg/L suggesting a modest increase of about 17 mg/L over the entire study period (Table 18).

Figure 98. Long term trend in Total Alkalinity (Fairfax County Lab Data). Station 9. Potomac mainstem.



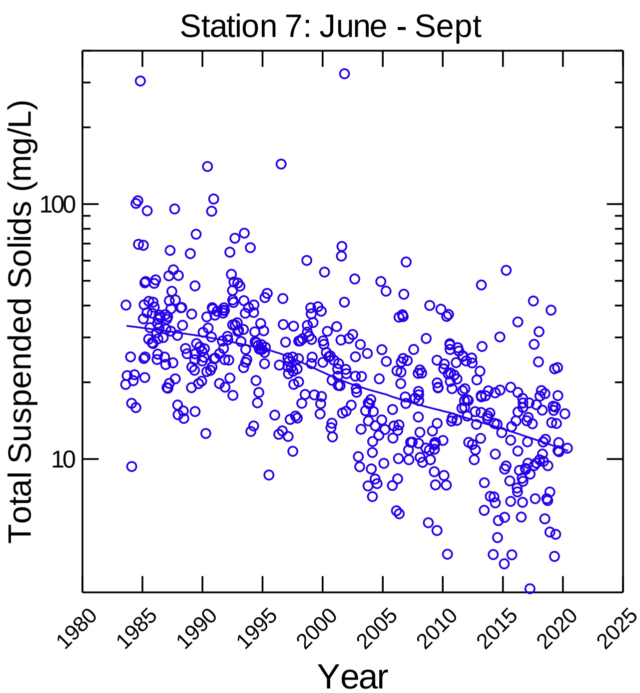

Biochemical oxygen demand has shown a distinct pattern over the long-term study period in Gunston Cove (Figure 99). In the 1980's the trend line rose from about 6 mg/L to 7 mg/L by 1989. Since then there has been a steady decline such that the trend line has dropped back to about 3 mg/L. BOD has shown a significant linear decline over the entire study period at a rate of 0.14 mg/L per year yielding a net decline of about 5.3 mg/L over the entire period of record (Table 18). It is difficult to tell if the decline is continuing as many readings are now below the detection limit.

Figure 99. Long term trend in Biochemical Oxygen Demand (Fairfax County Lab Data). Station 7. Gunston Cove.



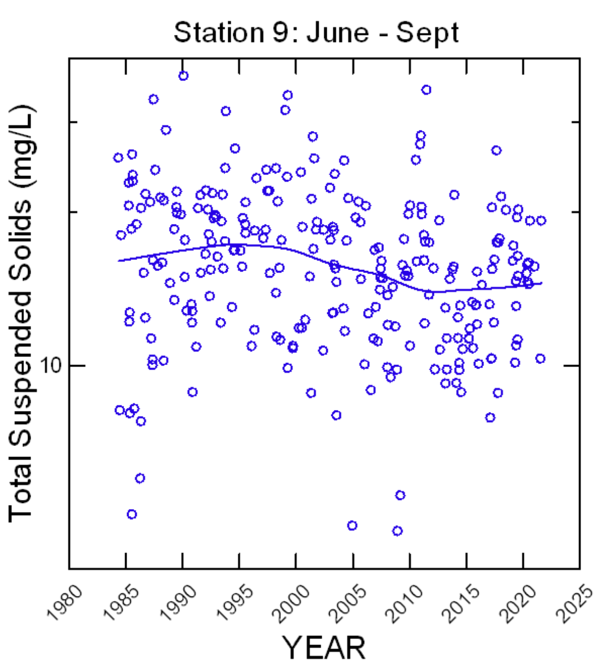

In the river biochemical oxygen demand exhibited a less distinct pattern through the mid 1990's (Figure 100). However, since that time it has decreased somewhat to a trend line value of about 2.0 mg/L. BOD in the river has exhibited a significant linear decrease at a rate of 0.04 units when the entire period of record was considered (Table 18). This would project to an overall decrease of 1.5 units. Many values now are non- detects of less than 2 mg/L making trends difficulty to examine.

Figure 100. Long term trend in Biochemical Oxygen Demand (Fairfax County Lab Data). Station 9. Potomac mainstem.



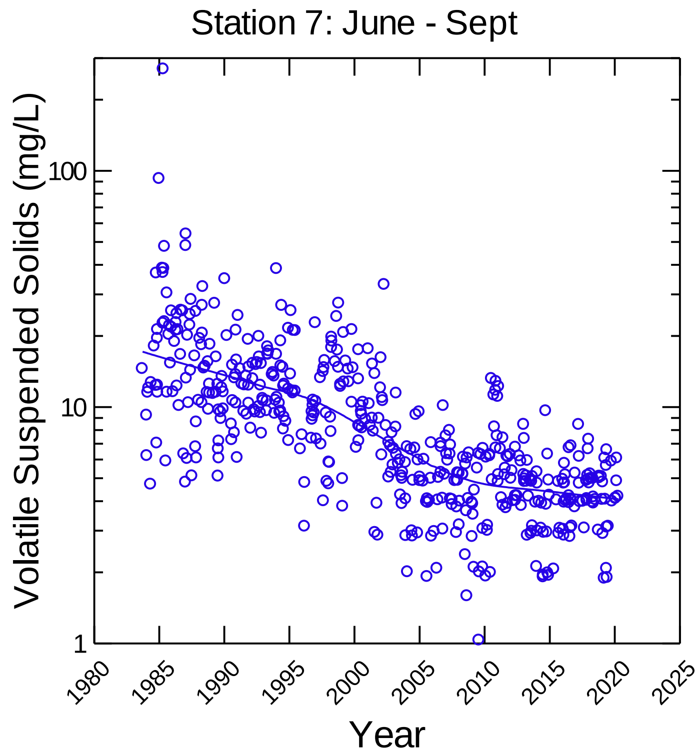

Total suspended solids (TSS) has shown a great deal of variability over the long-term study period. Nonetheless, a decreasing trend in TSS is clear in the cove with the trend line decreasing from about 32 mg/L in 1983 to about 10 mg/L in 2021 (Figure 101). Linear regression was significant indicating a decline of 0.82 mg/L per year yielding a total decline of 31 mg/L since 1984 (Table 18). Most readings in 2021 were near the trend line.

Figure 101. Long term trend in Total Suspended Solids (Fairfax County Lab Data). Station 7. Gunston Cove.



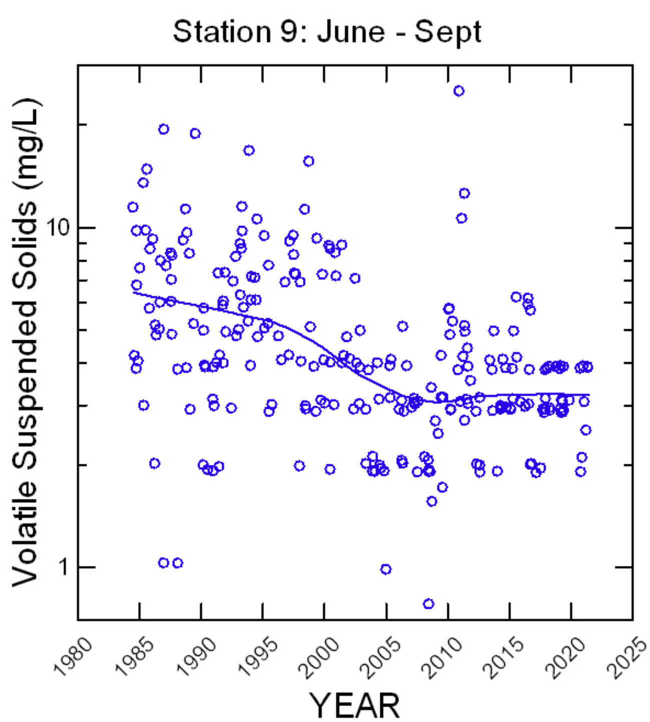

In the river TSS trends have not been as apparent (Figure 102). While much higher values have been observed sporadically, the LOWESS line remained steady at about 18-20 mg/L through most of the period with a slight decrease to about 15 mg/L suggested recently. In the river TSS exhibited a significant linear decline over the period of record at a rate of about 0.10 units per year yielding a total decline of about 3.8 mg/L over the entire study period (Table 18).

Figure 102. Long term trend in Total Suspended Solids (Fairfax County Lab Data). Station 9. Potomac mainstem.



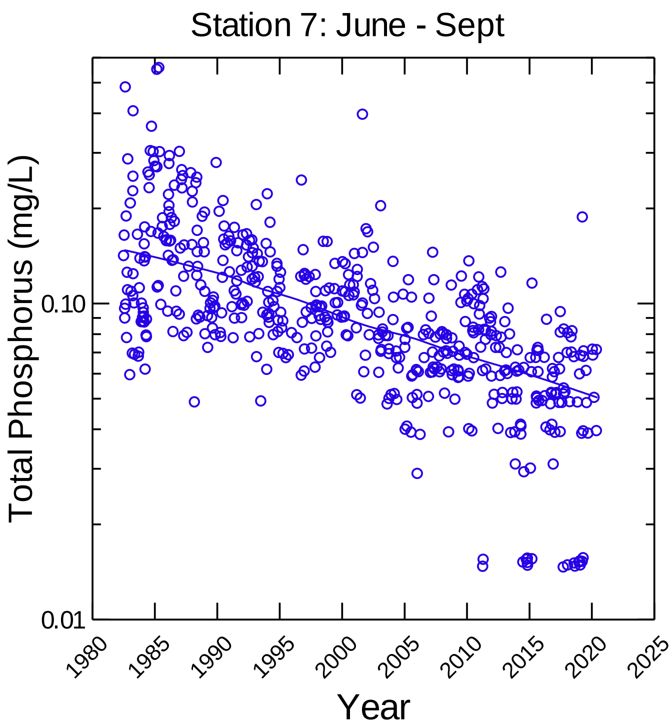

Volatile suspended solids have consistently declined over the study period in the cove (Figure 103). The LOWESS trend line has declined from 20 mg/L in 1984 to about 4 mg/L in 2021. VSS has demonstrated a significant linear decline at a rate of 0.52 mg/L per year or a total of 20 mg/L over the study period (Table 18).

Figure 103. Long term trend in Volatile Suspended Solids (Fairfax County Lab Data). Station 7. Gunston Cove.



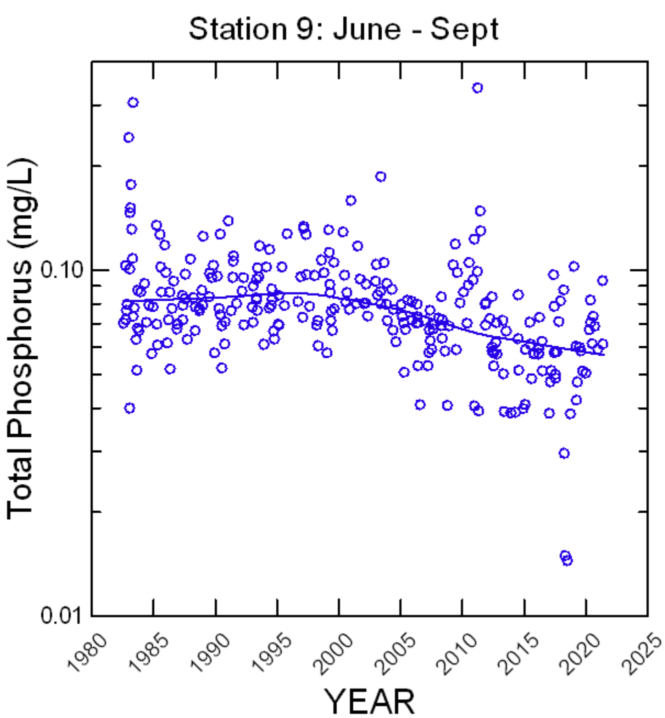

In the river the trend line for volatile suspended solids (VSS) was steady from 1984 through the mid 1990's, but decreased from 1995 to 2005. Trend line values of about 7 mg/L in 1984 dropped to about 3.5 mg/L by 2021 (Figure 104). VSS in the river demonstrated a significant linear decline at a rate of 0.12 mg/L per year or 4.2 mg/L since 1984 (Table 18).

Figure 104. Long term trend in Volatile Suspended Solids (Fairfax County Lab Data). Station 9. Potomac mainstem.



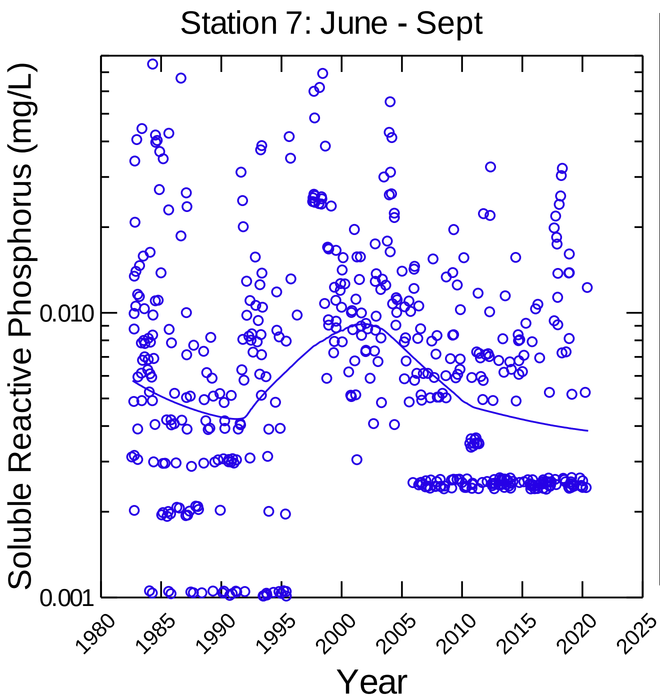

In the cove, total phosphorus (TP) has undergone a consistent steady decline since the late 1980's (Figure 105). By 2021 the trend line had dropped to 0.05 mg/L, less than half of the starting level. Linear regression over the entire period of record indicated a significant linear decline of -0.003 mg/L per year or 0.11 mg/L over the entire study period (Table 18).

Figure 105. Long term trend in Total Phosphorus (Fairfax County Lab Data). Station 7. Gunston Cove.



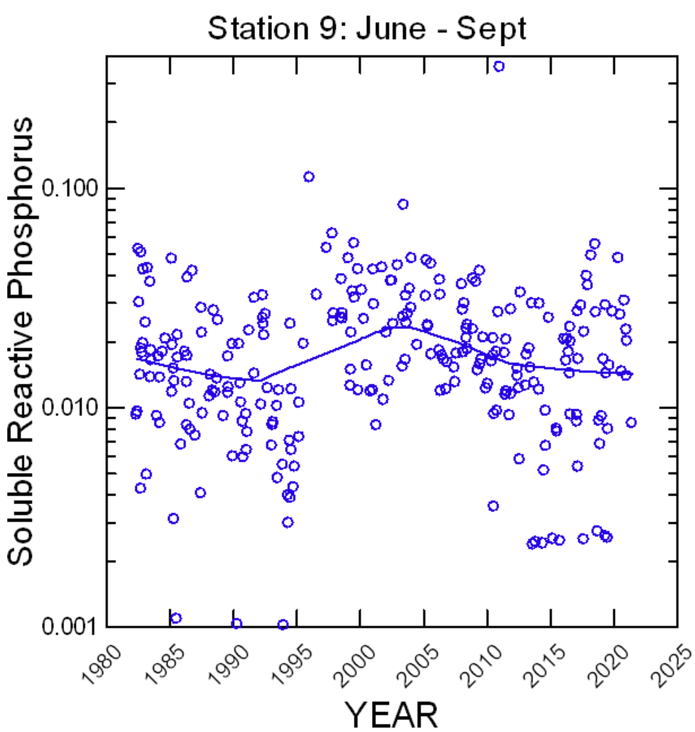

Total phosphorus (TP) values in the river have shown less of a trend over time (Figure 106). Values were steady through about 2000, then declined somewhat. TP exhibited a slight, but significant linear decrease in the river over the long-term study period with a very modest slope of -0.001 mg/L per year for a cumulative decrease of 0.04 mg/L over the period (Table 18).

Figure 106. Long term trend in Total Phosphorus (Fairfax County Lab Data). Station 9. Potomac mainstem.



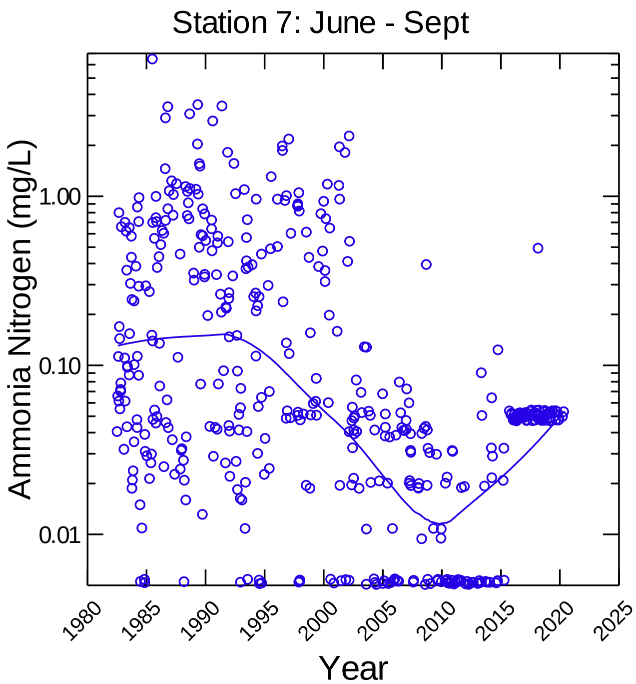

Soluble reactive phosphorus (SRP) declined in the cove during the first few years of the long-term data set, but demonstrated an increase to near its initial level by 2000 (Figure 107). Since then a decline has ensued. (Table 18). One possibility is that less SRP is entering the cove water; another is that increased SAV is taking more up. Note also that the detection limit has changed and that many readings are at the detection limit making trend analysis difficult and uncertain.

Figure 107. Long term trend in Soluble Reactive Phosphorus (Fairfax County Lab Data). Station 7. Gunston Cove.



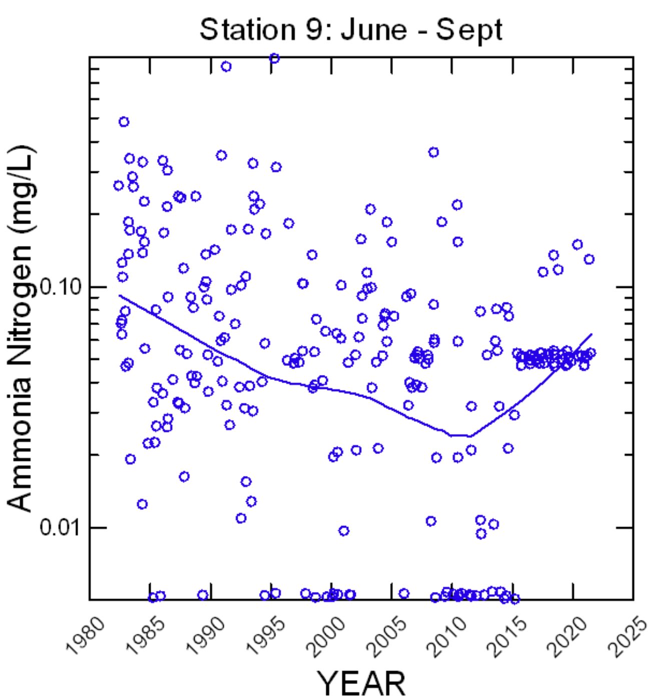

Soluble reactive phosphorus (SRP) in the river has generally been present at higher levels than in the cove, but has undergone a similar decline-resurgence-decline (Figure 108). Linear regression was not significant (Table 18). There were a significant number of non-detect values, but fewer than in the cove.

Figure 108. Long term trend in Soluble Reactive Phosphorus (Fairfax County Lab Data). Station 9. Potomac mainstem.



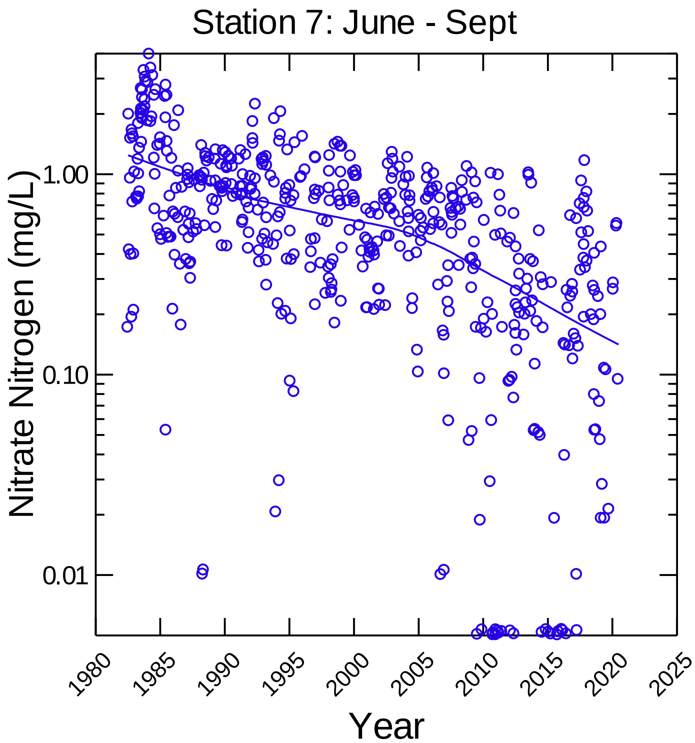

Ammonia nitrogen levels were very variable over the long term study period in the cove, but a trend of decreasing values is evident from the LOWESS trend line (Figure 109). Since 1989 the trend line has decreased from about 0.2 mg/L to about 0.02 mg/L. Linear regression has revealed a significant decline over the entire period of record with a rate of 0.015 mg/L per year yielding a total decline of 0.58 mg/L (Table 18). Note the increase in values below the detection limit over time (clustered at bottom of graph) and then, more recently, an increase in the detection limit to such a level that it is no longer possible to track trends.

Figure 109. Long term trend in Ammonia Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



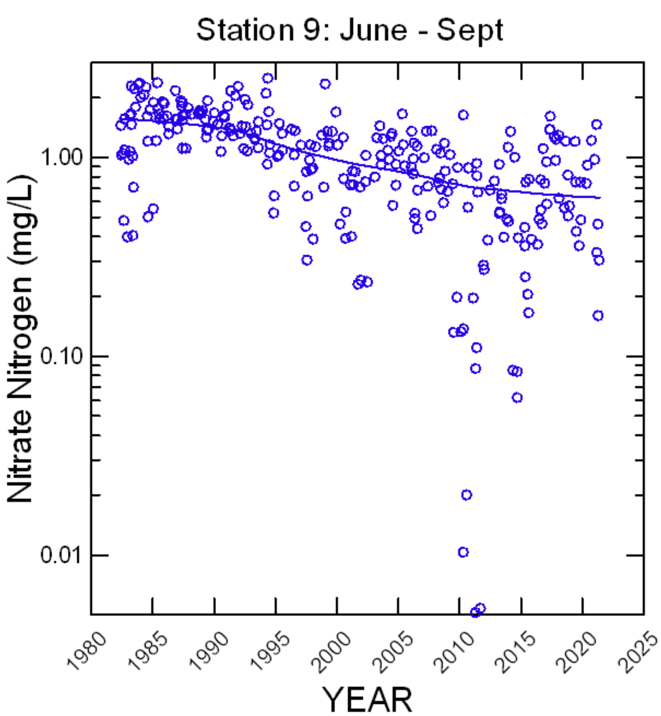

In the river a decreasing trend in ammonia nitrogen has also been observed over most of the study period (Figure 110). Between 1983 and 1999 the trend line dropped from 0.1 mg/L to 0.04 mg/L. Since 1999 it has continued to decline and is now at about 0.02 mg/L. Overall, in the river ammonia nitrogen has demonstrated a significant decline over the study period at a rate of 0.002 mg/L per year or a total of 0.07 over the study period (Table 18). Again, the number of non-detects is increasing and making it impossible to track future trends.

Figure 110. Long term trend in Ammonia Nitrogen (Fairfax County Lab Data). Station 9. Potomac mainstem.



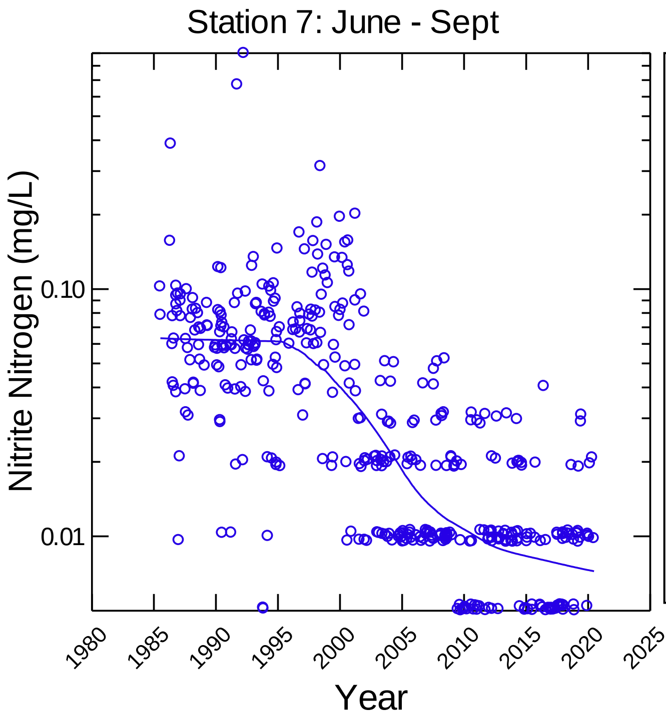

Nitrate nitrogen has demonstrated a steady decline in the cove over the entire period of record (Figure 111). The trend line was at about 1 mg/L in 1983 and by 2021 was below 0.15 mg/L. Linear regression suggested a decline rate of 0.030 mg/L per year yielding a total decline of 1.1 mg/L over the long-term study period (Table 18).

Figure 111. Long term trend in Nitrate Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



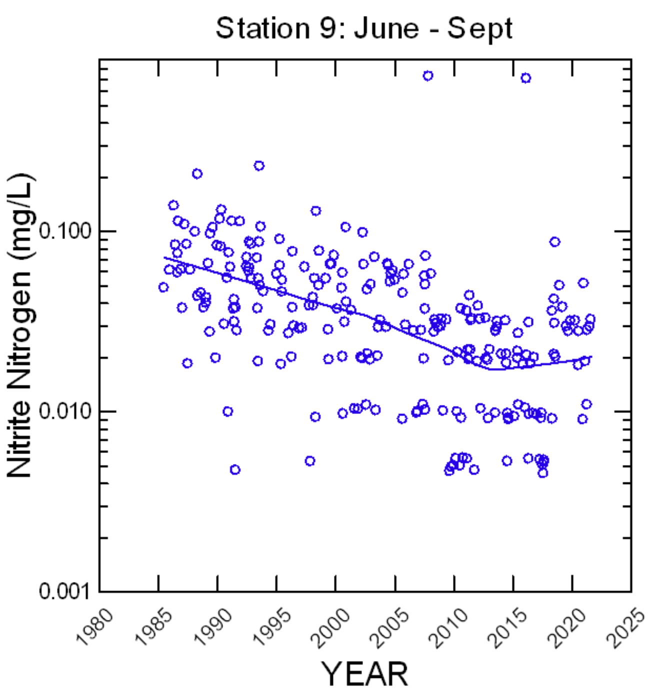

In the river nitrate nitrogen has declined steadily since about 1985 (Figure 112). The trend line dropped from 1.5 mg/L in the mid 1980's to 0.6 mg/L in 2020. Linear regression indicated a rate of decline of 0.029 mg/L per yr which would yielded a 1.1 mg/L decrease in nitrate nitrogen over the study period (Table 18).

Figure 112. Long term trend in Nitrate Nitrogen (Fairfax County Lab Data). Station 9. River mainstem.



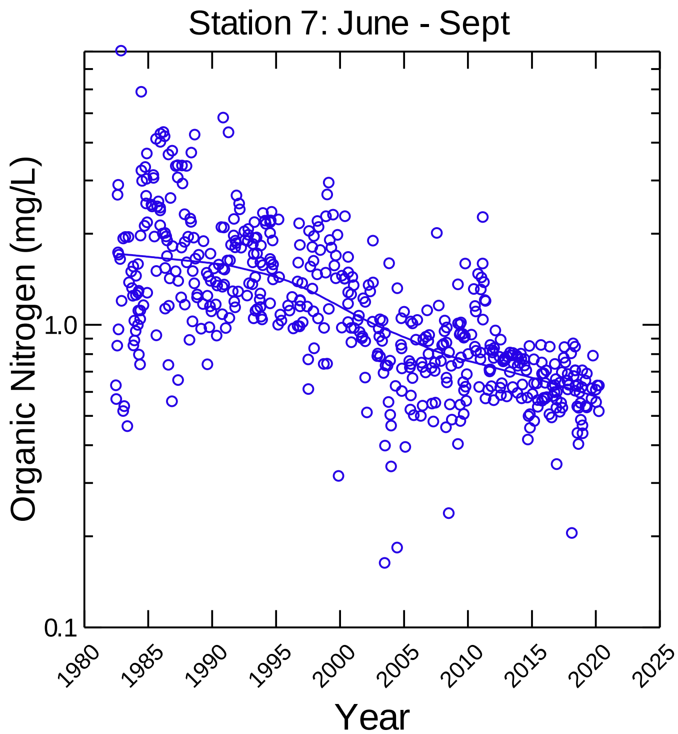

The trend line for nitrite nitrogen indicated steady values at about 0.06-0.07 mg/L through 1999 (Figure 113). Since then there is clear evidence for a decline with the LOWESS line dropping below 0.01 in 2013. Linear regression revealed a significant decline with a slope of 0.003 mg/L per year when the entire period of record was considered (Table 18). Most values in recent years have been at or below the detection limits.

Figure 113. Long term trend in Nitrite Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



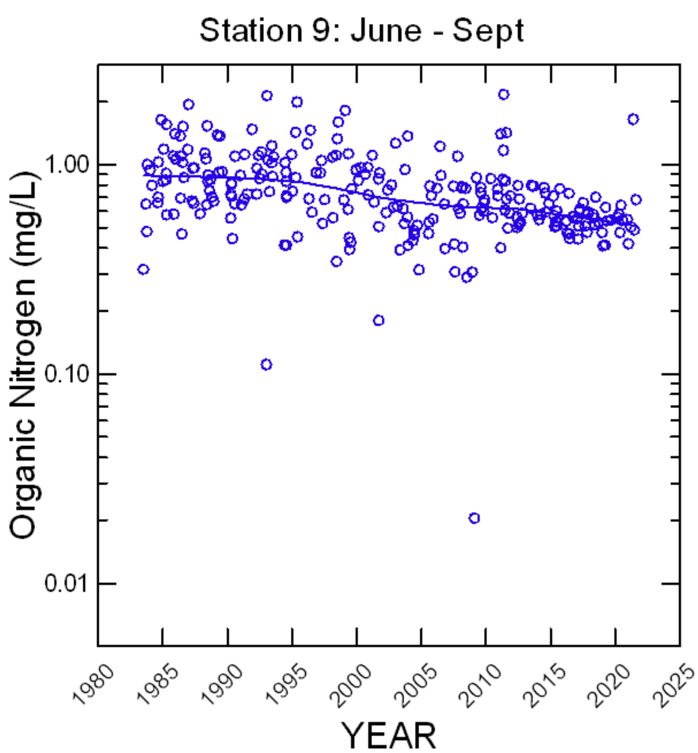

Nitrite nitrogen in the river demonstrated a pattern of decrease during the long term study period (Figure 114). The LOWESS line dropped from 0.07 mg/L in 1986 to less than 0.01 mg/L in 2018. Linear regression indicated a significant linear decline at a rate of 0.001 mg/L per year or 0.04 mg/L over the study period (Table 18).

Figure 114. Long term trend in Nitrite Nitrogen (Fairfax County Lab Data). Station 9. Potomac mainstem.



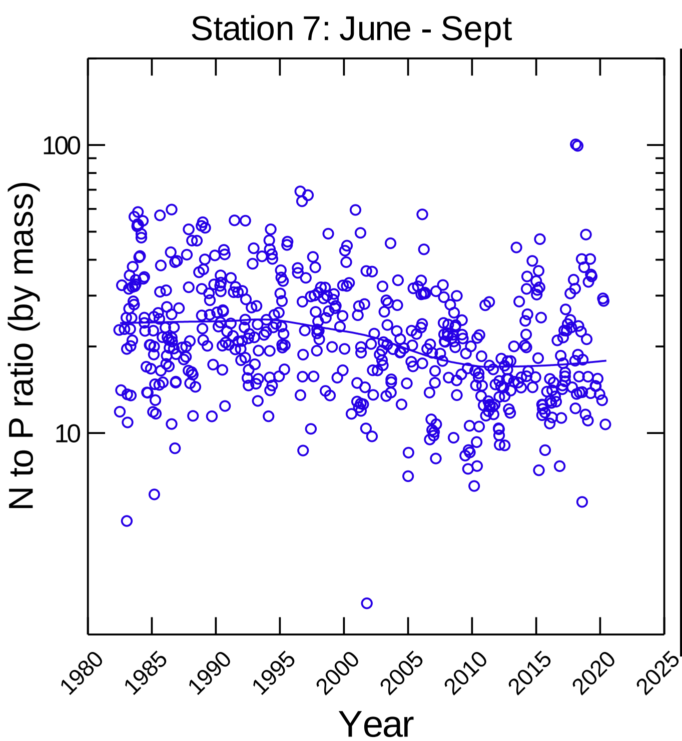

Organic nitrogen in the cove was fairly high in the 1980's and has since undergone a consistent decline through 2021 (Figure 115). In 1983 the trend line was at 1.5 mg/L and dropped below 0.6 mg/L by 2021. Regression analysis indicated a significant decline over the study period at a rate of about 0.043 mg/L per year or a total of 1.6 mg/L over the whole study period (Table 18).

Figure 115. Long term trend in Organic Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



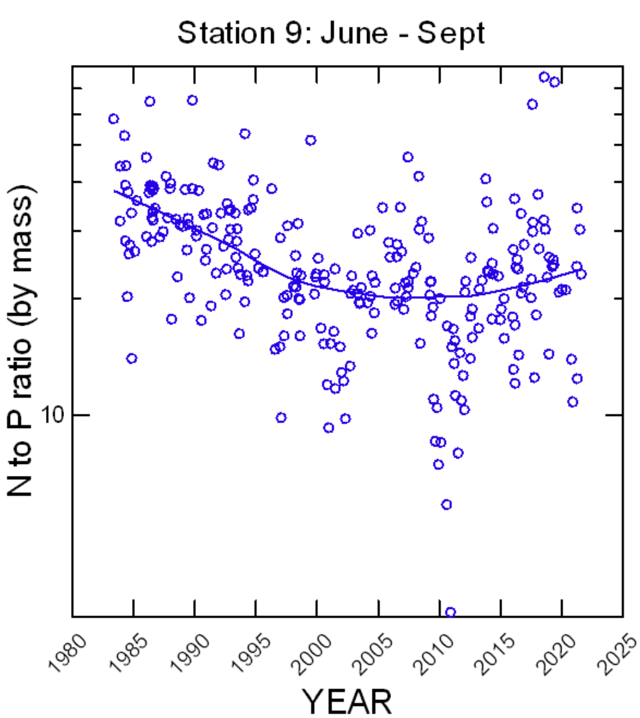

In the river organic nitrogen was steady from 1984 through 1995 and since then has shown perhaps a modest decline (Figure 116). The LOWESS line peaked at about 0.9 mg/L and has dropped to about 0.6 mg/L. Regression analysis indicated a significant linear decline at a rate of 0.01 mg/L when the entire period of record was considered for a total decline of 0.4 mg/L (Table 18).

Figure 116. Long term trend in Organic Nitrogen (Fairfax County Lab Data). Station 9. River mainstem.




Nitrogen to phosphorus ratio (N/P ratio) in the cove exhibited large variability, but the trend line was flat until about 1995. Since then, there has been a clear decline with the LOWESS line approaching 18 by 2021 (Figure 117). Regression analysis over the period of record indicates a statistically significant decline at a rate of 0.27 per year or about 10 units over the entire period (Table 18). This ratio is calculated using nitrate, TKN, and TP values and is less accurate when any of those are below detection limits.

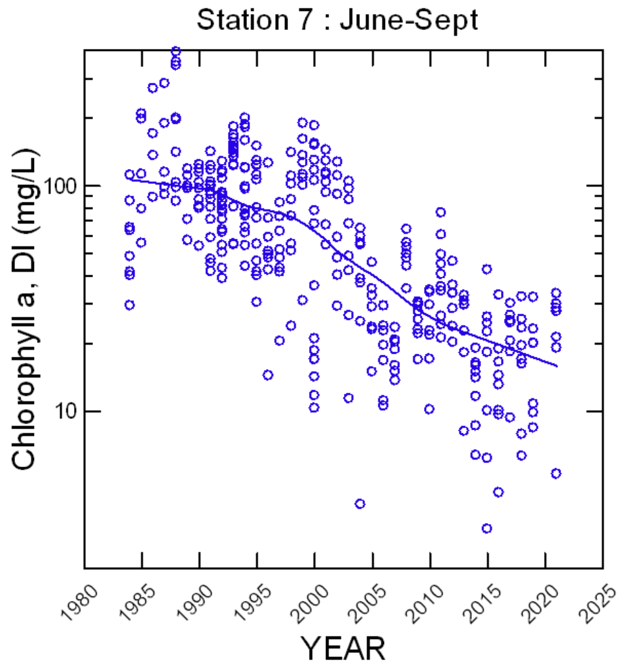
Figure 117. Long term trend in N to P Ratio (Fairfax County Lab Data). Station 7. Gunston Cove.




Nitrogen to phosphorus ratio in the river exhibited a strong continuous decline through about 2000 and has declined more slowly since then (Figure 118). The LOWESS trend line declined from about 35 in 1984 to 20 in 2010 before rising in the last decade. Linear regression analysis confirmed this decline and suggested a rate of 0.34 units per year or a total of 12 units over the long term study period (Table 18).

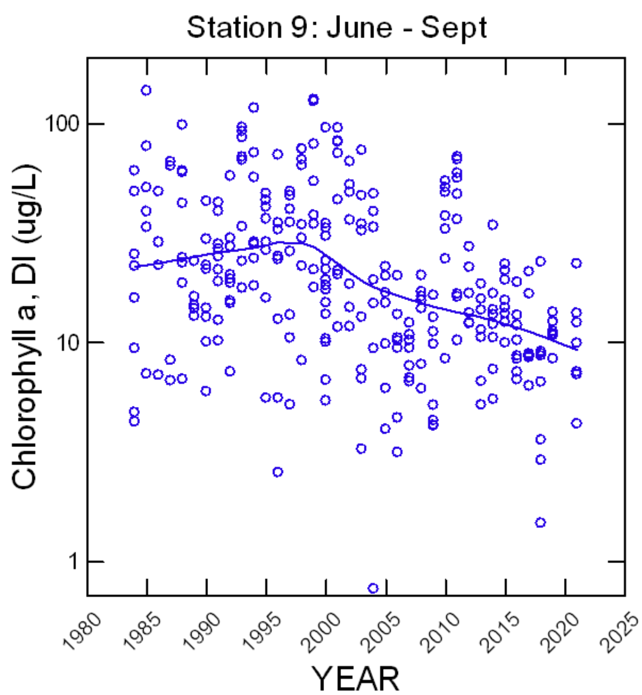
Figure 118. Long term trend in N to P Ratio (Fairfax County Lab Data). Station 9. River mainstem.

C. Phytoplankton Trends: 1984-2020



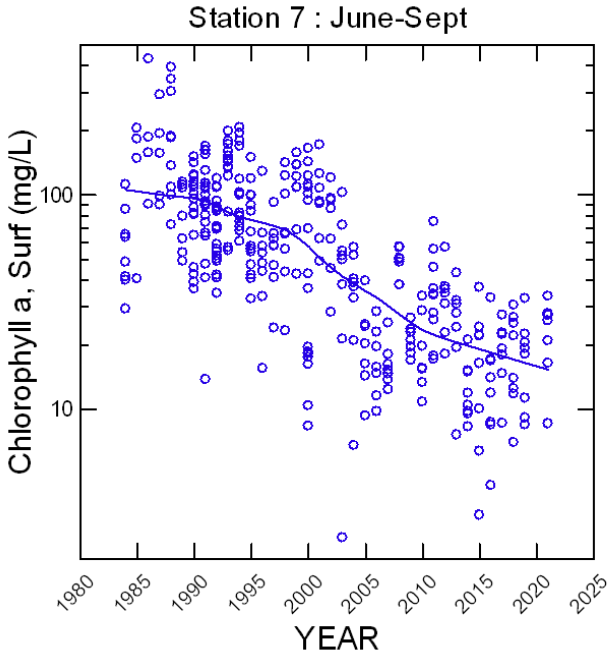

After increasing through much of the 1980's, depth-integrated chlorophyll *a* in the cove demonstrated a gradual decline from 1988 to 2000 and a much stronger decrease since then (Figure 119). The LOWESS line has declined from about 100 µg/L to about 15 µg/L in 2021. The observed decrease has resulted in chlorophyll values within the range of water clarity criteria allowing SAV growth to 0.5 m and 1.0 m (43 µg/L and 11 µg/L, respectively) (CBP 2006). This would imply adequate light to support SAV growth over much of Gunston Cove. Regression analysis has revealed a clear linear trend of decreasing values at the rate of 3.5 µg/L per year or 130 µg/L over the 35-year long term data set (Table 17).

Figure 119. Long term trend in Depth-integrated Chlorophyll *a* (GMU Lab Data). Station 7. Gunston Cove.



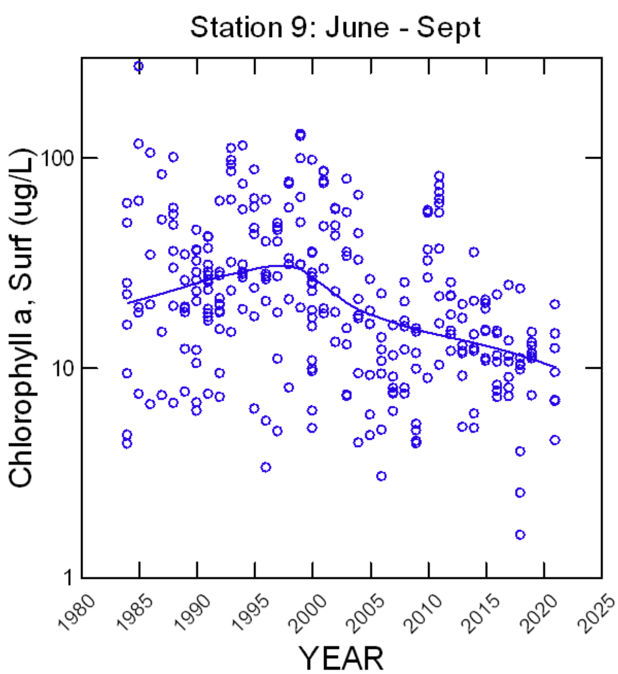

In the river depth-integrated chlorophyll *a* increased gradually through 2000 with the trend line rising from 20 to 30 µg/L (Figure 120). This was followed by a strong decline reaching about 10 µg/L by 2021. Regression analysis revealed a significant linear decline at a rate of 0.78 µg/L/yr when the entire period is considered (Table 17) yielding a total decline of about 30 ug/L.

Figure 120. Long term trend in Depth-integrated Chlorophyll *a* (GMU Lab Data). Station 9. River mainstem.



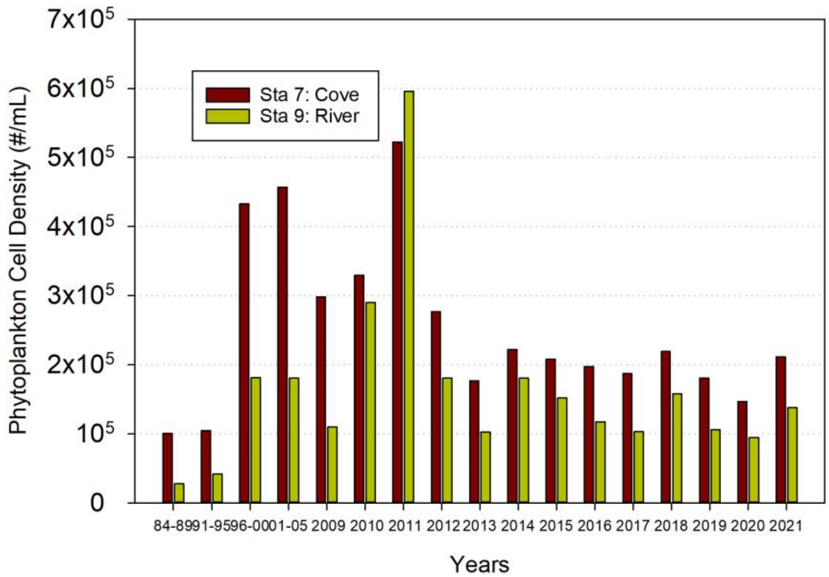

Surface chlorophyll *a* in the cove also exhibited a clear decline over the long-term study period, especially since 2000 (Figure 121). Trend line values of about 100 µg/L in 1988 dropped to about 15 µg/L in 2021. Linear regression confirmed the linear decline and suggested a rate of 3.6 µg/L per year or 130 µg/L over the entire study (Table 17).

Figure 121. Long term trend in Surface Chlorophyll *a* (GMU Data). Station 7. Gunston Cove.



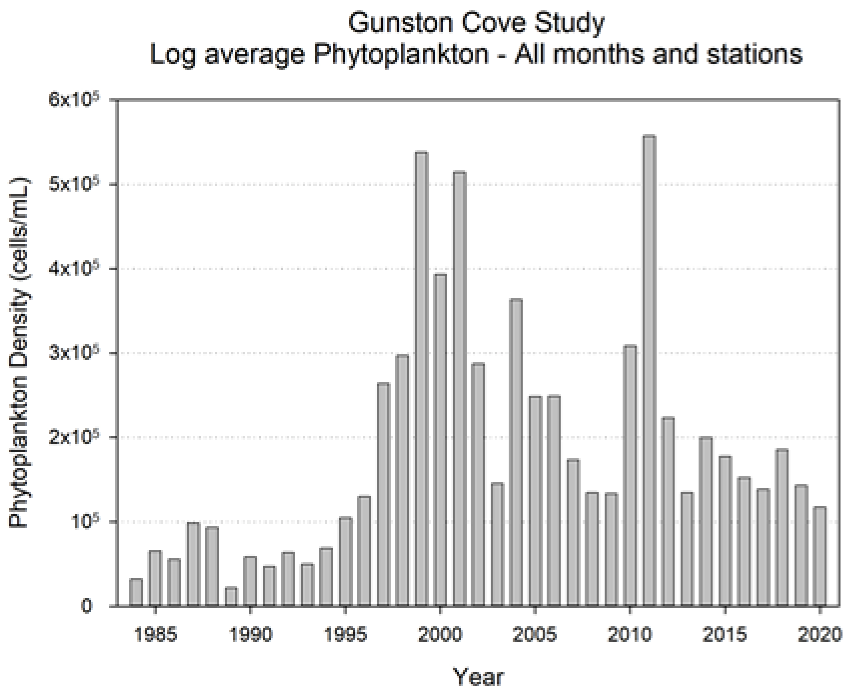

In the river the LOWESS line for surface chlorophyll *a* increased slowly from 1983 to 2000 and then declined markedly through 2021 (Figure 122). Values have stabilized since then at about 10 µg/L. Linear regression revealed a significant decline in surface chlorophyll across this period with a rate of 0.86 µg/L/yr or about 30 µg/L over the whole period (Table 17).

Figure 122. Long term trend in Surface Chlorophyll *a* (GMU Data). Station 9. River mainstem.




Phytoplankton cell density in both the cove and the river in 2021 was similar to values observed since 2012 (Figure 123). While cell density does not incorporate cell size, it does provide some measure of the abundance of phytoplankton and reflects the decrease in phytoplankton in the study area which is expected with lower nutrient loading and should help improve water clarity.

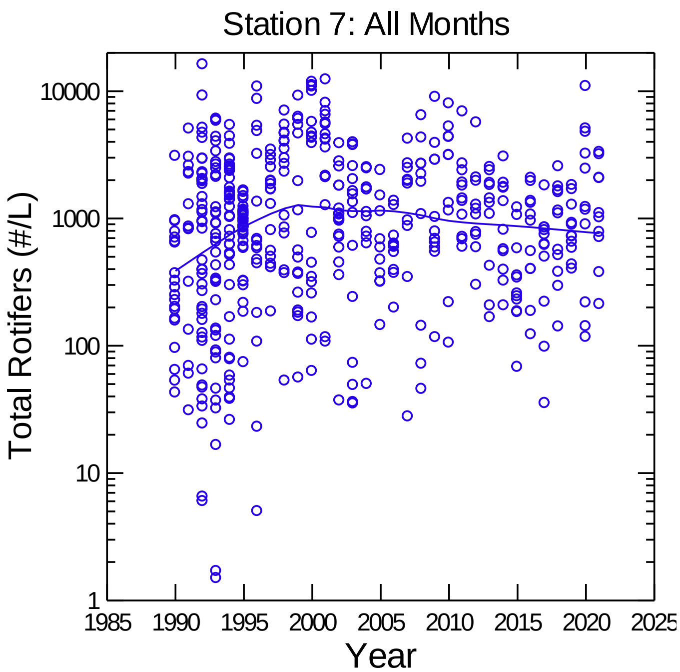
Figure 123. Interannual Comparison of Phytoplankton Density by Region.




By looking at individual years (Figure 124), we see that phytoplankton densities in 2021 remained lower than the high levels observed during the to 2005 and again in 2010-2011 and were among the lowest observed in any year since 1997.

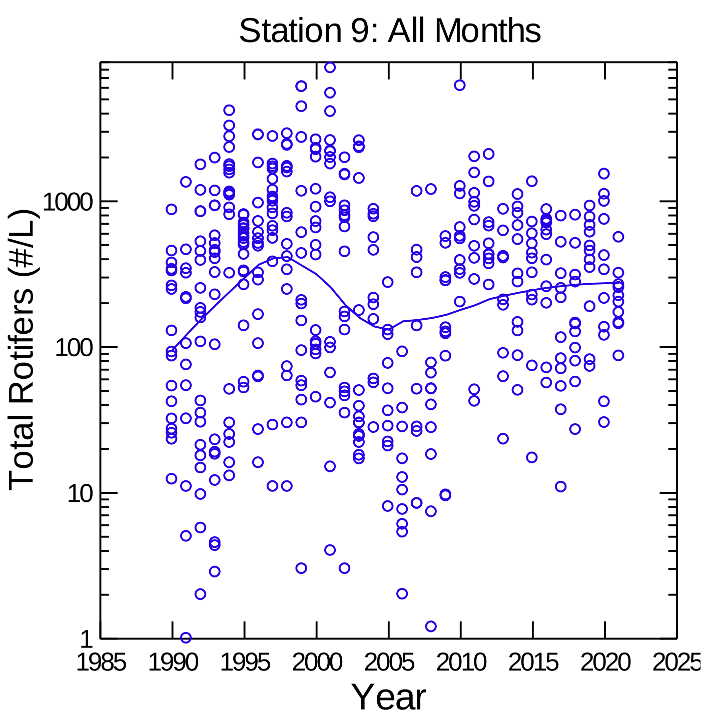
Figure 124. Interannual Trend in Average Phytoplankton Density.

D. Zooplankton Trends: 1990-2021




In the Cove total rotifers have been stable after an initial decade (1990-2000) of steady increase (Figure 125). The LOWESS fit line indicated about 800/L in 2021, up from about 400/L in 1990. Linear regression analysis continued to indicate a statistically significant linear increase in total rotifers over the period since 1990 (Table 19), but it is becoming more tenuous.

Figure 125. Long term trend in Total Rotifers. Station 7. Gunston Cove.




In the Potomac mainstem, rotifers exhibited an initial increase from 1990 to 1998, followed by a decline from 1999 to 2005 and more recently another increase (Figure 126). Trend line values in 1990 were about 80/L and as of 2021 are about 300/L approaching 1998 values. However, when the entire 1990-2018 period was considered, total rotifers did not exhibit a significant linear trend in the river (Table 19).

Figure 126. Long term trend in Total Rotifers. Station 9. River mainstem.

Table 19
Correlation and Linear Regression Coefficients
Zooplankton Parameters vs. Year for 1990-2021
All Nonzero Values Used, All Values Logged to Base 10

| | Station 7 | | | Station 9 | | |
|---|---|---|---|---|---|---|
| Parameter | Corr. Coeff. | Reg. Coeff. | Signif. | Corr. Coeff. | Reg. Coeff. | Signif. |
| *Asplanchna* (m) | 0.059 (351) | --- | NS | 0.058 (214) | --- | NS |
| *Brachionus* (m) | 0.092 (484) | 0.008 | 0.044 | 0.076 (403) | --- | NS |
| Conochilidae (m) | 0.073 (415) | --- | NS | 0.120 (334) | -0.011 | 0.029 |
| *Filinia* (m) | 0.104 (422) | 0.009 | 0.033 | 0.173 (300) | -0.012 | 0.003 |
| *Keratella* (m) | 0.261 (489) | 0.022 | <0.001 | 0.093 (415) | --- | NS |
| *Polyarthra* (m) | 0.090 (462) | 0.008 | 0.052 | 0.008 (384) | --- | NS |
| Total Rotifers (m) | 0.119 (508) | 0.008 | 0.007 | 0.035 (428) | --- | NS |
| | | | | | | |
| *Bosmina* (m) | 0.101 (301) | --- | NS | 0.128 (360) | -0.010 | 0.015 |
| *Diaphanosoma* (M) | 0.257 (405) | -0.035 | <0.001 | 0.250 (311) | -0.028 | <0.001 |
| *Daphnia* (M) | 0.150 (315) | -0.019 | 0.002 | 0.158 (214) | -0.015 | 0.016 |
| *Leptodora* (M) | 0.319 (243) | -0.033 | <0.001 | 0.334 (179) | -0.031 | <0.001 |
| | | | | | | |
| Copepod nauplii (m) | 0.396 (487) | 0.024 | <0.001 | 0.184 (424) | 0.013 | <0.001 |
| Calanoid copepods (M) | 0.225 (573) | -0.023 | <0.001 | 0.085 (447) | --- | --- |
| Cyclopoid copepods (M) | 0.085 (534) | -0.023 | 0.050 | 0.087 (433) | --- | --- |

*n* values (# of non-zero data points) are shown in Corr. Coeff. column in parentheses. Number of total samples indicated in headings.
Significance column indicates the probability that a correlation coefficient this large could be due to chance alone. If this probability is greater than 0.05, then NS (not significant) is indicated. * = marginally significant. M indicates species was quantified from macrozooplankton samples; m indicates quantification from microzooplankton samples.

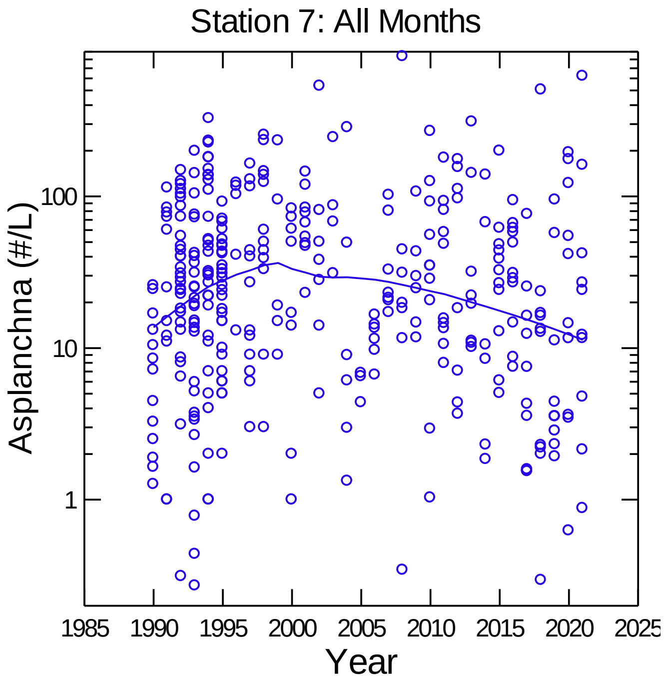
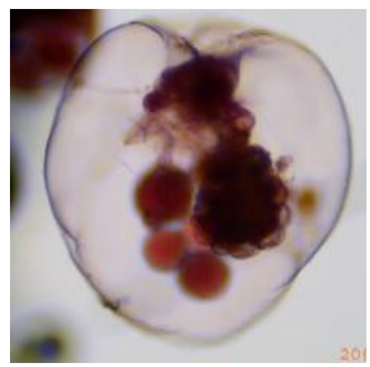
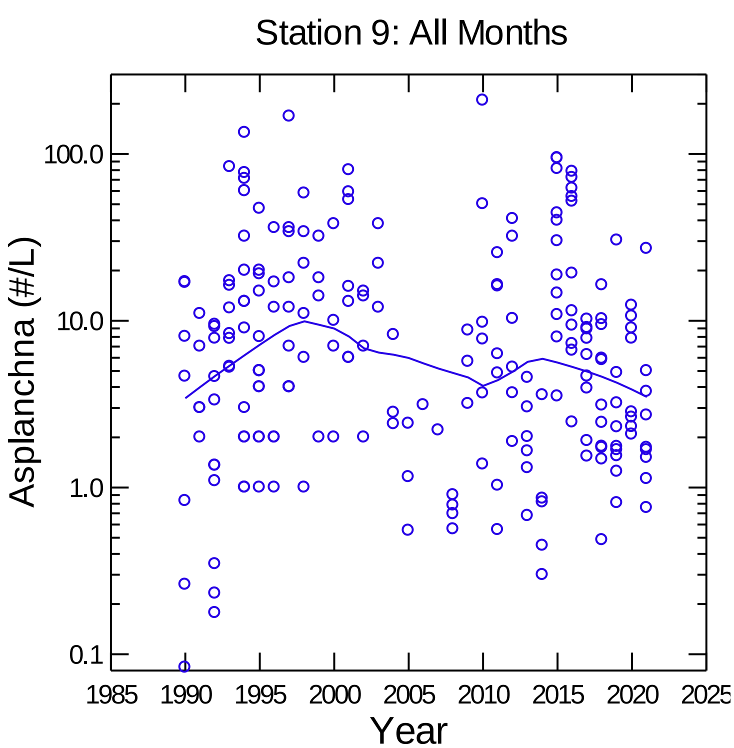



Figure 127. Long term trend in *Asplanchna*. Station 7. Gunston Cove.

*Asplanchna* has shown a similar increase as total rotifers but attained much lower abundance levels (Figure 127). The LOWESS line increased in the 1990's, but has sinced decreased to near initial levels of about 10/L in 2021. No linear trend was found over the study period (Table 19).

Photo credit: Laura Birsa






*Asplanchna* was found at even lower densities in the river and the trend line was at about 4/L in 2021 (Figure 128). No linear trend was indicated when the entire study period was considered (Table 19).

Figure 128. Long term trend in *Asplanchna*. Station 9. River mainstem.

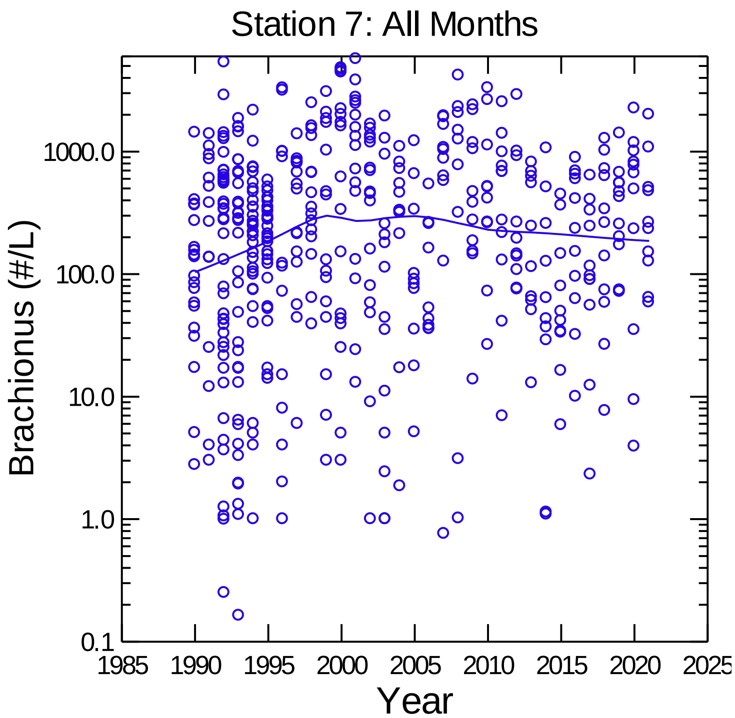



Figure 129. Long term trend in *Brachionus*. Station 7. Gunston Cove.

*Brachionus* is the dominant rotifer in Gunston Cove and the trends in total rotifers are generally mirrored in those in *Brachionus* (Figure 129). The LOWESS line for *Brachionus* suggested about 200/L in 2021, about twice what was found in 1990. A modest linear trend was found over the study period (Table 19).

Photo credit: Laura Birsa

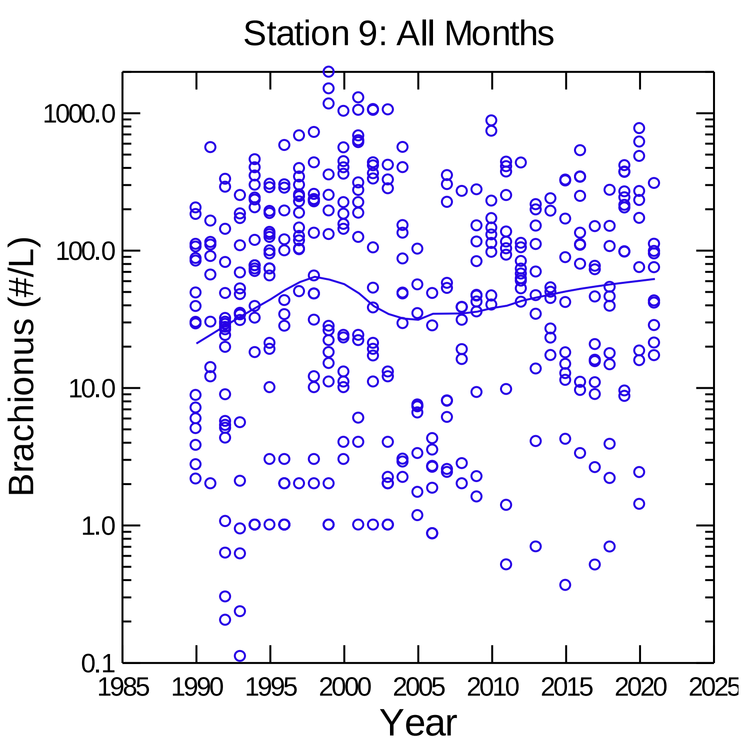
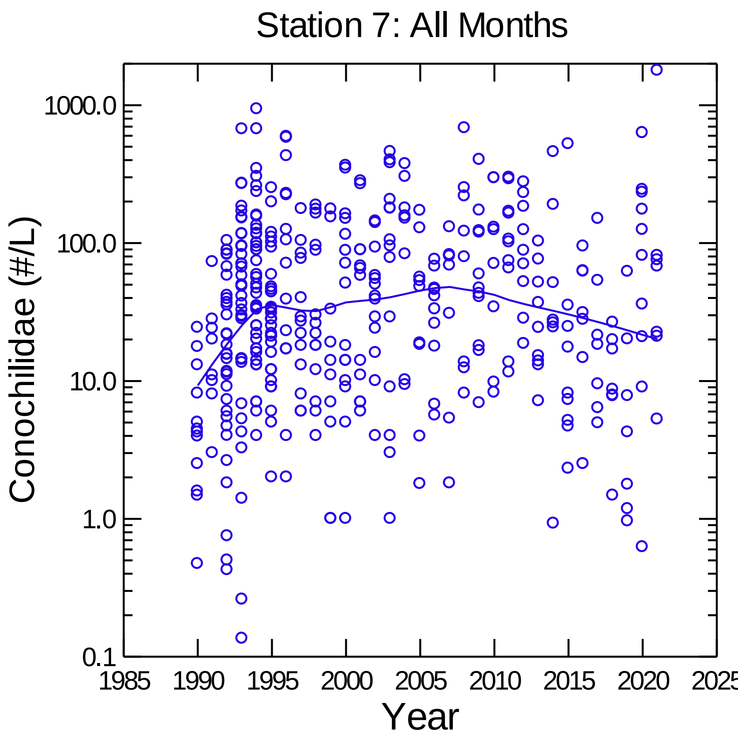



Figure 130. Long term trend in *Brachionus*. Station 9. River mainstem.

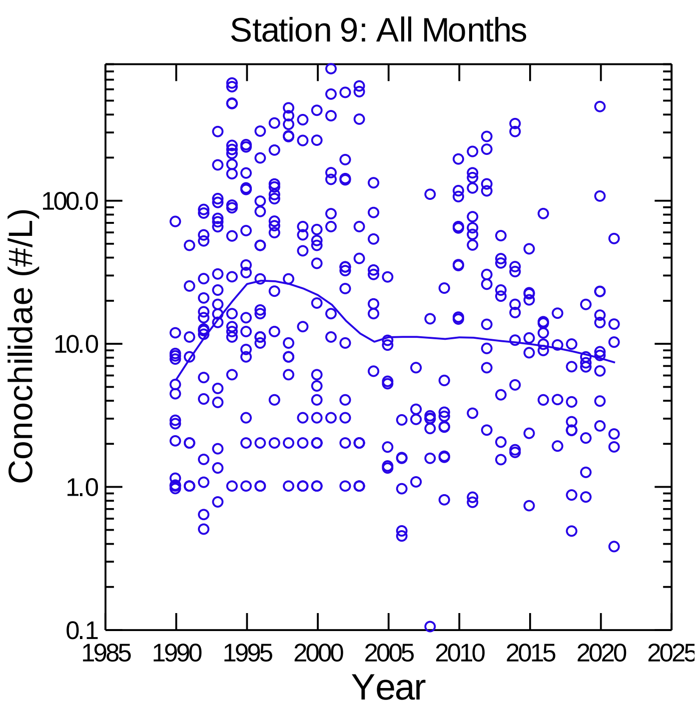
*Brachionus* was found at lower densities in the river. In the river the LOWESS line for *Brachionus* increased through 2000, but dropped markedly from 2000-2005. Since 2005 a steady increase has been noted with the trend line reaching about 60/L in 2021 (Figure 130). No linear trend was indicated when the entire study period was considered (Table 19).




Conochilidae increased strongly from 1990-1995 and since then has leveled off and recently shows a slight decline. In 2021 the LOWESS trend line stood at about 20/L (Figure 131). This was well above levels of about 9/L in 1990. Over the entire period of record, there was not a significant linear increase (Table 19).

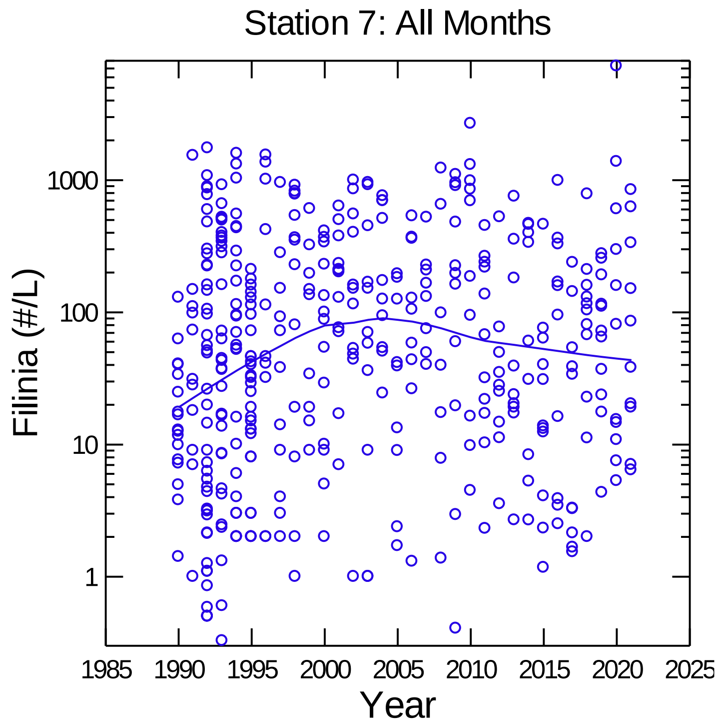
Photo credit: Laura Birsa

Figure 131. Long term trend in Conochilidae. Station 7. Gunston Cove.




In the river, Conochilidae exhibited a strong increase in the early 1990's similar to that observed in the cove (Figure 132). This was followed by a period of decline and recently a constant value. The trend line has gone from 3/L in 1990 to 30/L in 1995 to about 8/L in 2021. When the entire period of record was examined, no linear trend was found (Table 19).

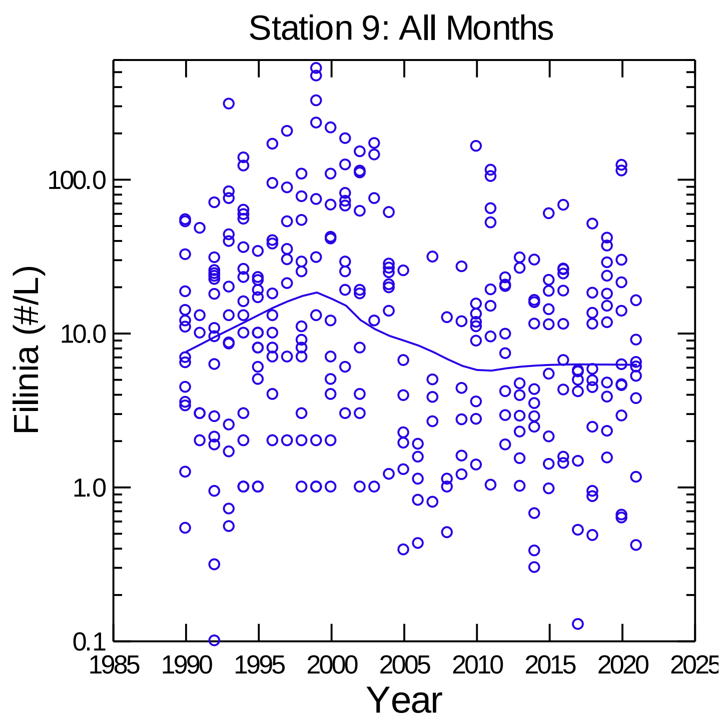
Figure 132. Long term trend in Conochilidae. Station 9. River mainstem.




In the cove *Filinia* exhibited a steady increase from 1990 through 2000 rising from about 20/L to nearly 100/L (Figure 133). It has shown a gradual decline in recent years to about 40/L in 2021. When the entire period of record was considered, there is evidence for a linear increase in the cove and in fact one very high reading 7000/L was observed in 2020 (Table 19).

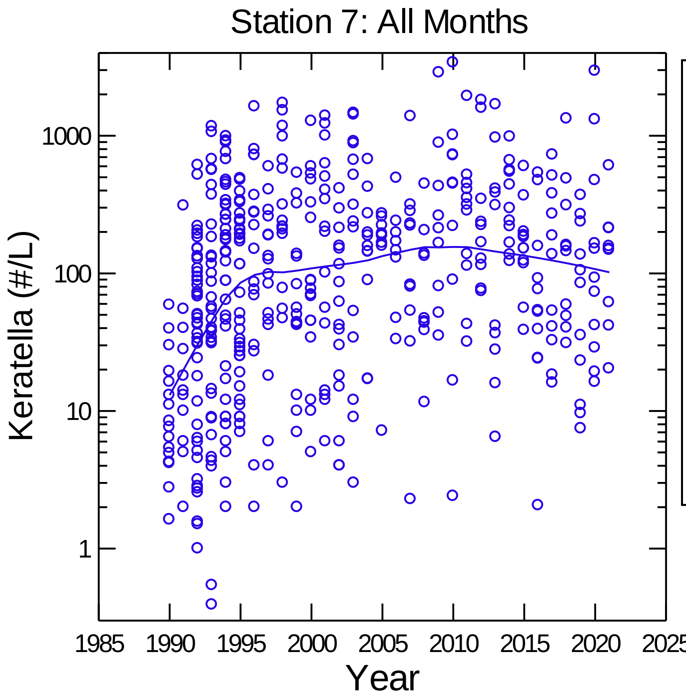
Photo credit: Laura Birsa

Figure 133. Long term trend in *Filinia*. Station 7. Gunston Cove.



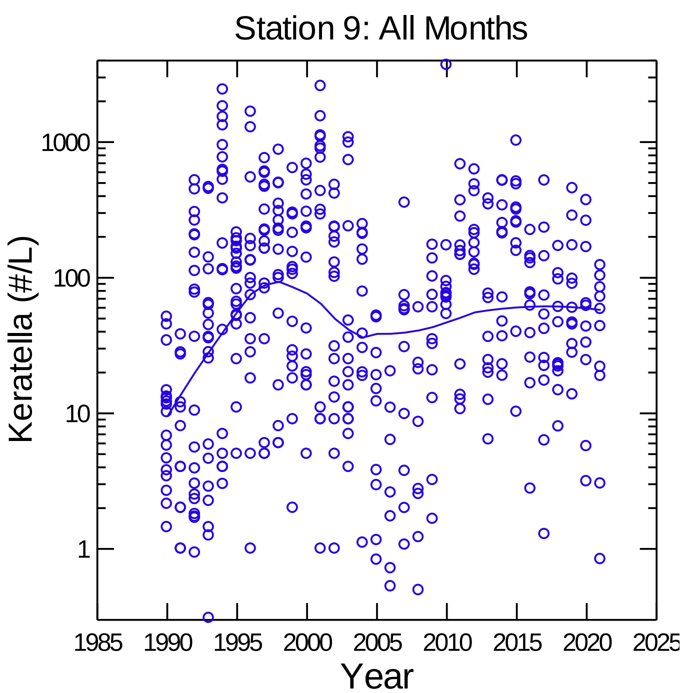

In the river *Filinia* demonstrated an increase through about 2001, declined from 2001-2010 and remained steady since. The trend line indicates about 7/L in 2020, about equal to the 7/L in 1990, but well below the peak of 20/L in 2000 (Figure 134). When the entire period of record was examined, there was a significant negative linear trend (Table 19).

Figure 134. Long term trend in *Filinia*. Station 9. River mainstem.



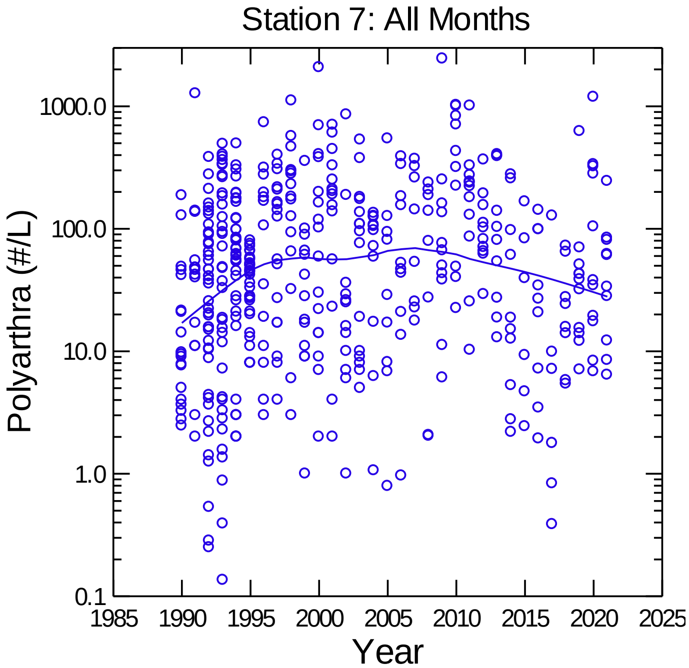

*Keratella* increased strongly from 1990 to 1995 and has shown a milder increase since then and most recently a slight decline with the trend line approaching 100/L in 2021 (Figure 135). When the entire period of record was examined, there was a significant linear increase (Table 19).

Figure 135. Long term trend in *Keratella*. Station 7. Gunston Cove.



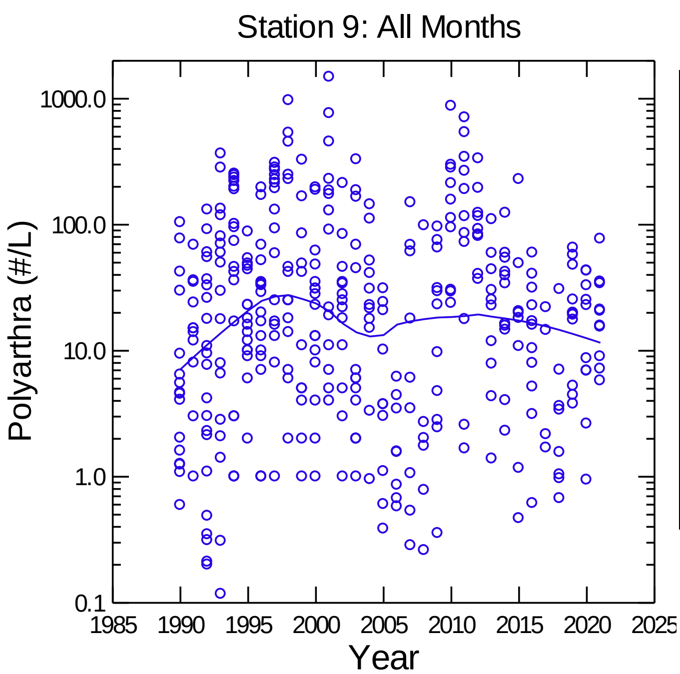

In the river *Keratella* increased from less than 10/L in 1990 to peak values of about 100/L in the mid to late 1990's (Figure 136). The trend line then declined to about 25/L, but since 2005 it has increased reaching about 60/L in 2020. Linear regression showed no evidence of a linear increase when the entire study period was considered (Table 19).

Figure 136. Long term trend in *Keratella*. Station 9. River mainstem.




The trend line for *Polyarthra* in the cove increased steadily from 1990 to about 2000 rising from 15/L to about 60/L (Figure 137). Since 2000 densities have increased more slowly and now are dropping again reaching 30/L by 2021. Regression analysis indicated a significant , but slight linear increase when the entire period of record was examined (Table 19).

Figure 137. Long term trend in *Polyarthra*. Station 7. Gunston Cove.




In the river *Polyarthra* showed a marked increase from 1990 to 2000 and then a decline to 2005. By 2021 the trend line approached 10/L (Figure 138). Linear regression analysis indicated a marginally significant positive trend over the period of record (Table 19).

Figure 138. Long term trend in *Polyarthra*. Station 9. River mainstem.

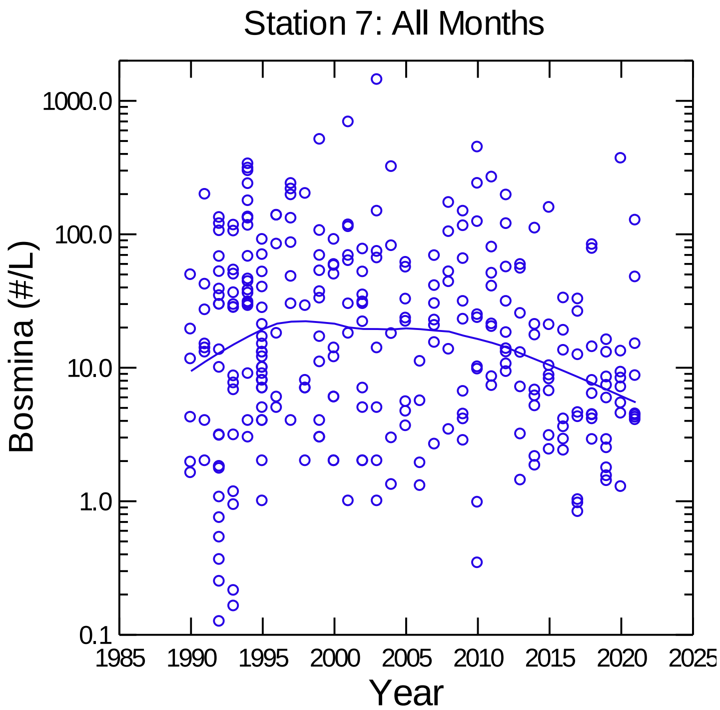



Figure 139. Long term trend in *Bosmina*. Station 7. Gunston Cove.

The trend line for *Bosmina* in the cove showed an increase from 8/L in 1990 to about 20/L in 2000 (Figure 139). Since 2000 densities have declined reaching about 5/L in 2021. Linear regression did not indicate a significant trend in the cove over the entire period of record (Table 19).

Photo credit: Laura Birsa

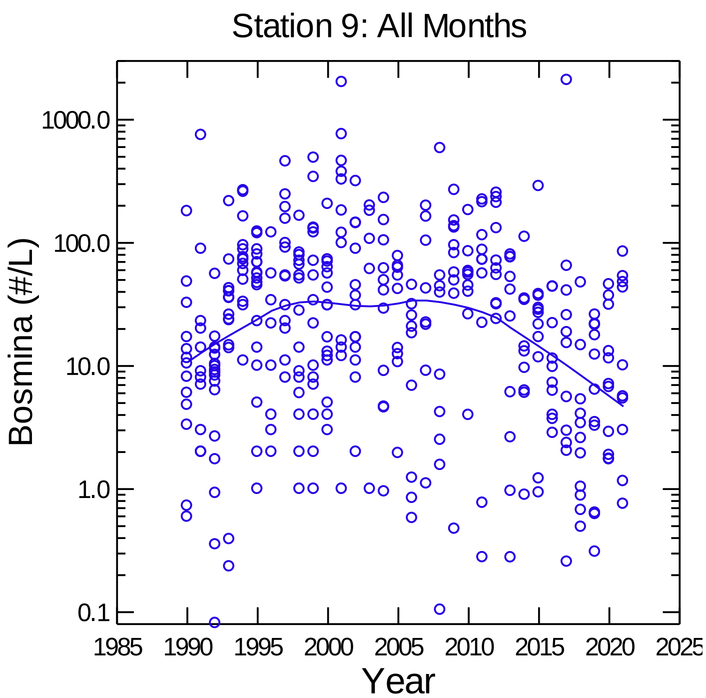
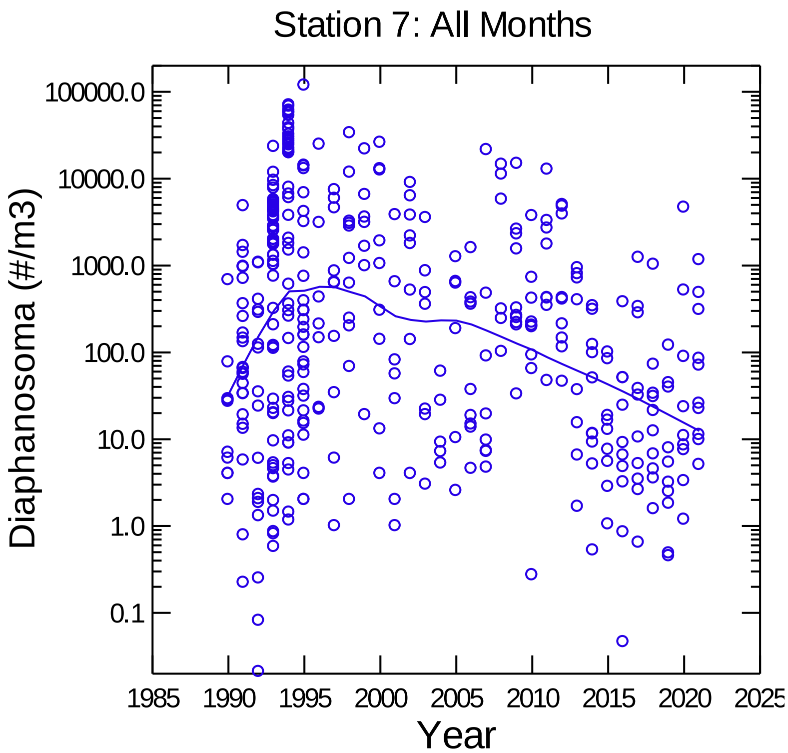



Figure 140. Long term trend in *Bosmina*. Station 9. River mainstem.

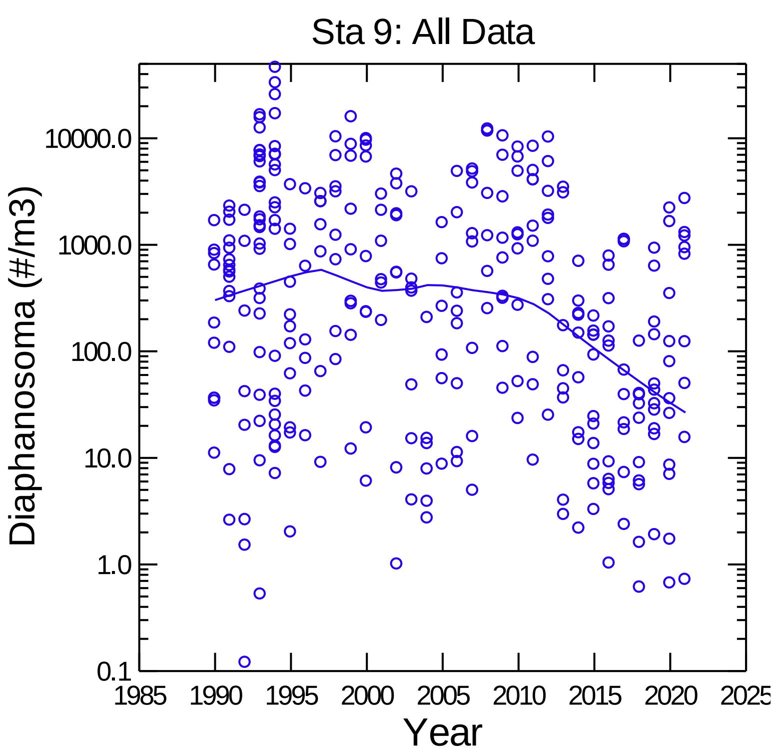
In the river mainstem the LOWESS curve for *Bosmina* increased from 1990 to 1995, and remained rather constant from 1995 to 2010 at about 30/L (Figure 140). Recently, it has declined markedly to about 4/L in 2021. Regression analysis did not indicate a slight negative linear trend over the entire period of record (Table 19).




*Diaphanosoma* increased strongly in the early 1990s from about 12/$m^3$ nearly 600/$m^3$. It gradually declined and by 2021 the trend line was nearing 10/$m^3$ (Figure 141). Linear regression analysis of the entire period of record indicated a significant decline (Table 19).

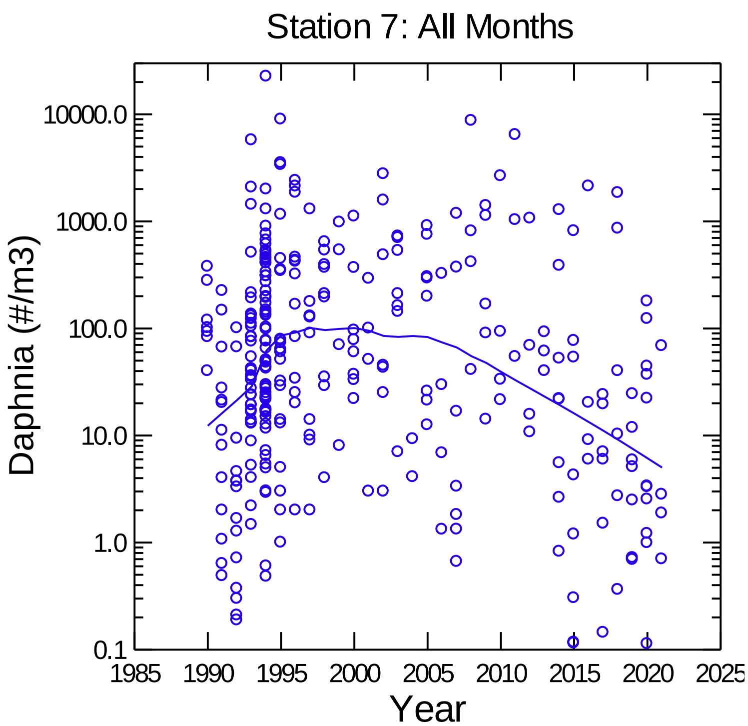
Photo credit: Laura Birsa

Figure 141. Long term trend in *Diaphanosoma*. Station 7. Gunston Cove.




In the river the LOWESS line suggested a generally stable pattern in *Diaphanosoma* until 2010 until a decline set in (Figure 142). The trend line value of 30/$m^3$ found in 2021 compared with values as high as 600/$m^3$ in 1999. Regression analysis indicated a significant declining trend over the period of record (Table 19).

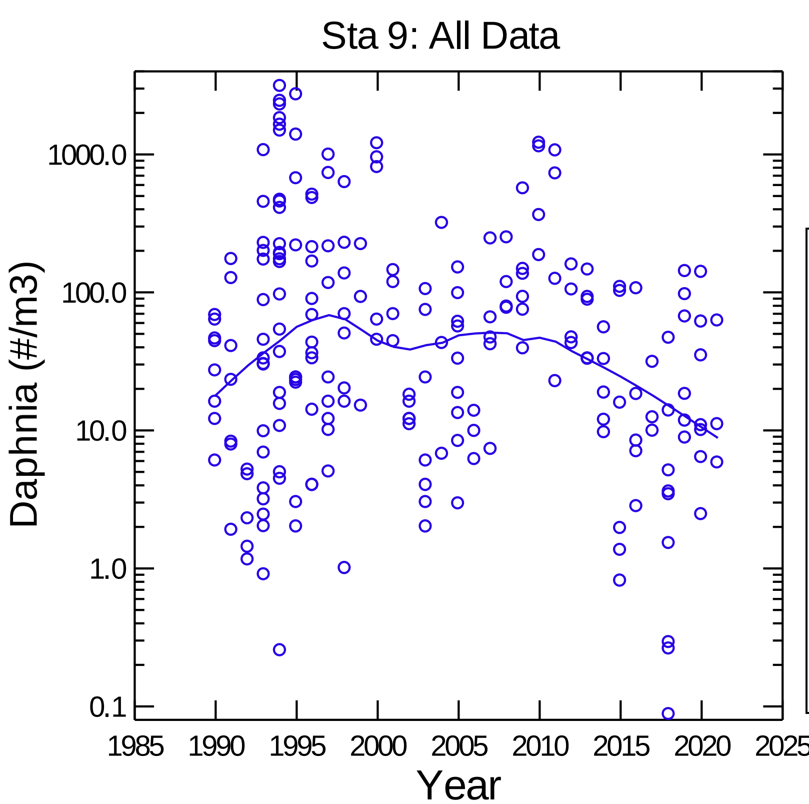
Figure 142. Long term trend in *Diaphanosoma*. Station 9. River mainstem.




*Daphnia* in the cove has declined slowly since 1995 from about 100/$m^3$ to 5/$m^3$ in 2021 (Figure 143). Regression analysis examining the entire period of record showed a significant decline (Table 19).

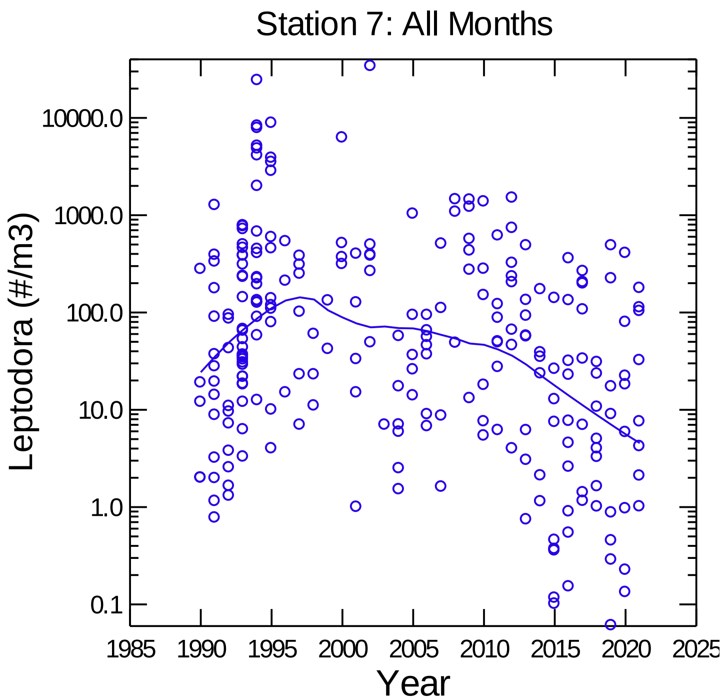
Figure 143. Long term trend in *Daphnia*. Station 7. Gunston Cove.

Photo credit: Laura Birsa



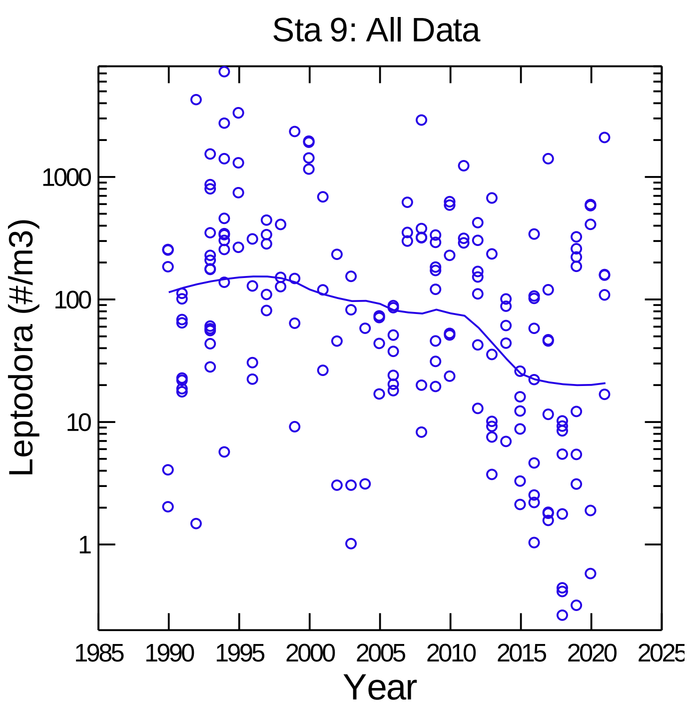

*Daphnia* in the river increased early on, but has since declined slightly (Figure 144). The trend line in 2021 dropped to 10/$m^3$, even lower than the level observed at the beginning of the record in 1990. Regression analysis indicated a significant negative trend over the study period (Table 19).

Figure 144. Long term trend in *Daphnia*. Station 9. River mainstem.



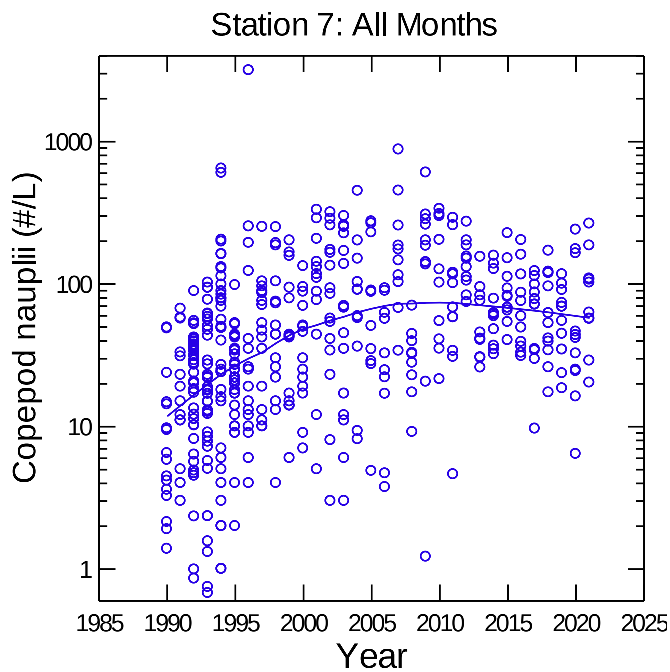

In the cove the trend line for *Leptodora*, the large predaceous cladoceran, has gradually decreased since 1995 and in 2021 reached about 4/$m^3$, down from its high of about 100/$m^3$ in 1994 (Figure 145). There was evidence for a significant negative linear trend in *Leptodora* over the entire study period (Table 19).

Figure 145. Long term trend in *Leptodora*. Station 7. Gunston Cove.




In the river, *Leptodora* densities continued a general decline which began in 1995 resulting in trend line values of about 20/$m^3$ for 2021 (Figure 146). These values are well below the peak of 200/$m^3$ in 1994. Interestingly, several data points in 2020 and 2021 were well above the trend line. Linear regression analysis detected a significant negative linear trend when the whole study period was considered (Table 19).

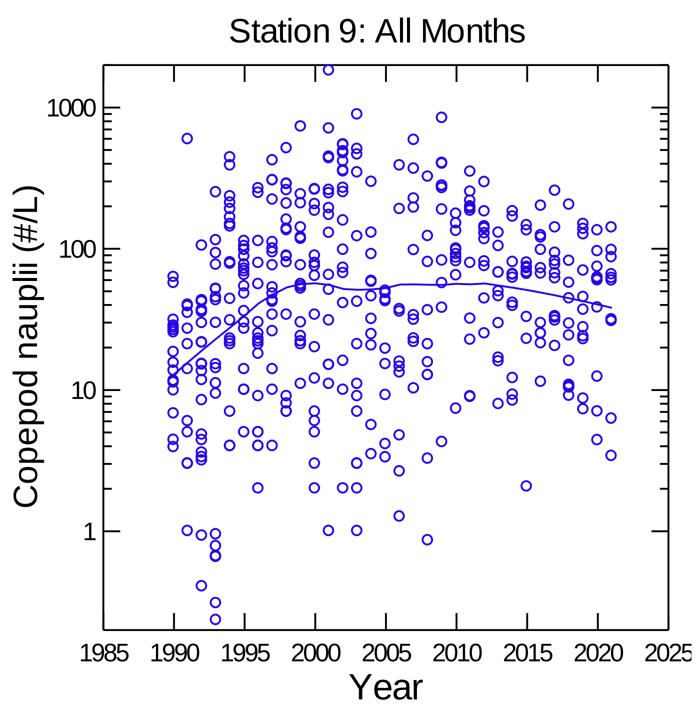
Figure 146. Long term trend in *Leptodora*. Station 9. River mainstem.




Copepod nauplii, the immature stages of copepods, have shown a positive trend since inception, but they are now leveling at about 70/L as of 2021 (Figure 147). These values are well above the initial values of about 10/L in 1990. A strong linear increase was observed over the study period (Table 19).

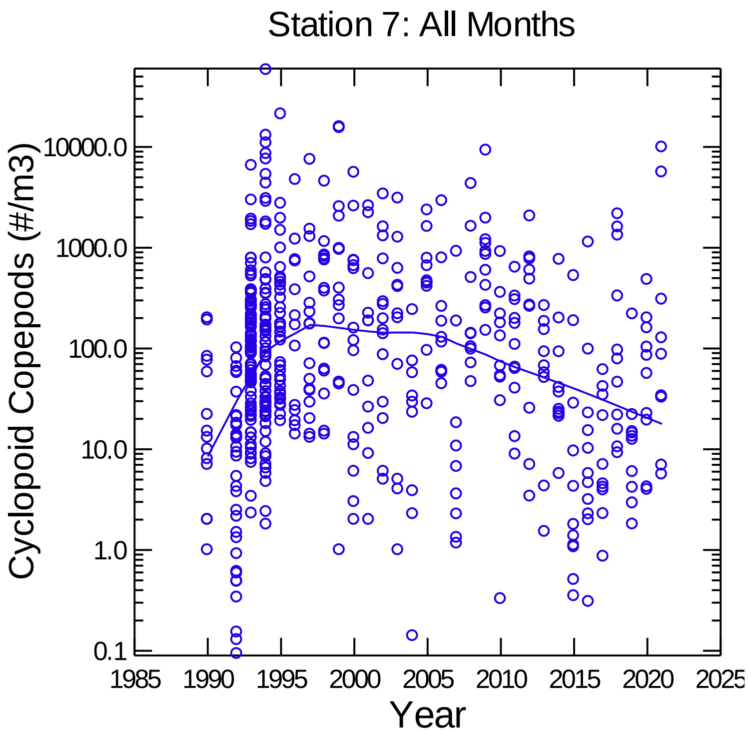
Photo credit: Laura Birsa

Figure 147. Long term trend in Copepod Nauplii. Station 7. Gunston Cove.




In the river, copepod nauplii showed a a similar leveling of an upward trend (Figure 148). The 2021 LOWESS trend line value was about 40/L, up from an initial value of 10/L in 1990, similar to the previous peak. A significant linear increase was found for nauplii in the river over the study period (Table 19).

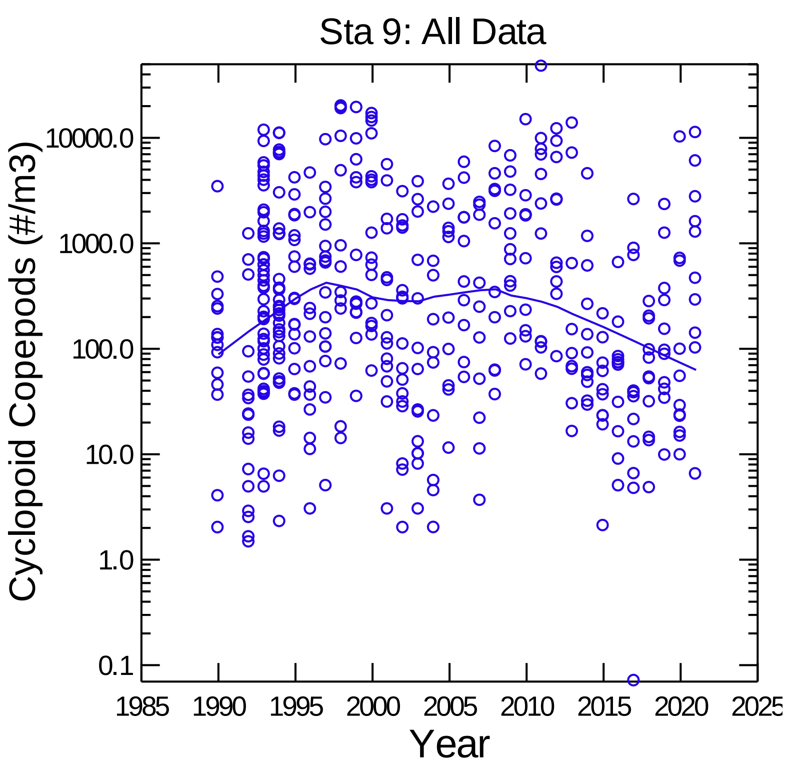
Figure 148. Long term trend in Copepod Nauplii. Station 9. River mainstem.




In the cove, cyclopoid copepods increased strongly in the early 1990's, were steady from 1995 to 2005 at about 200/m$^3$, and since have decreased slowly to about 20/m$^3$ in 2020 (Figure 149). Cyclopoid copepods exhibited a significant negative linear trend in the cove over the study period (Table 19).

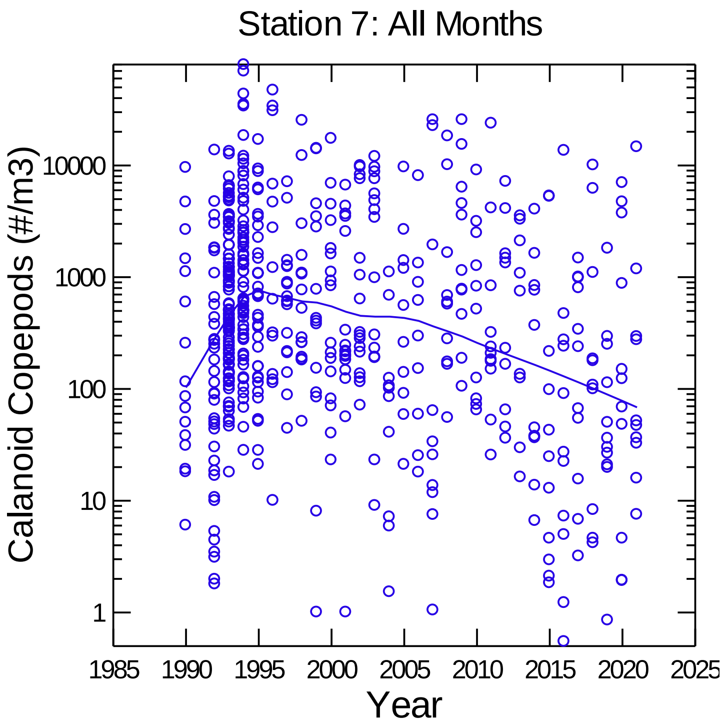
Photo credit: Laura Birsa

Figure 149. Long term trend in Cyclopoid Copepods. Station 7. Gunston Cove




Cyclopoid copepods have shown several cycles over the period (Figure 150). The trend line has varied from 90/m$^3$ to about 400/m$^3$. In 2021 cyclopoids were at a low point of about 60/m$^3$ according to the trend line although all data for 2021 was well above the trend line. No linear increase was found when the entire study period was considered (Table 19).

Figure 150. Long term trend in Cyclopoid Copepods. Station 9. River mainstem




Calanoid copepods (Figure 151) in the cove increased greatly in the early 1990's to near 1000/m$^3$ and then have gradually declined to about 70/m$^3$ in 2021. A significant negative trend was revealed by regression analysis (Table 19).

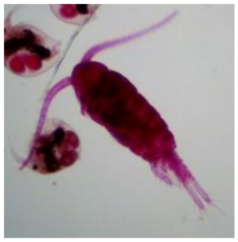
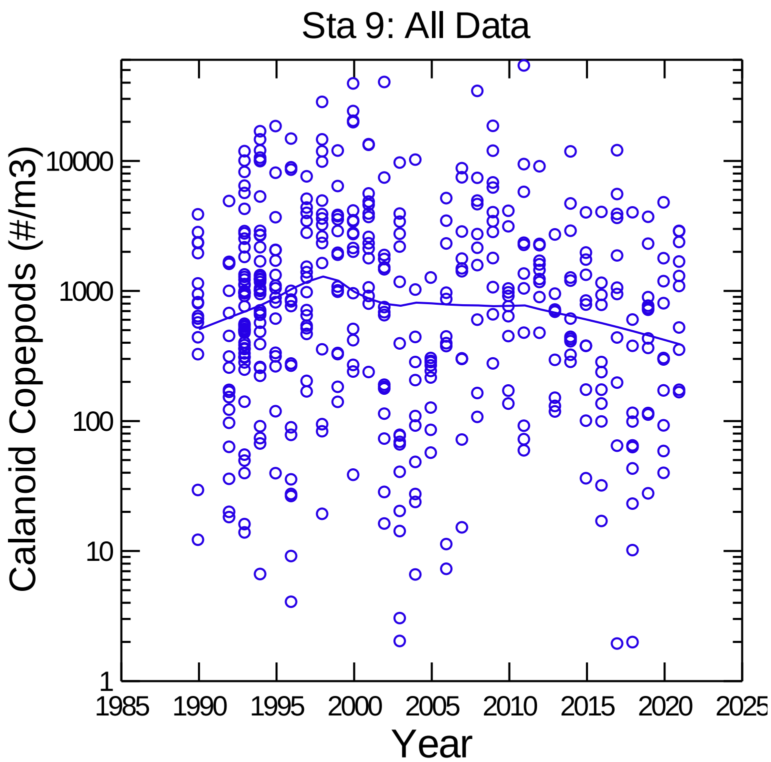


Photo credit: Laura Birsa

Figure 151. Long term trend in Calanoid Copepods. Station 7. Gunston Cove



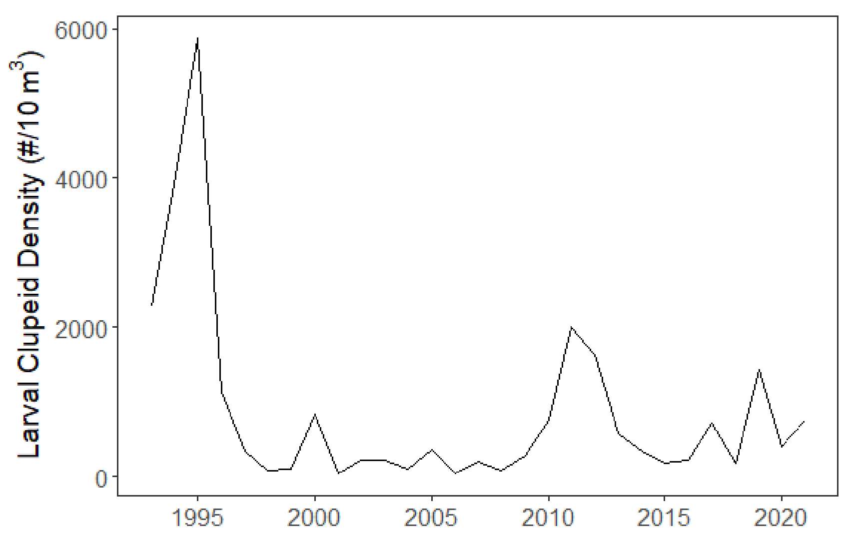

In the river calanoid copepods have varied a lot over the years, but the trend line has changed only gradually and was at 300/m$^3$ in 2021 (Figure 153). There was not a statistically significant linear trend (Table 16).

Figure 152. Long term trend in Calanoid Copepods. Station 9. River mainstem

E. Ichthyoplankton Trends: 1993-2021

Ichthyoplankton monitoring provides a crucial link between nutrients, phytoplankton, zooplankton and juvenile fishes in seines and trawls. The ability of larvae to find food after yolk is consumed may represent a critical period when survival determines the abundance of a year-class. The timing of peak density of feeding stage fish larvae is a complex function of reproductive output as well as the temperature and flow regimes. These peaks may coincide with an abundance or scarcity of zooplankton prey. When the timing of fish larva predators overlaps with their zooplankton prey, the result is often a high abundance of juveniles that can be observed in high density in seines and trawl samples from throughout the cove. In addition, high densities of larvae but low juvenile abundance may indicate that other factors (e.g., lack of significant refuge for settling juveniles) are modifying the abundance of a year-class.

The dominant species in the ichthyoplankton samples, namely Clupeids (which are primarily river herring and Gizzard Shad), Morone sp. (mostly White Perch), and Atherinids (Inland Silversides), all exhibited a spike in density in 1996 followed by a decline in numbers until about 2008 (Figures 153, 155, 157, 159). Yellow Perch showed a similar peak in 1996 and has not been a dominant species since. The declines in Clupeid larvae were followed by increases starting in 2010 (Figure 153; Table 20). Especially 2010-2012 showed very high density of these larvae, while numbers decreased again from 2013-2016. Although there was a small increase in 2017 and a larger increase in 2019, our 2021 samples were back down to the level of 2017. It is possible that this is natural variation, and that these populations rely on a few highly successful year classes. However, from 2017 – 2021 the numbers are higher than the early 2000. A moratorium on river herring since 2012 may be allowing the numbers to increase over time.



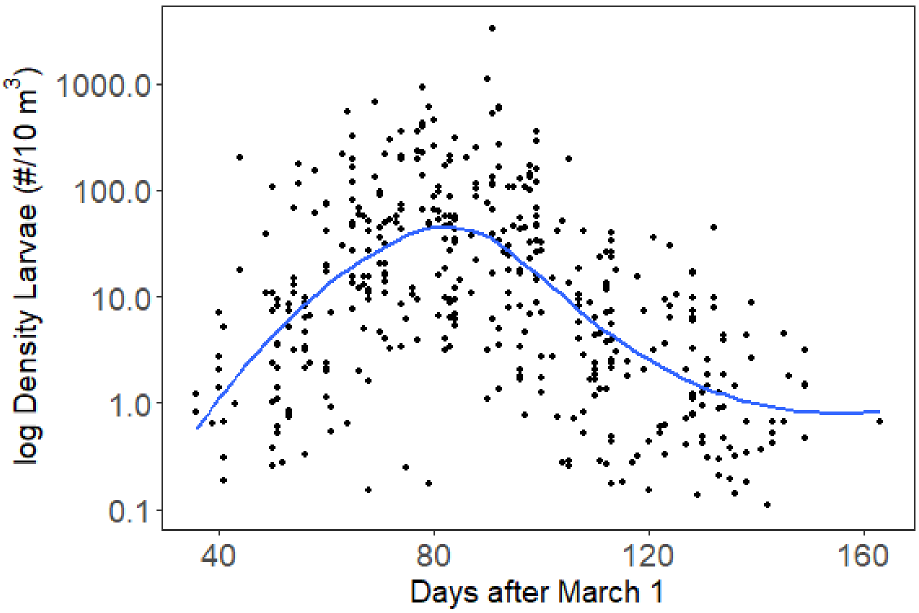

The trend in number of White Perch and Striped Bass larvae per 10 m$^3$ since 1993 is depicted in the graph in Figure 153. Two peaks are observed in 1995 and 2012 with low densities in other years.

Figure 153. Long-term trend in Clupeid Larvae (*Alosa sp.* and *Dorosoma sp.*; abundance 10 m$^{-3}$).

Table 20. Density of larval fishes Collected in Gunston Cove and the Potomac mainstem (abundance 10 $m^{-3}$).

| Year | *Alosa* sp. | *Dorosoma* sp. | *Lepomis* sp. | *Morone* sp. | *Perca flavescens* | *Menidia beryllina* |
|---|---|---|---|---|---|---|
| 2021 | 510 | 84 | 1 | 88 | 0 | 20 |
| 2020 | 176 | 155 | 1 | 95 | 0 | 44 |
| 2019 | 975 | 365 | 1 | 39 | 0 | 1 |
| 2018 | 72 | 38 | 4 | 4 | 0 | 3 |
| 2017 | 312 | 148 | 41 | 62 | 1 | 5 |
| 2016 | 105 | 87 | 2 | 87 | 0 | 7 |
| 2015 | 41 | 29 | 0 | 2 | 0 | 21 |
| 2014 | 102 | 115 | 0 | 61 | 0 | 0 |
| 2013 | 133 | 220 | 3 | 112 | 1 | 1 |
| 2012 | 476 | 1395 | 0 | 330 | 0 | 0 |
| 2011 | 149 | 2007 | 0 | 62 | 0 | 0 |
| 2010 | 247 | 1032 | 0 | 88 | 15 | 10 |
| 2009 | 38 | 276 | 0 | 58 | 0 | 2 |
| 2008 | 4 | 85 | 0 | 61 | 1 | 1 |
| 2007 | 17 | 209 | 0 | 40 | 12 | 5 |
| 2006 | 9 | 37 | 0 | 8 | 20 | 8 |
| 2005 | 88 | 280 | 0 | 35 | 0 | 3 |
| 2004 | 245 | 94 | 0 | 42 | 0 | 5 |
| 2003 | 110 | 170 | 0 | 30 | 6 | 4 |
| 2002 | 998 | 30 | 0 | 28 | 1 | 1 |
| 2001 | 95 | 5 | 0 | 3 | 0 | 1 |
| 2000 | 8 | 97 | 0 | 128 | 2 | 102 |
| 1999 | 435 | 94 | 3 | 63 | 0 | 13 |
| 1998 | 674 | 84 | 1 | 115 | 3 | 0 |
| 1997 | 1305 | 265 | 31 | 146 | 6 | 8 |
| 1996 | 834 | 1118 | 0 | 571 | 91 | 0 |
| 1995 | 721 | 810 | 10 | 333 | 8 | 9 |
| 1994 | 640 | 202 | 38 | 176 | 0 | 57 |
| 1993 | 33 | 298 | 1 | 112 | 1 | 15 |

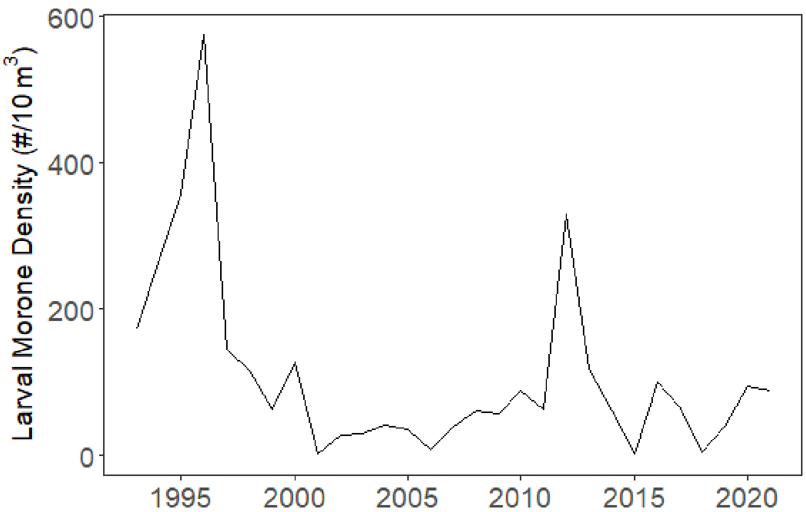
The peaks in abundance over the season reflect characteristic spawning times of each species (Figures 154, 156, 158, and 160). Clupeid larval density shows a distinct peak mid-May (Figure 154). Clupeid larvae are dominated by Gizzard Shad, which spawns later in the season than river herring (Alewife and Blueback Herring). However, river herring larvae are part of this peak as well; although their spawning season is from mid-March to mid-May, spawning occurs higher upstream, and larvae subsequently drift down to Gunston Cove. Morone sp., which are mostly White Perch, have high larval abundances early in the season and then taper off (Figure 156). Silversides have a small peak in late May/early June, with low densities continuing to be present throughout the season (Figure 158). The earliest peak is from Yellow Perch (Figure 160), which may even be at its highest before our sampling starts.




The seasonal pattern in clupeid larvae for 1993-2021 (Figure 154) shows that a peak in density occurs about 80 days after March 1, or mid-May.

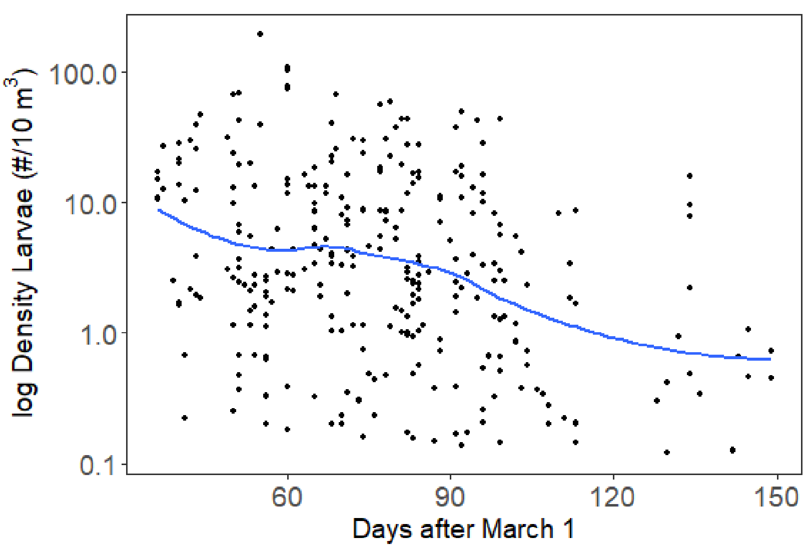
Figure 154. Seasonal trends in Clupeid Larvae (*Alosa sp.* and *Dorosoma sp.*; abundance $10m^{-3}$).

The long-term trend in annual average density of *Morone* larvae shows a high similarity with that of Clupeid larvae (Figure 155). While densities are lower, the same pattern of high peaks in 1995 and 2012, and low densities in other years is seen. Looking at the seasonal pattern (Figure 156), we may miss high densities of larvae occurring in spring, as our sampling of larvae in Gunston Cove starts mid-April. With the high abundance of juveniles and adults each year, our Morone larval sample is likely not representative of the total larval production. White perch is also a migratory species, and juveniles may come in the system from elsewhere.




The trend in number of White Perch and Striped Bass larvae per 10 $m^3$ since 1993 is depicted in the graph in Figure 155. Two peaks are observed in 1995 and 2012 with low densities in other years.

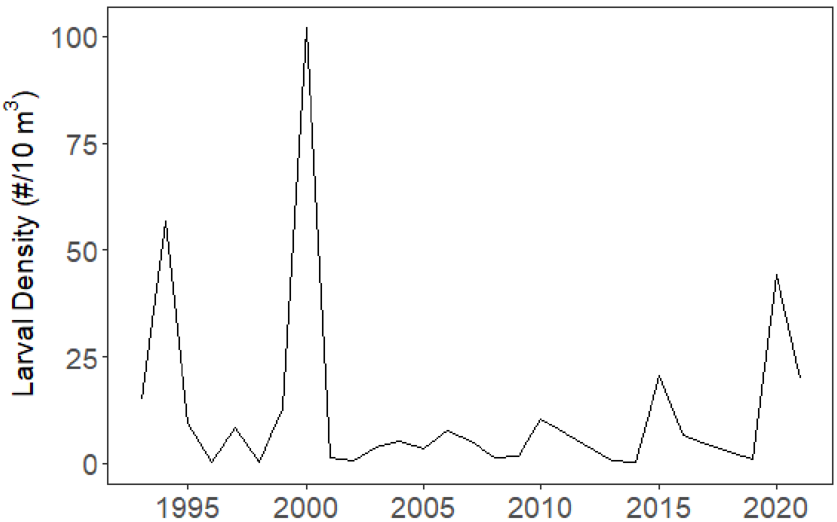
Figure 155. Long term trend in *Morone sp.* larvae (abundance 10 $m^{-3}$).




The seasonal density of *Morone* sp. larvae per 10 $m^3$ is shown in Figure 156. Highest densities are at the start of the sampling season.

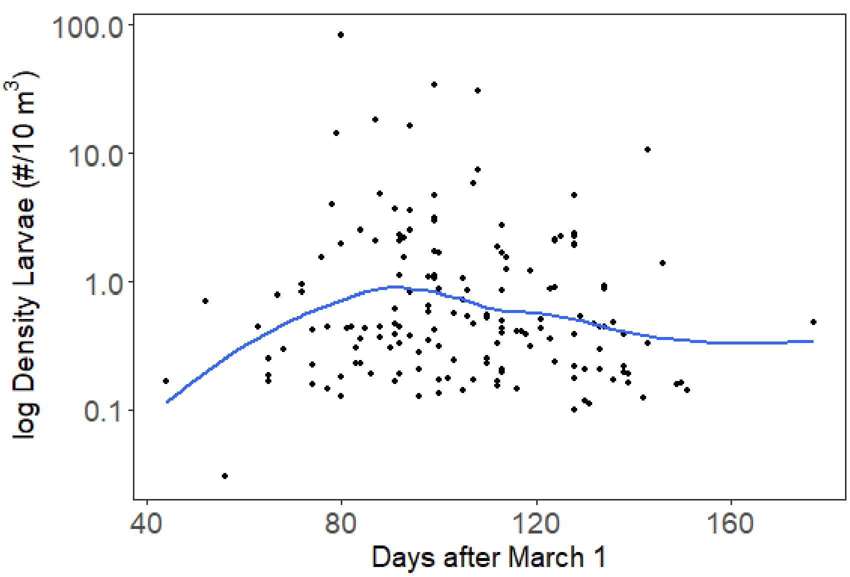
Figure 156. Seasonal pattern in *Morone sp.* larvae (abundance 10 $m^{-3}$) from 1993-2021. X-axis represents days after March 1st.

The long-term trend in annual average density of Inland Silverside larvae also shows the highest peaks early in the timeseries, with highest peaks occurring in 1994 and 2000 (Figure 157). However, after some small peaks in 2006, 2010, and 2015, 2020 showed the third highest peak in the period of record. The numbers in 2021 were less than 2020 but still greater than most years. Perhaps as previously speculated, reduced human activities surrounding COVID 19 have allowed for stronger silverside year classes.



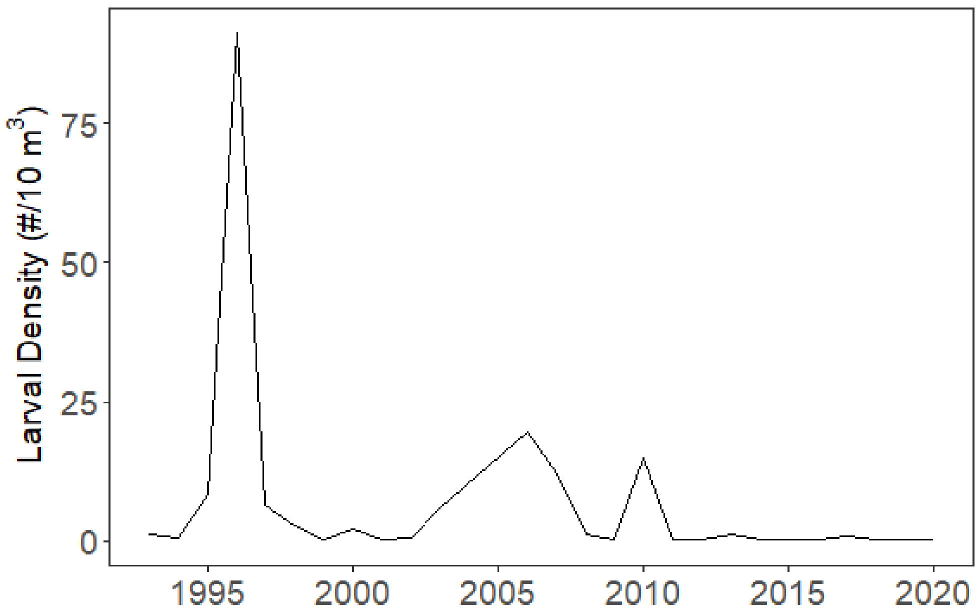

The long-term trend in density of Inland Silverside is presented in Figure 157. After high peaks in 1994 and 2000, densities have been moderate to low with some small peaks in 2006, 2010, and 2015. 2020 adds the third highest peak in the period of record.

Figure 157. Long-term trend in *Menidia beryllina* larvae (abundance 10 m$^{-3}$).



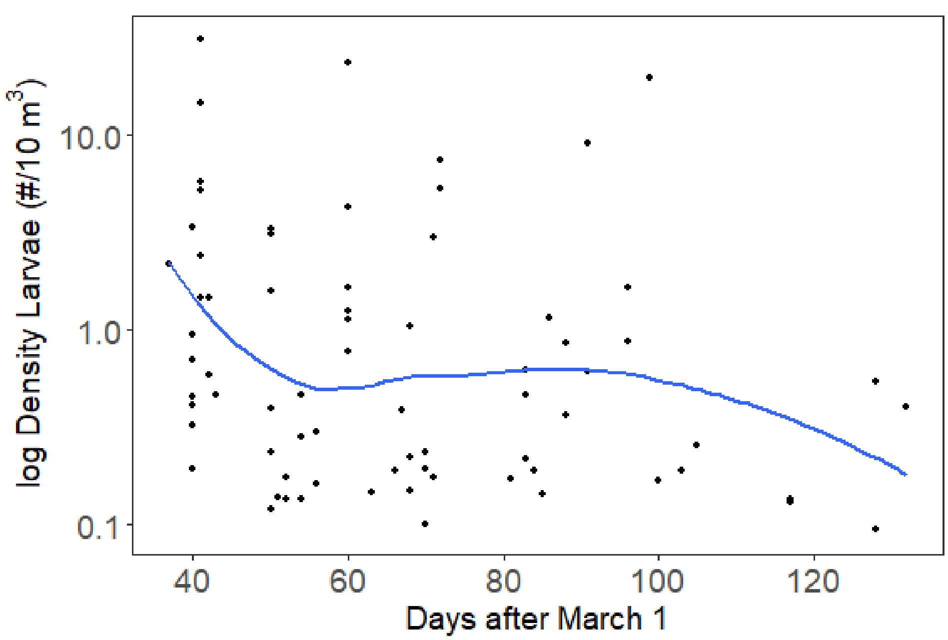

The seasonal occurrence of Inland Silverside per 10m$^3$ is shown in a LOWESS graph in Figure 158. The pattern shows maximum density around 90 days after March 1, or around the first week of June.

Figure 158. Seasonal pattern in *Menidia beryllina* larvae (abundance 10 m$^{-3}$) from 1993 - 2021. The x-axis represents the number of days after March 1.




The long-term trend in density of Yellow Perch larvae since 1993. Following unusually high densities in 1996, abundances decreased to low values, especially since 2011 (Figure 159)

Figure 159. Long-term trend in *Perca flavescens* larvae (abundance 10 $m^{-3}$).




The long-term pattern of seasonal occurrence of Yellow Perch larval density is presented in Figure 160. The greatest densities occur in early to mid-April, while spawning continues producing low densities throughout the season. Total density is low, which is likely the main reason for this unpronounced spawning pattern.

Figure 160. Seasonal pattern in *Perca flavescens* larvae (abundance 10 $m^{-3}$) from 1993 - 2021. The x-axis represents the number of days after March 1.

## F. Adult and Juvenile Fish Trends: 1984-2021

### Trawls

#### Overall patterns

Annual abundance of juvenile fishes inside Gunston Cove is indexed by mean catch per trawl in the inner cove (stations 7 and 10 combined; Table 18, Figure 162). Since 1984, this index has fluctuated by over an order of magnitude, and the pattern was predominately due to changes in the catch rate of White Perch (Figure 148). The one high peak in 2004 that was not caused by high White Perch abundance was caused by a large catch of Blueback Herring (Figure 149). The White Perch numbers in 2021 were much lower than 2020. However, this decrease is still higher than earlier years, continuing the trend of higher peaks and shallower troughs since 2006. There seems to be an increasing trend in CPUE driving by White Perch abundances (Figure 148). The high numbers of White Perch were predominantly small juveniles. Trawl catches in station 7 and 9 were dominated by White Perch, with an equal proportion of White Perch and Redear Sunfish at station 10. This trend was driven by a high catch of small Redear Sunfish during the September sampling at station 10.

The remaining component of the total catch (species other than White Perch) made up a moderate to large proportion of the catch until 1990; a relatively small part of the catch between 1991 and 2000; and moderate to large proportion of the catch from 2001 to 2019. There was a high peak in catches other than White Perch in 2004, which was primarily due to exceptionally high catches of Blueback Herring (Figure 148; Figure 149). The high peak in Blueback Herring catches in 2004 stands out in otherwise low catches (Figure 149). Generally, both herring species have been found in higher abundances since 2000 than in the decade before that. We included Alosa sp. (unidentified herring or shad) in Figure 149 in 2016 (for all years), so that abundances of herring or shad are not missed simply because they could not be identified to the species level. This revealed the second highest peak in Alosines in 2010. In 2021 we see another uptick in the Alosa CPUE.

Table 21. Mean catch per trawl of adult and juvenile fishes at Stations 7 and 10 combined. 1984-2021.

| Year | All Species | White Perch | All Alosa Sp. | Blueback Herring | Alewife | Gizzard Shad | Bay Anchovy | Spottail Shiner | Brown Bullhead | Pumpkinseed |
|---|---|---|---|---|---|---|---|---|---|---|
| 2021 | 158.1 | 107.2 | 11.3 | 4.6 | 4.8 | 0.2 | 1.8 | 15.8 | 0.0 | 2.7 |
| 2020 | 568.7 | 522.1 | 2.6 | 0.3 | 2.0 | 0.7 | 0.0 | 33.9 | 0.1 | 4.3 |
| 2019 | 269.1 | 141.9 | 5.0 | 0.1 | 0.9 | 0.0 | 0.9 | 104.4 | 0.1 | 2.3 |
| 2018 | 147.1 | 79.1 | 2.7 | 0.0 | 0.4 | 0.2 | 0.0 | 30.5 | 0.8 | 4.8 |
| 2017 | 151.7 | 106.5 | 1.2 | 0.0 | 0.5 | 0.0 | 0.0 | 11.7 | 0.1 | 6.2 |
| 2016 | 170.4 | 121.7 | 12.7 | 0.0 | 0.1 | 0.1 | 0.3 | 13.7 | 0.3 | 1.2 |
| 2015 | 284.2 | 172.3 | 34.4 | 26.1 | 4.2 | 0.2 | 0.1 | 64.4 | 0.1 | 1.1 |
| 2014 | 92.3 | 46.2 | 10.4 | 2.1 | 1.3 | 0.2 | 1.4 | 15.6 | 0.3 | 0.5 |
| 2013 | 158.8 | 97.9 | 13.1 | 6.8 | 2.9 | 0.1 | 1.4 | 31.0 | 0.6 | 1.8 |
| 2012 | 164.5 | 128.7 | 1.7 | 0.1 | 0.2 | 3.3 | 0.4 | 11.8 | 0.6 | 2.1 |
| 2011 | 96.8 | 43.5 | 3.3 | 0.1 | 1.2 | 0.1 | 0.0 | 19.9 | 0.1 | 2.0 |
| 2010 | 372.9 | 248.1 | 109.1 | 0.2 | 52.9 | 2.2 | 0.4 | 6.0 | 0.5 | 1.4 |
| 2009 | 93.7 | 18.3 | 46.6 | 1.0 | 45.2 | 0.6 | 6.2 | 2.7 | 0.1 | 3.1 |
| 2008 | 69.8 | 16.1 | 0.1 | 0.0 | 0.0 | 4.0 | 0.2 | 2.5 | 0.6 | 7.0 |
| 2007 | 227.2 | 141.4 | 37.2 | 23.6 | 8.8 | 0.1 | 15.8 | 20.1 | 0.2 | 2.6 |
| 2006 | 26.1 | 9.6 | 2.7 | 1.6 | 0.6 | 0.2 | 2.3 | 3.0 | 0.4 | 1.8 |
| 2005 | 68.4 | 21.0 | 33.1 | 11.8 | 16.4 | 1.1 | 0.0 | 6.6 | 0.4 | 1.4 |
| 2004 | 408.4 | 23.4 | 373.2 | 337.5 | 33.1 | 0.9 | 0.6 | 8.0 | 0.0 | 0.5 |
| 2003 | 54.2 | 13.2 | 23.9 | 18.8 | 3.5 | 0.0 | 7.4 | 2.8 | 0.1 | 0.4 |
| 2002 | 80.1 | 15.1 | 39.5 | 9.8 | 28.5 | 0.1 | 15.8 | 0.6 | 0.0 | 1.7 |
| 2001 | 143.5 | 47.0 | 50.6 | 40.5 | 9.9 | 0.3 | 35.1 | 2.8 | 3.3 | 1.4 |
| 2000 | 68.0 | 53.3 | 5.4 | 3.6 | 1.9 | 2.3 | 1.7 | 1.3 | 1.9 | 0.6 |
| 1999 | 86.9 | 63.2 | 4.7 | 4.2 | 0.5 | 1.0 | 5.4 | 4.8 | 2.4 | 1.8 |

| Year | All Species | White Perch | All Alosa Sp. | Blueback Herring | Alewife | Gizzard Shad | Bay Anchovy | Spottail Shiner | Brown Bullhead | Pumpkinseed |
|---|---|---|---|---|---|---|---|---|---|---|
| 1998 | 83.2 | 63.8 | 3.0 | 2.2 | 0.8 | 0.5 | 3.7 | 6.4 | 0.9 | 1.6 |
| 1997 | 81.4 | 61.6 | 2.9 | 1.9 | 1.0 | 5.0 | 2.6 | 2.9 | 1.5 | 1.4 |
| 1996 | 54.1 | 37.1 | 8.5 | 4.0 | 4.4 | 0.5 | 0.2 | 2.6 | 0.5 | 2.0 |
| 1995 | 90.4 | 71.1 | 6.2 | 4.1 | 2.1 | 0.4 | 3.0 | 2.9 | 2.1 | 1.9 |
| 1994 | 102.8 | 77.7 | 6.5 | 6.5 | 0.0 | 0.4 | 1.1 | 6.3 | 2.4 | 2.6 |
| 1993 | 246.6 | 216.0 | 2.0 | 1.4 | 0.6 | 1.4 | 0.6 | 7.3 | 4.5 | 3.4 |
| 1992 | 112.8 | 81.6 | 0.2 | 0.2 | 0.0 | 0.9 | 0.8 | 2.4 | 11.5 | 5.1 |
| 1991 | 123.1 | 91.5 | 1.4 | 0.9 | 0.5 | 7.6 | 2.5 | 2.7 | 11.6 | 1.7 |
| 1990 | 68.8 | 31.6 | 24.1 | 21.1 | 3.1 | 0.1 | 1.1 | 1.1 | 9.0 | 0.5 |
| 1989 | 78.2 | 14.9 | 16.4 | 16.1 | 0.2 | 42.1 | 0.2 | 0.5 | 3.0 | 0.6 |
| 1988 | 126.6 | 74.5 | 20.3 | 10.5 | 7.0 | 13.5 | 8.3 | 1.9 | 5.2 | 0.7 |
| 1987 | 109.2 | 54.6 | 19.6 | 16.4 | 3.2 | 5.6 | 8.8 | 0.7 | 17.2 | 1.4 |
| 1986 | 130.9 | 69.9 | 24.6 | 1.8 | 22.7 | 4.2 | 4.0 | 1.2 | 18.1 | 0.6 |
| 1985 | 135.9 | 43.9 | 25.8 | 8.6 | 10.7 | 2.9 | 48.2 | 1.1 | 9.8 | 0.1 |
| 1984 | 213.2 | 127.4 | 11.9 | 6.0 | 0.6 | 13.3 | 22.0 | 1.5 | 32.9 | 0.2 |

Table 22. Mean catch per trawl of selected adult and juvenile fishes for all months at Station 9. 1988-2021

| Year | All Species | All Alosa Sp. | Alewife | Blueback Herring | White Perch | Bay Anchovy | Spottail Shiner | Brown Bullhead | Blue Catfish | Channel Catfish | Tesselated Darter |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2021 | 11.8 | 0.5 | 0.0 | 0.0 | 8.2 | 0.1 | 0.7 | 0.0 | 2.0 | 0.0 | 0.1 |
| 2020 | 29.2 | 0.2 | 0.2 | 0.0 | 20.8 | 0.0 | 3.8 | 0.0 | 3.6 | 0.2 | 0.0 |
| 2019 | 54.7 | 24.5 | 11.3 | 9.6 | 16.1 | 0.0 | 8.9 | 0.0 | 1.3 | 0.0 | 0.5 |
| 2018 | 41.8 | 0.0 | 0.0 | 0.0 | 27.6 | 0.0 | 1.6 | 0.7 | 8.5 | 0.0 | 1.8 |
| 2017 | 9.0 | 0.1 | 0.0 | 0.0 | 8.5 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 |
| 2016 | 10.1 | 2.0 | 0.0 | 0.0 | 2.0 | 4.9 | 0.0 | 0.0 | 1.2 | 0.0 | 0.0 |
| 2015 | 15.8 | 10.3 | 7.8 | 0.2 | 1.5 | 0.5 | 0.2 | 0.2 | 2.8 | 0.2 | 0.0 |
| 2014 | 16.9 | 6.8 | 3.7 | 1.0 | 3.0 | 3.3 | 0.1 | 0.1 | 3.1 | 0.0 | 0.4 |
| 2013 | 12.2 | 3.9 | 2.1 | 0.6 | 1.5 | 1.6 | 0.0 | 0.0 | 4.5 | 0.0 | 0.2 |
| 2012 | 62.1 | 0.0 | 0.0 | 0.0 | 21.6 | 31.7 | 0.8 | 0.0 | 7.3 | 0.3 | 0.0 |
| 2011 | 33.9 | 0.4 | 0.2 | 0.0 | 21.2 | 0.0 | 0.2 | 0.1 | 5.1 | 6.4 | 0.3 |
| 2010 | 38.7 | 0.1 | 0.0 | 0.0 | 10.8 | 7.9 | 0.0 | 0.1 | 19.5 | 0.0 | 0.0 |
| 2009 | 34.6 | 2.3 | 0.5 | 0.4 | 13.7 | 7.6 | 0.5 | 0.2 | 8.7 | 0.6 | 0.1 |
| 2008 | 118.7 | 0.1 | 0.0 | 0.0 | 13.9 | 99.9 | 0.6 | 0.1 | 3.7 | 0.0 | 0.0 |
| 2007 | 253.8 | 52.7 | 17.2 | 2.5 | 195.7 | 0.7 | 1.1 | 0.0 | 1.8 | 0.0 | 0.9 |
| 2006 | 68.1 | 0.2 | 0.0 | 0.2 | 31.0 | 3.0 | 0.2 | 8.0 | 19.9 | 4.6 | 0.0 |
| 2005 | 95.0 | 15.4 | 14.3 | 1.1 | 36.5 | 12.1 | 1.8 | 2.1 | 18.3 | 4.7 | 0.1 |
| 2004 | 41.9 | 3.8 | 3.4 | 0.3 | 20.4 | 0.0 | 1.1 | 0.0 | 5.2 | 6.6 | 0.3 |
| 2003 | 65.8 | 0.3 | 0.1 | 0.1 | 32.6 | 0.0 | 0.6 | 0.0 | 7.4 | 14.4 | 1.2 |
| 2002 | 55.2 | 1.2 | 0.7 | 0.4 | 28.2 | 0.5 | 0.1 | 0.0 | 6.8 | 10.8 | 1.0 |
| 2001 | 77.1 | 0.1 | 0.1 | 0.1 | 40.1 | 22.2 | 0.1 | 0.9 | 2.7 | 5.5 | 0.8 |
| 2000 | 52.1 | 0.1 | 0.1 | 0.0 | 43.4 | 0.0 | 0.1 | 2.1 | 0.0 | 3.9 | 0.0 |

| Year | All Species | All Alosa Sp. | Alewife | Blueback Herring | White Perch | Bay Anchovy | Spottail Shiner | Brown Bullhead | Blue Catfish | Channel Catfish | Tesselated Darter |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1999 | 23.1 | 0.0 | 0.0 | 0.0 | 18.9 | 0.2 | 0.0 | 0.2 | 0.0 | 2.4 | 0.0 |
| 1998 | 22.3 | 0.1 | 0.1 | 0.0 | 12.9 | 0.4 | 0.1 | 0.2 | 0.0 | 6.2 | 2.0 |
| 1997 | 50.1 | 0.0 | 0.0 | 0.0 | 37.8 | 0.0 | 1.1 | 0.4 | 0.0 | 9.1 | 0.4 |
| 1996 | 13.8 | 0.0 | 0.0 | 0.0 | 7.0 | 0.0 | 0.1 | 0.1 | 0.0 | 5.7 | 0.8 |
| 1995 | 30.5 | 0.3 | 0.3 | 0.0 | 16.8 | 0.2 | 0.2 | 4.2 | 0.0 | 8.0 | 0.1 |
| 1994 | 32.0 | 0.0 | 0.0 | 0.0 | 13.4 | 0.1 | 0.0 | 2.4 | 0.0 | 6.4 | 3.5 |
| 1993 | 31.2 | 0.1 | 0.0 | 0.1 | 6.4 | 0.0 | 6.2 | 1.4 | 0.0 | 6.8 | 7.5 |
| 1992 | 29.0 | 0.1 | 0.0 | 0.1 | 13.4 | 0.0 | 0.2 | 1.1 | 0.0 | 1.8 | 3.3 |
| 1991 | 70.9 | 0.1 | 0.1 | 0.0 | 43.7 | 2.0 | 0.1 | 1.1 | 0.0 | 15.9 | 0.2 |
| 1990 | 102.8 | 0.1 | 0.1 | 0.0 | 50.8 | 0.0 | 0.1 | 5.1 | 0.0 | 40.9 | 0.1 |
| 1989 | 14.2 | 1.0 | 0.2 | 0.8 | 7.8 | 0.4 | 0.0 | 1.5 | 0.0 | 1.9 | 0.3 |
| 1988 | 19.2 | 0.2 | 0.2 | 0.0 | 5.2 | 11.5 | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 |
| 1986 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

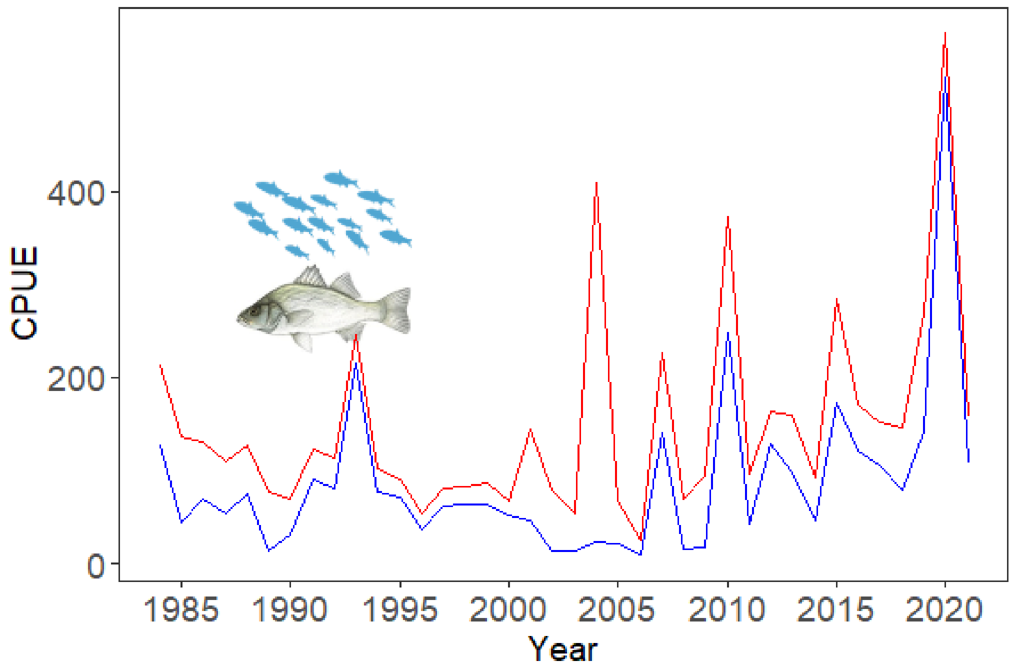



Figure 161. Trawls. Annual Averages. All Species (red) and *Morone americana* (blue). Cove Stations 7 and 10. 1984-2021.

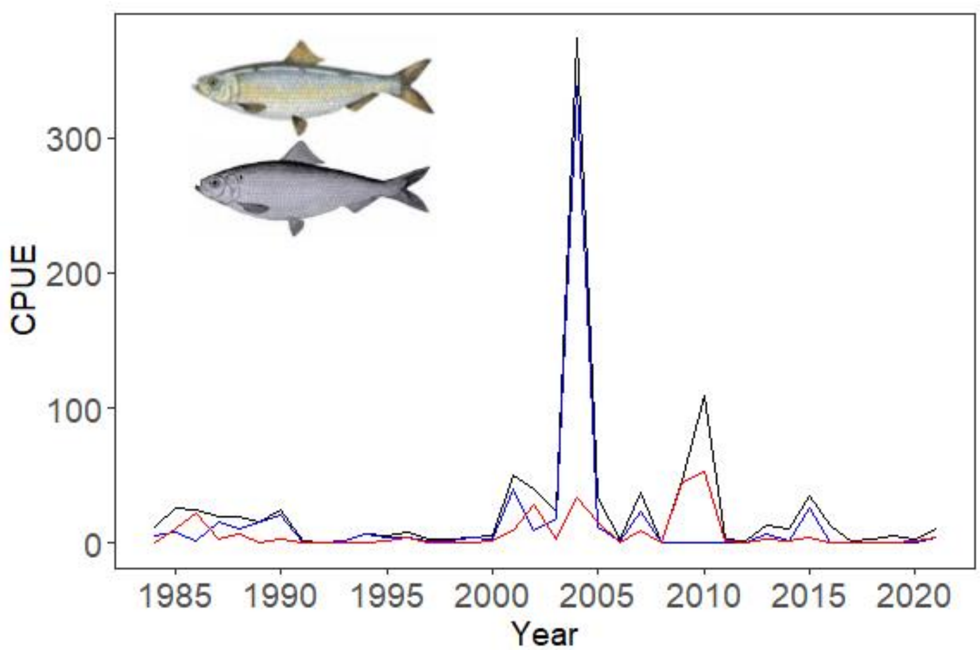



Figure 162. Trawls. Annual Averages. *Alosa aestivalis* (blue), *Alosa pseudoharengus* (red), and all combined *Alosa sp.* (black). Cove Stations 7 and 10.

Gizzard Shad (Dorosoma cepedianum) catch rates in trawls in 2021 were low which contributes to a pattern of low abundance after a high peak in 1989 (Figure 150). Smaller peaks later occurred in 1991, 1997, 2008, and 2012, that were all an order of magnitude lower than the 1989 peak. Bay Anchovy (Anchoa mitchilli) catch rates in 2021 were higher than both 2019 and 2020, but still within the range of the last five years at inner cove stations. Trends in the data suggests decreasing trend over the length of the survey. They are primarily resident in more saline portions of the estuary, and display sporadic occurrence in tidal freshwater. Any decreases in Gunston Cove therefore do not indicate a declining trend in the abundance of this species overall.

Spottail Shiner and sunfishes have been consistently collected in the majority of all trawl and seine samples (Figure 151). An increasing trend has been observed for Spottail Shiner since the beginning of the survey. In recent years (since 2000), a more sharply increasing pattern is seen in the midst of high variability, with high numbers in 2007, 2011, 2013, 2015, and 2018 (Figure 165). We collected an unprecedented high number of Spottail Shiner specimens in 2019. These individuals were mostly juveniles, indicating relatively high reproductive success as measured by this survey. In 2021 the numbers were lower than both 2019 and 2020, but higher than historical values, contributing to the increasing trend. The trends for sunfishes showed a similar pattern of higher abundance since 2005 than before. Other sunfish species than Bluegill and Pumpkinseed have been included in the trend, which better reveals the increases in sunfishes that also include Green Sunfish, Redbreast Sunfish, and hybrids. Peaks occurred in 2008, 2011, and 2017. Sunfishes are associated with SAV, so their trend seems closely aligned with the expansion of SAV in 2005.

Bullhead Catfish catches were once again low in 2021, fitting the trend of continuing decline that has proceeded continuously since the start of the survey (Figure 152). Tessellated Darter (*Etheostoma olmstedi*) numbers were higher than 2021, but still much lower than the 2018 highest observed abundance peak. The second highest peak in the period of record was observed in 1992. The slightly higher numbers in 2021 than 2020 tracks well with an increasing trend since 2005 as well. Potentially as a result of the SAV expansion mentioned above.

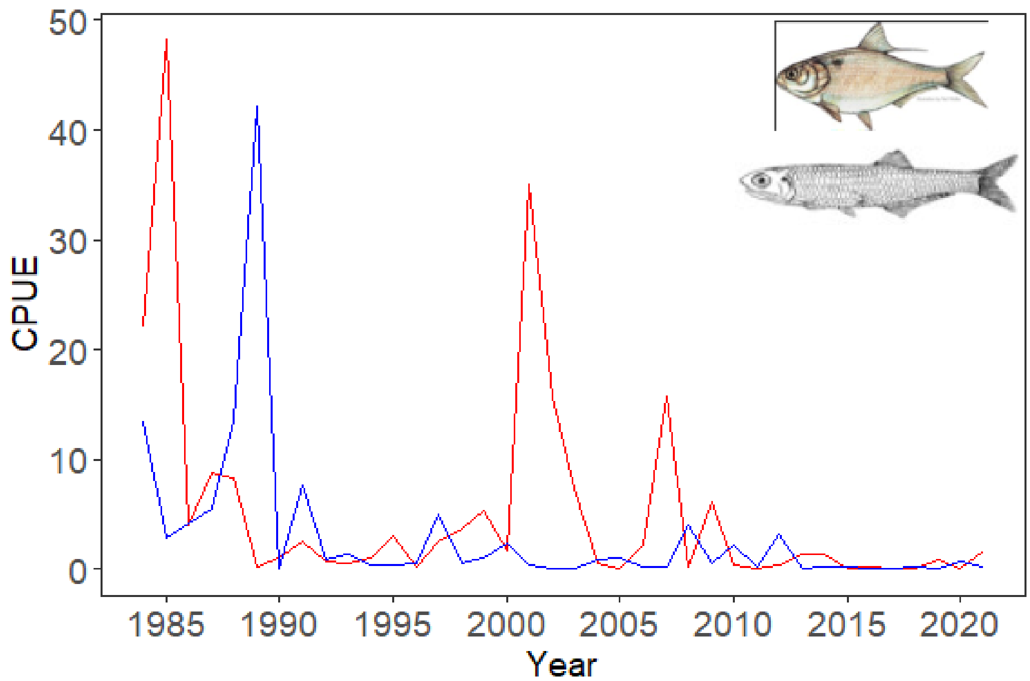



Figure 163. Trawls. Annual Averages. Cove Stations 7 and 10. *Dorosoma cepedianum* (blue) and *Anchoa mitchilli* (red).

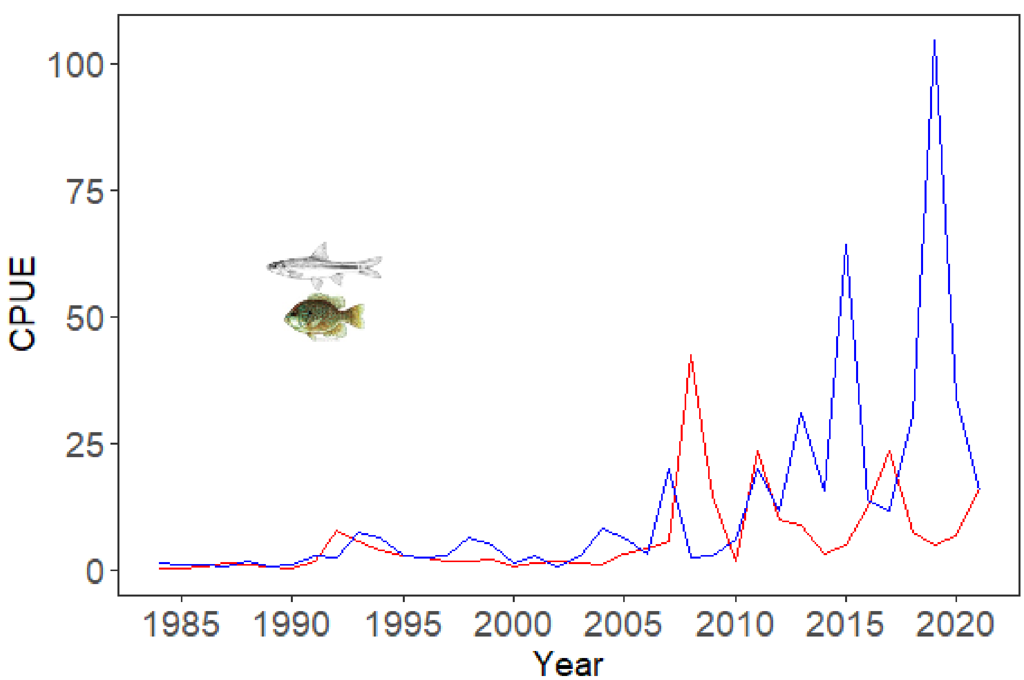



Figure 164. Trawls. Annual Averages. *Notropis hudsonius* (blue) and all *Lepomis sp.* (red). Cove Stations 7 and 10.

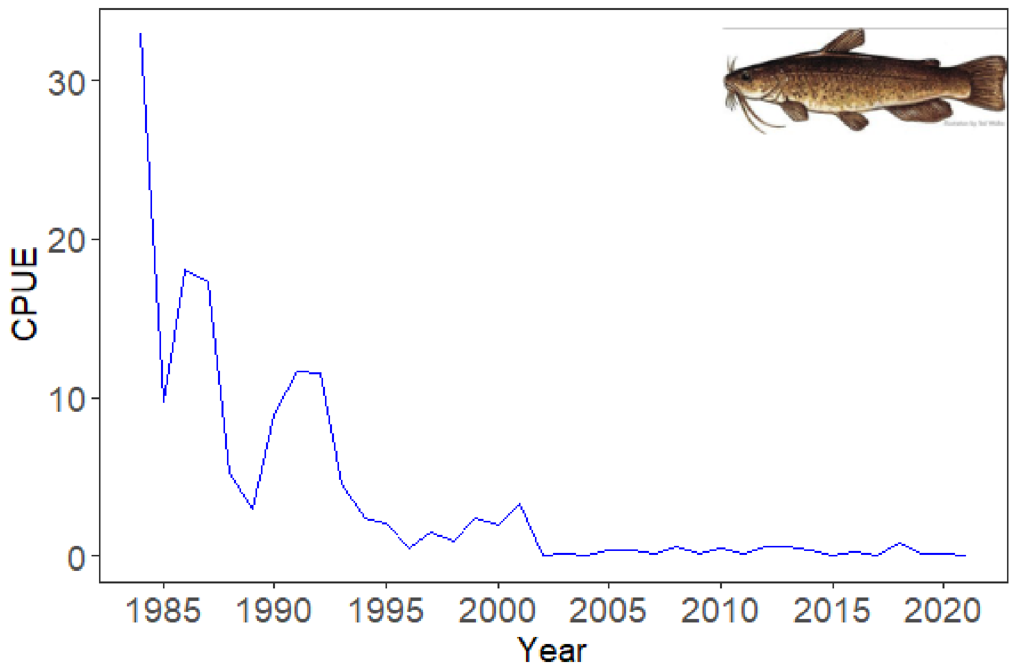



Figure 165. Annual Averages. *Ameiurus nebulosus*. Cove Stations 7 and 10.

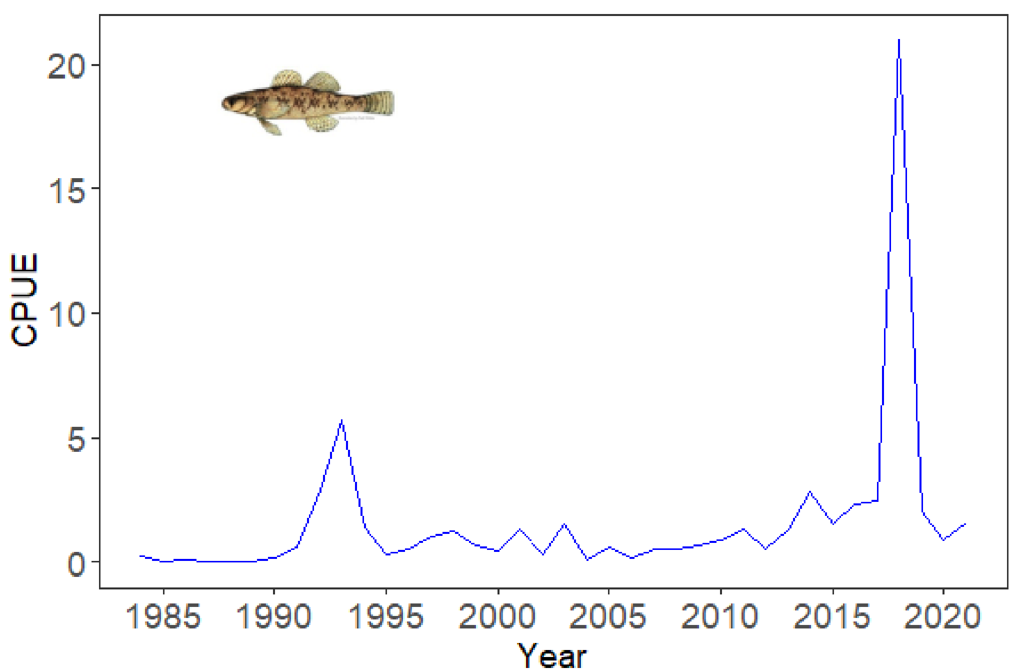



Figure 166. Trawls. Annual Averages of *Etheostoma olmstedi*. Cove stations 7 and 10.

Mean total catch at station 9 (river channel) in 2021 was similar to 2020 and lower than the previous few years (Table 19, Figure 154). Total catch was mainly comprised of White Perch, and both total catch and White Perch abundance decreased in 2021. The high total abundance in 2019 was due to catches of Spottail Shiner and Alosines. In 2018 an increase in catch was due to an increase in Blue Catfish catch. Blue Catfish was spotted in Station 9 again in 2019, 2020, and 2021 with 22 individuals collected. Blue Catfish are regularly collected at station 9 and rarely at the inner cove stations. Before 2017, Blue Catfish were never collected at the inner cove station, but a few were collected there too in 2017, 2018, 2019 and 2020. In 2021 Blue Catfish were collected at all stations demonstrating further encroachment into the cove.

Since 1988 when station 9 was incorporated as part of the survey, Bay Anchovy, Spottail Shiner, and American Eel have occurred sporadically at station 9 (Figure 155). We find high abundance of Bay Anchovy once every 5 years or so, with one very distinct peak in 2008. Spottail Shiner is found in low numbers every year at station 9, which saw an uptick in 2019, and remained relatively high in 2020, but decreased again in 2021. American Eel has remained rare since 1994.

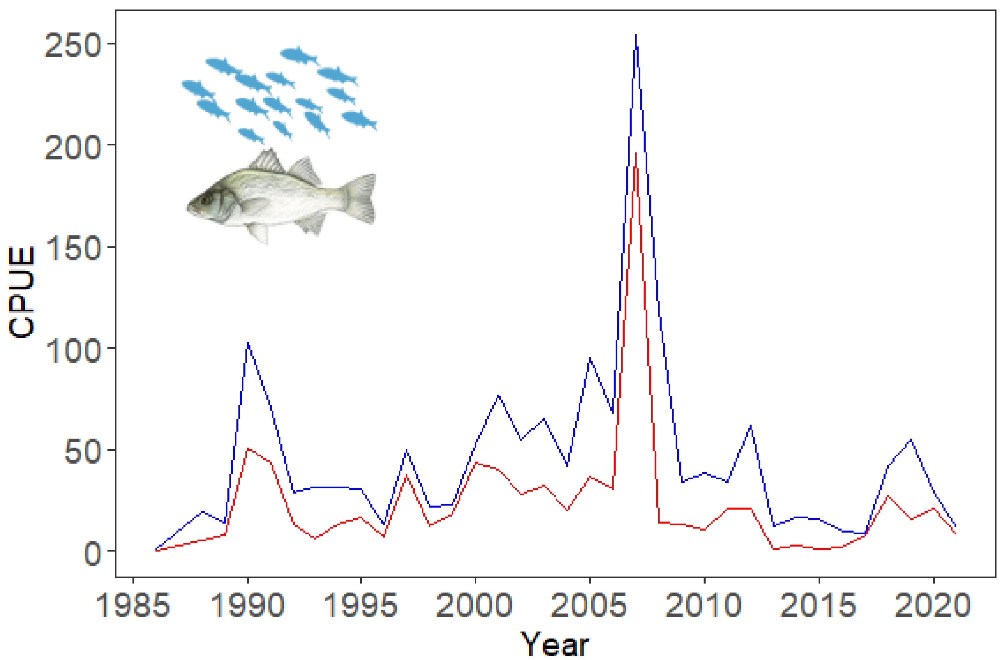



Figure 167. Trawls. Annual averages. River Station (9). Total catch (blue) and *Morone americana* (red).

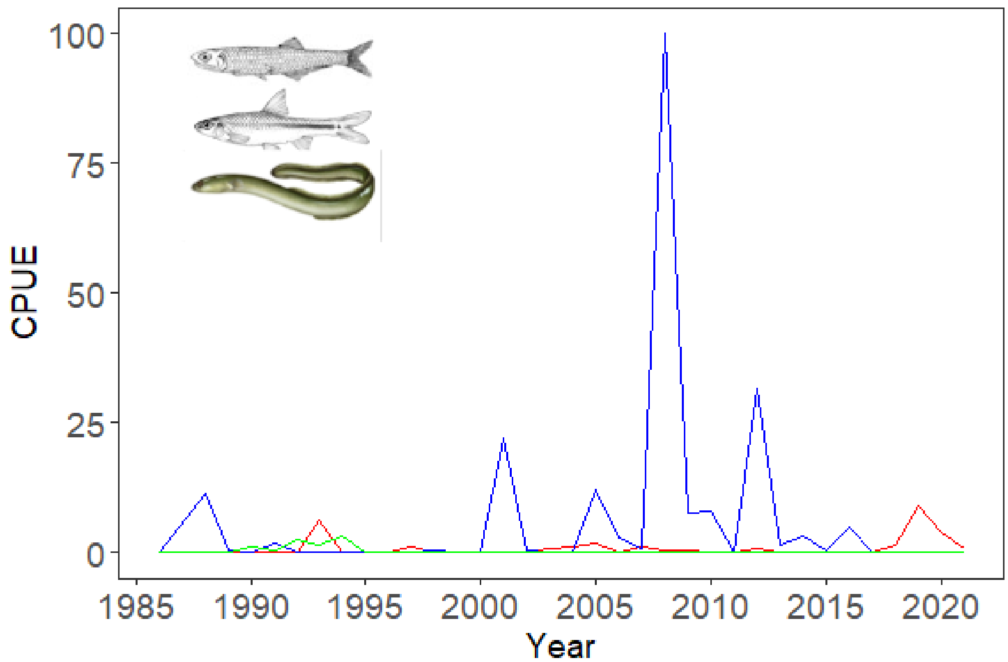



Figure 168. Trawls. Annual Averages. River Station (9). *Anchoa mitchilli* (Blue), *Notropis hudsonius* (red), and *Anguilla rostrata* (green).

Catch rates for native catfish species have been variable and low at station 9 since 2007 (Figure 156), with only a small peak from Channel Catfish in 2011. No native catfishes were collected at station 9 in 2021, but all three species were collected at stations 7 and 10. However, even with these few collected individuals, the long-term mean trends identifying a decline in native catfishes remain. The invasive Blue Catfish was positively identified on the survey in 2001 and has been captured in high numbers relative to White Bullhead, Channel Catfish and Brown Bullhead ever since (Figure 156). In 2021, we collected 22 Blue Catfish at station 9. Since Blue Catfish occupy the same niche, but can grow to larger sizes, it generally outcompetes the native catfish population (Schloesser et al., 2011). Blue Catfish numbers have remained relatively consistent over the last few years, albeit higher than native catfishes, potentially indicating a new stable state with decreased native and elevated invasive catfish. Continued monitoring in the growth of this population is warranted.

Station 9 generally represents low catch rates for the demersal species Tessellated Darter and Hogchoker (Figure 157). In 2018 however, while not unprecedented as in the cove, the mainstem saw a peak in Tessellated Darter abundance. Less were collected in 2019, but abundances were still above average for recent years. No Hogchokers or Tessellated Darters were collected in 2020, while a low number Tessellated Darters were collected in 2021, but Hogchokers remained absent from our catch.

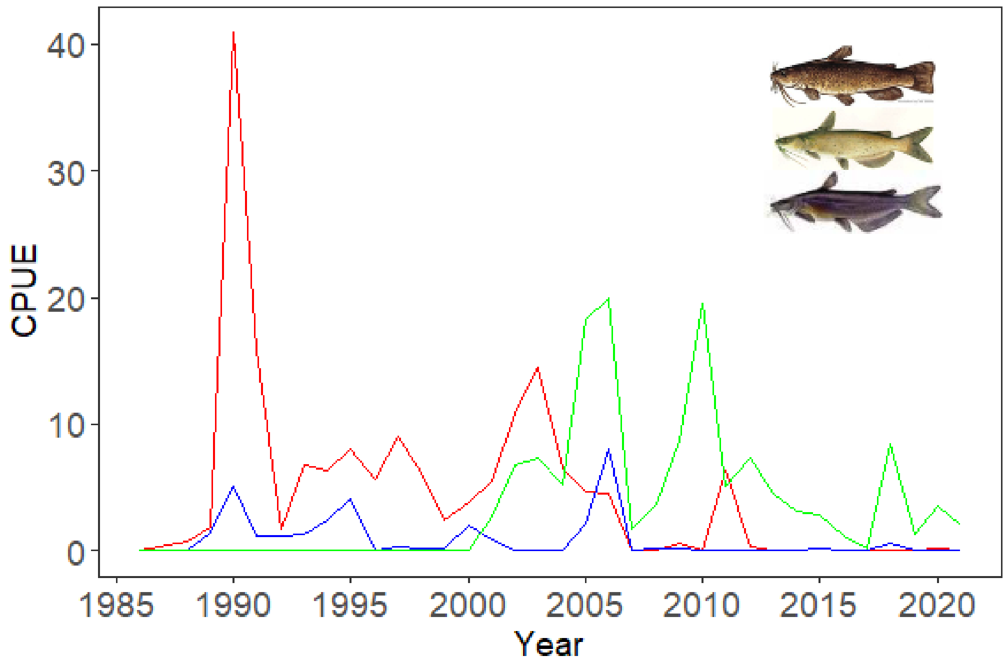



Figure 169. Trawls. Annual Averages. River Station (9). *Ameiurus nebulosus* (blue), *Ictalurus punctatus* (red), and *Ictalurus furcatus* (green).

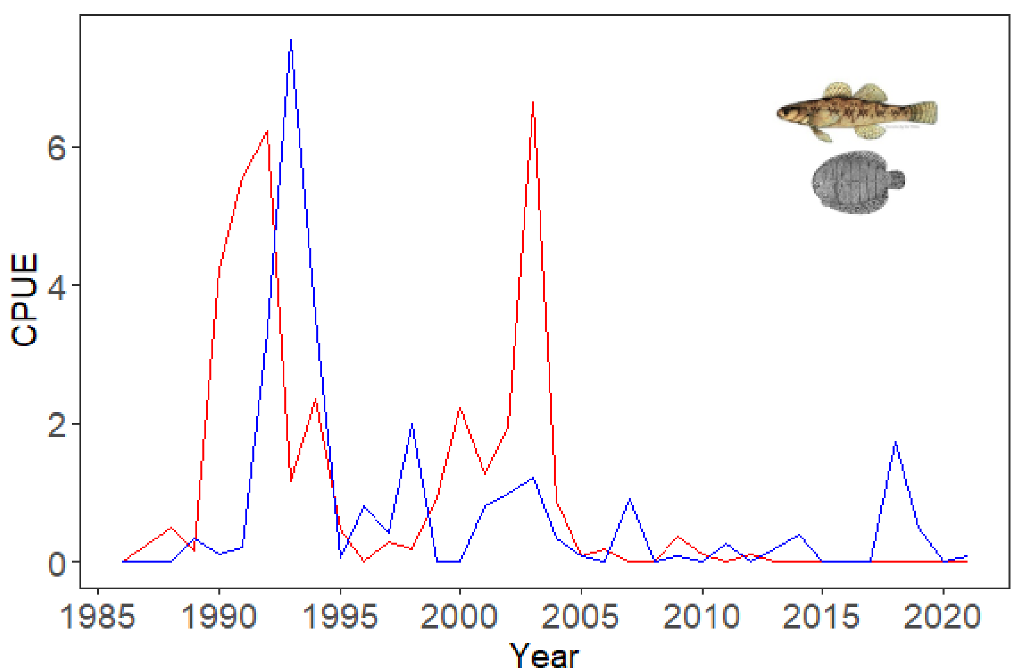



Figure 170. Trawls. Annual Averages. *Etheostoma olmstedi* (blue) and *Trinectes maculatus* (red). River Station (9).

The mean catch of all trawl stations combined in 2021 (106.1) was lower than 2020 (343.9, the highest year on record) and similar to the long-term mean of 103 (Table 20). While using catch per unit effort allows for between year comparisons, the low number of trawls performed in 2020 likely provided an overly high biased estimate. Our 2021 collections indicate that trawl CPUE has remained similar to the long-term average.

Table 23. Mean catch per trawl of selected adult and juvenile fishes for all months at Stations 7, 9, and 10 combined. 1984-2021.

| Year | All Species | White Perch | All Alosa Sp. | Blueback Herring | Alewife | Gizzard Shad | Bay Anchovy | Spottail Shiner | Brown Bullhead | Blue Catfish | Channel Catfish |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2021 | 106.1 | 72.1 | 7.5 | 2.9 | 3.1 | 0.1 | 1.2 | 10.5 | 0.0 | 0.8 | 0.0 |
| 2020 | 343.9 | 313.2 | 1.6 | 0.2 | 1.2 | 0.4 | 0.0 | 21.3 | 0.1 | 1.6 | 0.1 |
| 2019 | 179.8 | 89.5 | 13.1 | 4.1 | 5.2 | 0.0 | 0.5 | 64.6 | 0.1 | 0.6 | 0.0 |
| 2018 | 106.3 | 59.2 | 1.6 | 0.0 | 0.2 | 0.1 | 0.0 | 19.3 | 0.7 | 3.4 | 0.0 |
| 2017 | 89.6 | 63.9 | 0.7 | 0.0 | 0.3 | 0.0 | 0.0 | 6.6 | 0.0 | 0.2 | 0.0 |
| 2016 | 103.6 | 71.8 | 8.2 | 0.0 | 0.0 | 0.0 | 2.2 | 8.0 | 0.2 | 0.5 | 0.0 |
| 2015 | 161.2 | 94.0 | 23.3 | 14.2 | 5.8 | 0.1 | 0.2 | 35.0 | 0.1 | 1.3 | 0.1 |
| 2014 | 62.1 | 28.9 | 8.9 | 1.7 | 2.3 | 0.1 | 2.2 | 9.4 | 0.2 | 1.3 | 0.0 |
| 2013 | 102.4 | 60.8 | 9.6 | 4.4 | 2.6 | 0.2 | 1.5 | 19.1 | 0.4 | 2.3 | 0.0 |
| 2012 | 123.5 | 85.8 | 1.0 | 0.0 | 0.1 | 2.0 | 12.9 | 7.4 | 0.4 | 2.9 | 0.2 |
| 2011 | 74.5 | 35.6 | 2.3 | 0.1 | 0.9 | 0.1 | 0.0 | 12.9 | 0.1 | 2.0 | 2.3 |
| 2010 | 247.6 | 159.1 | 68.2 | 0.1 | 33.0 | 1.4 | 3.2 | 3.8 | 0.3 | 7.9 | 0.0 |
| 2009 | 73.4 | 16.7 | 31.4 | 0.8 | 29.9 | 0.4 | 6.7 | 1.9 | 0.2 | 3.0 | 0.3 |
| 2008 | 83.8 | 15.5 | 0.1 | 0.0 | 0.0 | 2.9 | 28.7 | 2.0 | 0.4 | 1.2 | 0.0 |
| 2007 | 236.1 | 159.5 | 42.4 | 16.6 | 11.6 | 0.1 | 10.7 | 13.8 | 0.1 | 0.7 | 0.0 |
| 2006 | 41.1 | 17.2 | 1.8 | 1.1 | 0.4 | 0.1 | 2.5 | 2.0 | 3.1 | 7.1 | 1.6 |
| 2005 | 77.8 | 26.5 | 26.8 | 8.0 | 15.6 | 0.7 | 4.3 | 4.9 | 1.0 | 7.0 | 1.8 |
| 2004 | 271.0 | 22.3 | 234.7 | 211.1 | 22.0 | 0.5 | 0.4 | 5.4 | 0.0 | 2.0 | 2.5 |
| 2003 | 58.1 | 19.7 | 16.0 | 12.6 | 2.3 | 0.0 | 4.9 | 2.1 | 0.1 | 2.5 | 5.4 |
| 2002 | 71.7 | 19.6 | 26.5 | 6.6 | 19.0 | 0.1 | 10.6 | 0.4 | 0.0 | 4.1 | 4.6 |
| 2001 | 122.3 | 44.8 | 34.5 | 27.6 | 6.8 | 0.3 | 31.0 | 1.9 | 2.5 | 0.9 | 1.8 |
| 2000 | 65.3 | 48.8 | 4.2 | 2.3 | 1.9 | 1.5 | 1.1 | 2.1 | 1.9 | 0.0 | 1.3 |
| 1999 | 65.6 | 48.4 | 3.1 | 2.8 | 0.3 | 0.7 | 3.7 | 3.2 | 1.7 | 0.0 | 0.8 |

| Year | All Species | White Perch | All Alosa Sp. | Blueback Herring | Alewife | Gizzard Shad | Bay Anchovy | Spottail Shiner | Brown Bullhead | Blue Catfish | Channel Catfish |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1998 | 62.9 | 46.8 | 2.0 | 1.4 | 0.6 | 0.4 | 2.6 | 4.3 | 0.7 | 0.0 | 2.1 |
| 1997 | 71.0 | 53.6 | 2.0 | 1.3 | 0.7 | 3.3 | 1.7 | 2.3 | 1.1 | 0.0 | 3.1 |
| 1996 | 36.0 | 23.7 | 4.5 | 2.1 | 2.3 | 0.3 | 0.1 | 1.5 | 0.3 | 0.0 | 2.4 |
| 1995 | 78.8 | 58.4 | 3.7 | 2.4 | 1.3 | 1.2 | 2.9 | 2.2 | 1.9 | 0.0 | 4.7 |
| 1994 | 90.5 | 68.1 | 2.4 | 2.3 | 0.1 | 0.3 | 0.8 | 6.5 | 1.4 | 0.0 | 2.1 |
| 1993 | 162.4 | 131.7 | 2.3 | 2.0 | 0.3 | 1.0 | 2.2 | 7.6 | 1.9 | 0.0 | 2.1 |
| 1992 | 119.8 | 88.2 | 1.3 | 0.6 | 0.7 | 0.4 | 1.0 | 2.3 | 4.5 | 0.0 | 1.5 |
| 1991 | 148.9 | 82.4 | 17.5 | 12.5 | 5.0 | 5.3 | 26.2 | 2.8 | 4.5 | 0.0 | 2.8 |
| 1990 | 67.5 | 31.2 | 19.1 | 16.1 | 3.0 | 0.1 | 0.8 | 2.5 | 4.0 | 0.0 | 6.9 |
| 1989 | 62.4 | 9.1 | 26.4 | 25.8 | 0.6 | 20.8 | 0.6 | 0.4 | 1.4 | 0.0 | 0.6 |
| 1988 | 79.5 | 32.9 | 18.8 | 14.4 | 3.3 | 6.9 | 13.7 | 1.2 | 2.4 | 0.0 | 0.3 |
| 1987 | 104.1 | 49.7 | 15.3 | 14.1 | 1.2 | 6.5 | 20.5 | 1.2 | 7.2 | 0.0 | 0.1 |
| 1986 | 84.1 | 49.3 | 13.2 | 2.5 | 10.7 | 2.3 | 4.9 | 0.8 | 7.2 | 0.0 | 0.1 |
| 1985 | 93.1 | 33.0 | 18.7 | 7.7 | 5.6 | 1.4 | 29.4 | 1.4 | 4.6 | 0.0 | 0.3 |
| 1984 | 149.3 | 95.4 | 7.9 | 4.8 | 0.4 | 6.4 | 17.7 | 1.9 | 14.1 | 0.0 | 0.4 |

Table 24. Mean catch per trawl of adult and juvenile fishes in all months at each station.

| Year | 7 | 9 | 10 |
|---|---|---|---|
| 2021 | 261.8 | 11.8 | 54.3 |
| 2020 | 789.4 | 29.2 | 17.0 |
| 2019 | 356.2 | 54.7 | 112.4 |
| 2018 | 199.7 | 41.8 | 88.6 |
| 2017 | 187.9 | 9.0 | 30.7 |
| 2016 | 224.3 | 10.1 | 35.8 |
| 2015 | 360.0 | 15.8 | 31.7 |
| 2014 | 103.2 | 16.9 | 70.4 |
| 2013 | 236.0 | 12.2 | 30.3 |
| 2012 | 225.4 | 62.1 | 42.6 |
| 2011 | 113.5 | 33.9 | 76.4 |
| 2010 | 616.7 | 38.7 | 7.3 |
| 2009 | 142.8 | 34.6 | 49.1 |
| 2008 | 49.8 | 118.7 | 89.9 |
| 2007 | 390.1 | 253.8 | 64.4 |
| 2006 | 40.7 | 68.1 | 7.8 |
| 2005 | 106.4 | 95.0 | 22.0 |
| 2004 | 740.5 | 41.9 | 28.9 |
| 2003 | 68.9 | 65.8 | 39.5 |
| 2002 | 88.8 | 55.2 | 70.9 |
| 2001 | 167.8 | 77.1 | 119.1 |
| 2000 | 95.1 | 52.1 | 42.5 |
| 1999 | 117.1 | 23.1 | 56.8 |
| 1998 | 88.2 | 22.3 | 78.2 |
| 1997 | 111.2 | 50.1 | 51.6 |
| 1996 | 73.9 | 13.8 | 31.5 |
| 1995 | 109.3 | 30.5 | 71.4 |
| 1994 | 144.9 | 32.0 | 60.7 |
| 1993 | 377.1 | 31.2 | 116.1 |
| 1992 | 155.5 | 29.0 | 70.2 |
| 1991 | 185.9 | 70.9 | 66.5 |
| 1990 | 76.5 | 102.8 | 62.0 |

| Year | 7 | 9 | 10 |
|---|---|---|---|
| 1989 | 52.6 | 14.2 | 103.8 |
| 1988 | 154.8 | 19.2 | 98.5 |
| 1987 | 84.6 | NA | 136.9 |
| 1986 | 101.8 | 1.0 | 157.1 |
| 1985 | 123.0 | NA | 148.8 |
| 1984 | 220.6 | NA | 205.8 |

Table 25. The number of trawls per station in each month at Stations 7, 9, and 10 in each year.

| Year | Station | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2021 | 10 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2021 | 7 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2021 | 9 | 0 | 0 | 1 | 2 | 3 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2020 | 10 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 2020 | 7 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2020 | 9 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2019 | 10 | 0 | 0 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2019 | 7 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2019 | 9 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2018 | 10 | 0 | 0 | 1 | 2 | 2 | 2 | 1 | 1 | 0 | 0 | 0 |
| 2018 | 7 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2018 | 9 | 0 | 0 | 1 | 2 | 4 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2017 | 10 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2017 | 7 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2017 | 9 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2016 | 10 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2016 | 7 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2016 | 9 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2015 | 10 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2015 | 7 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2015 | 9 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 0 |
| 2014 | 10 | 0 | 0 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2014 | 7 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2014 | 9 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2013 | 10 | 0 | 0 | 1 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |

| Year | Station | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2013 | 7 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2013 | 9 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2012 | 10 | 0 | 0 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2012 | 7 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2012 | 9 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2011 | 10 | 0 | 0 | 1 | 2 | 3 | 2 | 0 | 1 | 0 | 0 | 0 |
| 2011 | 7 | 0 | 0 | 1 | 2 | 3 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2011 | 9 | 0 | 0 | 1 | 2 | 3 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2010 | 10 | 0 | 0 | 1 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| 2010 | 7 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2010 | 9 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2009 | 10 | 0 | 0 | 1 | 2 | 2 | 2 | 3 | 1 | 0 | 0 | 0 |
| 2009 | 7 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2009 | 9 | 0 | 0 | 1 | 3 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2008 | 10 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2008 | 7 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2008 | 9 | 0 | 0 | 1 | 1 | 2 | 1 | 2 | 1 | 0 | 0 | 0 |
| 2007 | 10 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2007 | 7 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2007 | 9 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2006 | 10 | 0 | 0 | 1 | 2 | 2 | 1 | 2 | 0 | 0 | 0 | 0 |
| 2006 | 7 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2006 | 9 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2005 | 10 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 |
| 2005 | 7 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 0 | 0 |
| 2005 | 9 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 0 | 0 |
| 2004 | 10 | 0 | 0 | 0 | 1 | 2 | 2 | 1 | 1 | 0 | 0 | 0 |
| 2004 | 7 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2004 | 9 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2003 | 10 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |
| 2003 | 7 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |
| 2003 | 9 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |
| 2002 | 10 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 2002 | 7 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 2002 | 9 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 2001 | 10 | 0 | 1 | 2 | 2 | 1 | 2 | 3 | 2 | 1 | 1 | 1 |

| Year | Station | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 7 | 0 | 1 | 2 | 2 | 1 | 2 | 3 | 2 | 1 | 1 | 1 |
| 2001 | 9 | 0 | 1 | 2 | 1 | 1 | 2 | 3 | 2 | 1 | 1 | 1 |
| 2000 | 10 | 0 | 1 | 2 | 2 | 3 | 2 | 3 | 2 | 1 | 1 | 1 |
| 2000 | 7 | 0 | 1 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| 2000 | 9 | 0 | 1 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| 1999 | 10 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 1999 | 7 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 1999 | 9 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 1998 | 10 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 1998 | 7 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 1998 | 9 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 1997 | 10 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 |
| 1997 | 7 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 |
| 1997 | 9 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 |
| 1996 | 10 | 0 | 1 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 1 |
| 1996 | 7 | 0 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 |
| 1996 | 9 | 0 | 1 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 1 |
| 1995 | 10 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 0 |
| 1995 | 7 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 0 |
| 1995 | 9 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 1 | 0 |
| 1994 | 10 | 0 | 1 | 1 | 1 | 2 | 2 | 0 | 2 | 2 | 1 | 0 |
| 1994 | 7 | 0 | 1 | 1 | 1 | 2 | 2 | 0 | 2 | 2 | 1 | 0 |
| 1994 | 9 | 0 | 0 | 1 | 1 | 2 | 2 | 0 | 2 | 2 | 1 | 0 |
| 1993 | 10 | 0 | 0 | 1 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 1 |
| 1993 | 7 | 0 | 0 | 1 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 1 |
| 1993 | 9 | 0 | 1 | 1 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 1 |
| 1992 | 10 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1992 | 7 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1992 | 9 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1991 | 10 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1991 | 7 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1991 | 9 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1990 | 10 | 0 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 1990 | 7 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 1990 | 9 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 1989 | 10 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 0 |

| Year | Station | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1989 | 7 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 0 |
| 1989 | 9 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 0 |
| 1988 | 10 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 0 |
| 1988 | 7 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 0 |
| 1988 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 0 |
| 1987 | 10 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 1987 | 7 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1986 | 10 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1986 | 7 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1986 | 9 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1985 | 10 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 2 | 1 | 0 |
| 1985 | 7 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 2 | 1 | 0 |
| 1984 | 10 | 0 | 1 | 2 | 4 | 3 | 4 | 2 | 4 | 5 | 2 | 1 |
| 1984 | 7 | 0 | 1 | 2 | 4 | 2 | 4 | 2 | 5 | 5 | 2 | 1 |

## Seines

*Overall Patterns*

The long-term trend of seine catches shows a stable pattern of catches amidst inter-annual variability (Table 23, Figure 172). Of the three most abundant years high catches were due to a high abundance of Alosines those years: 1994 and 2004 were driven primarily by large catches of Alewife, whereas high catch rates in 1991 were a result of high catch rates of Blueback Herring (Table 23). The most abundant species in seine catches overall and in 2020 is Banded Killifish.  The number of seine tows over the period of record is shown in Table 24.

Table 26. Mean Catch per Seine of Selected Adult and Juvenile Fishes at all Stations and all Months. 1985-2021.

| Year | All Species | White Perch | Banded Killifish | Blueback Herring | Alewife | All Alosa Sp | Spottail Shiner | Inland Silverside |
|---|---|---|---|---|---|---|---|---|
| 2021 | 328.6 | 20.8 | 231.1 | 0.7 | 0.8 | 5.2 | 4.1 | 17.6 |
| 2020 | 139.4 | 8.9 | 70.2 | 0.0 | 5.8 | 11.2 | 1.7 | 5.8 |
| 2019 | 112.6 | 15.4 | 42.6 | 0.0 | 0.6 | 28.3 | 1.3 | 4.9 |

| Year | All Species | White Perch | Banded Killifish | Blueback Herring | Alewife | All Alosa Sp | Spottail Shiner | Inland Silverside |
|---|---|---|---|---|---|---|---|---|
| 2018 | 118.5 | 4.5 | 50.5 | 0.0 | 0.0 | 46.4 | 2.3 | 1.8 |
| 2017 | 100.9 | 9.2 | 57.9 | 0.0 | 0.3 | 0.9 | 2.0 | 14.9 |
| 2016 | 114.3 | 11.6 | 64.5 | 0.0 | 0.0 | 6.9 | 1.2 | 8.1 |
| 2015 | 171.2 | 33.1 | 76.1 | 0.5 | 0.4 | 17.1 | 5.2 | 4.7 |
| 2014 | 169.5 | 11.9 | 121.4 | 3.5 | 0.1 | 8.3 | 4.1 | 4.1 |
| 2013 | 117.4 | 8.3 | 92.6 | 0.1 | 0.2 | 2.1 | 0.4 | 0.7 |
| 2012 | 186.0 | 5.4 | 131.7 | 0.0 | 2.1 | 4.5 | 6.1 | 12.4 |
| 2011 | 140.8 | 31.0 | 76.3 | 0.0 | 1.3 | 2.0 | 2.4 | 1.5 |
| 2010 | 249.4 | 15.8 | 175.6 | 0.1 | 1.6 | 4.6 | 1.6 | 1.3 |
| 2009 | 186.5 | 18.7 | 67.4 | 0.3 | 0.1 | 1.4 | 3.6 | 6.9 |
| 2008 | 196.5 | 15.4 | 51.8 | 0.3 | 0.1 | 2.5 | 3.0 | 14.9 |
| 2007 | 130.4 | 15.0 | 40.6 | 6.7 | 2.2 | 17.6 | 3.4 | 2.3 |
| 2006 | 165.3 | 7.6 | 113.7 | 3.2 | 0.4 | 6.2 | 3.6 | 16.2 |
| 2005 | 202.0 | 32.0 | 125.2 | 1.0 | 5.4 | 7.2 | 9.7 | 5.6 |
| 2004 | 304.5 | 45.3 | 99.1 | 11.1 | 73.8 | 85.2 | 38.1 | 9.5 |
| 2003 | 100.6 | 7.5 | 42.9 | 2.3 | 2.8 | 7.5 | 7.3 | 4.8 |
| 2002 | 164.4 | 23.1 | 89.7 | 0.0 | 2.2 | 3.2 | 12.5 | 14.4 |
| 2001 | 134.0 | 30.2 | 54.6 | 0.0 | 4.9 | 5.6 | 14.3 | 7.6 |
| 2000 | 152.2 | 28.9 | 26.2 | 1.7 | 6.0 | 7.7 | 23.5 | 50.1 |
| 1999 | 108.1 | 18.3 | 19.0 | 14.4 | 0.4 | 14.8 | 12.3 | 25.0 |
| 1998 | 111.6 | 22.2 | 31.6 | 2.1 | 1.0 | 3.1 | 25.9 | 8.7 |
| 1997 | 96.8 | 12.8 | 34.0 | 17.6 | 1.5 | 19.0 | 4.5 | 13.8 |
| 1996 | 103.6 | 29.1 | 18.2 | 15.4 | 5.4 | 22.2 | 11.8 | 4.7 |
| 1995 | 88.8 | 26.1 | 16.3 | 2.1 | 2.8 | 5.0 | 5.8 | 12.5 |
| 1994 | 294.9 | 15.6 | 13.9 | 0.0 | 250.2 | 250.2 | 7.2 | 0.1 |
| 1993 | 73.6 | 13.4 | 26.1 | 3.2 | 1.3 | 4.5 | 8.5 | 9.1 |
| 1992 | 154.5 | 43.6 | 35.8 | 39.2 | 0.0 | 39.2 | 9.0 | 5.8 |
| 1991 | 204.9 | 30.2 | 45.1 | 66.2 | 0.2 | 66.4 | 17.5 | 6.0 |
| 1990 | 118.7 | 41.2 | 27.8 | 7.4 | 1.1 | 8.5 | 9.0 | 4.0 |
| 1989 | 130.8 | 39.9 | 25.8 | 1.8 | 0.5 | 2.2 | 8.1 | 1.9 |
| 1988 | 146.5 | 42.1 | 48.6 | 2.2 | 0.3 | 2.6 | 9.3 | 6.2 |
| 1987 | 108.9 | 36.7 | 31.9 | 0.0 | 0.0 | 0.0 | 8.0 | 11.6 |
| 1986 | 130.5 | 55.1 | 15.3 | 0.2 | 0.8 | 1.3 | 6.4 | 20.0 |
| 1985 | 120.2 | 36.8 | 11.7 | 0.0 | 0.1 | 0.2 | 13.2 | 29.3 |

Table 27. The number of seines in each month at Station 4, 4B, 6, and 11 in each year. 1985-2021.

| Year | Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2021 | 4 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2021 | 6 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 | 0 |
| 2021 | 11 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2021 | 4B | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2020 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| 2020 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2020 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2020 | 4B | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2019 | 4 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| 2019 | 6 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2019 | 11 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2019 | 4B | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2018 | 4 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2018 | 6 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2018 | 11 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2018 | 4B | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2017 | 4 | 0 | 0 | 0 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2017 | 6 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2017 | 11 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2017 | 4B | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2016 | 4 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2016 | 6 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2016 | 11 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2016 | 4B | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2015 | 4 | 0 | 0 | 0 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2015 | 6 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2015 | 11 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2015 | 4B | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2014 | 4 | 0 | 0 | 0 | 1 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 |
| 2014 | 6 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2014 | 11 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2014 | 4B | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2013 | 4 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 | 0 |
| 2013 | 6 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |

| Year | Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2013 | 11 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2013 | 4B | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2012 | 4 | 0 | 0 | 0 | 1 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| 2012 | 6 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2012 | 11 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2012 | 4B | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2011 | 4 | 0 | 0 | 0 | 1 | 3 | 3 | 3 | 2 | 1 | 0 | 0 | 0 |
| 2011 | 6 | 0 | 0 | 0 | 1 | 2 | 3 | 2 | 2 | 0 | 1 | 0 | 0 |
| 2011 | 11 | 0 | 0 | 0 | 1 | 2 | 3 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2011 | 4B | 0 | 0 | 0 | 1 | 2 | 3 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2010 | 4 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2010 | 6 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2010 | 11 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2010 | 4B | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2009 | 4 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2009 | 6 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2009 | 11 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2009 | 4B | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2008 | 4 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2008 | 6 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2008 | 11 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2008 | 4B | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2007 | 4 | 0 | 0 | 0 | 1 | 2 | 1 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2007 | 6 | 0 | 0 | 0 | 1 | 2 | 1 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2007 | 11 | 0 | 0 | 0 | 1 | 2 | 1 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2007 | 4B | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2006 | 4 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 2006 | 6 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| 2006 | 11 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2005 | 4 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 | 0 |
| 2005 | 6 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 | 0 |
| 2005 | 11 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 0 | 0 |
| 2004 | 4 | 0 | 0 | 0 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| 2004 | 6 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2004 | 11 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 |
| 2003 | 4 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 |

| Year | Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2003 | 6 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 |
| 2003 | 11 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 |
| 2002 | 4 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 2002 | 6 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 2002 | 11 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 2001 | 4 | 0 | 0 | 1 | 2 | 2 | 1 | 2 | 3 | 2 | 1 | 1 | 1 |
| 2001 | 6 | 0 | 0 | 1 | 2 | 2 | 1 | 2 | 3 | 2 | 0 | 1 | 1 |
| 2001 | 11 | 0 | 0 | 1 | 2 | 2 | 1 | 2 | 3 | 2 | 1 | 1 | 1 |
| 2000 | 4 | 0 | 0 | 1 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| 2000 | 6 | 0 | 0 | 1 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| 2000 | 11 | 0 | 0 | 1 | 2 | 2 | 3 | 1 | 2 | 0 | 1 | 1 | 2 |
| 1999 | 4 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 1 | 1 |
| 1999 | 6 | 0 | 0 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 1 |
| 1999 | 11 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 1998 | 4 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 1998 | 6 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 1998 | 11 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 1997 | 4 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 |
| 1997 | 6 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 |
| 1997 | 11 | 0 | 0 | 1 | 3 | 4 | 2 | 2 | 2 | 2 | 2 | 1 | 1 |
| 1996 | 4 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 |
| 1996 | 6 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 |
| 1996 | 11 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 |
| 1995 | 4 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 0 |
| 1995 | 6 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 0 |
| 1995 | 11 | 0 | 0 | 1 | 2 | 2 | 1 | 2 | 2 | 3 | 2 | 1 | 0 |
| 1994 | 4 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1994 | 6 | 0 | 0 | 3 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1994 | 11 | 0 | 0 | 3 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1993 | 4 | 0 | 0 | 1 | 2 | 2 | 1 | 3 | 2 | 0 | 1 | 1 | 1 |
| 1993 | 6 | 0 | 0 | 1 | 1 | 2 | 1 | 3 | 2 | 0 | 1 | 1 | 1 |
| 1993 | 11 | 0 | 0 | 1 | 2 | 2 | 1 | 3 | 2 | 0 | 1 | 1 | 1 |
| 1992 | 4 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1992 | 6 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1992 | 11 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1991 | 4 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |

| Year | Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1991 | 6 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 0 |
| 1991 | 11 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1990 | 4 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 1990 | 6 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 1990 | 11 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 1989 | 4 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1989 | 6 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1989 | 11 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 1988 | 4 | 0 | 0 | 1 | 1 | 0 | 2 | 2 | 1 | 1 | 1 | 1 | 0 |
| 1988 | 6 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 0 |
| 1988 | 11 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 0 |
| 1987 | 4 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 1987 | 6 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| 1987 | 11 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 1986 | 4 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 3 | 4 | 0 | 0 |
| 1986 | 6 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 5 | 2 | 1 | 0 |
| 1986 | 11 | 2 | 1 | 0 | 1 | 1 | 1 | 0 | 2 | 4 | 4 | 1 | 0 |
| 1985 | 4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 3 | 4 | 0 |
| 1985 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 3 | 4 | 0 |
| 1985 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 3 | 4 | 0 |

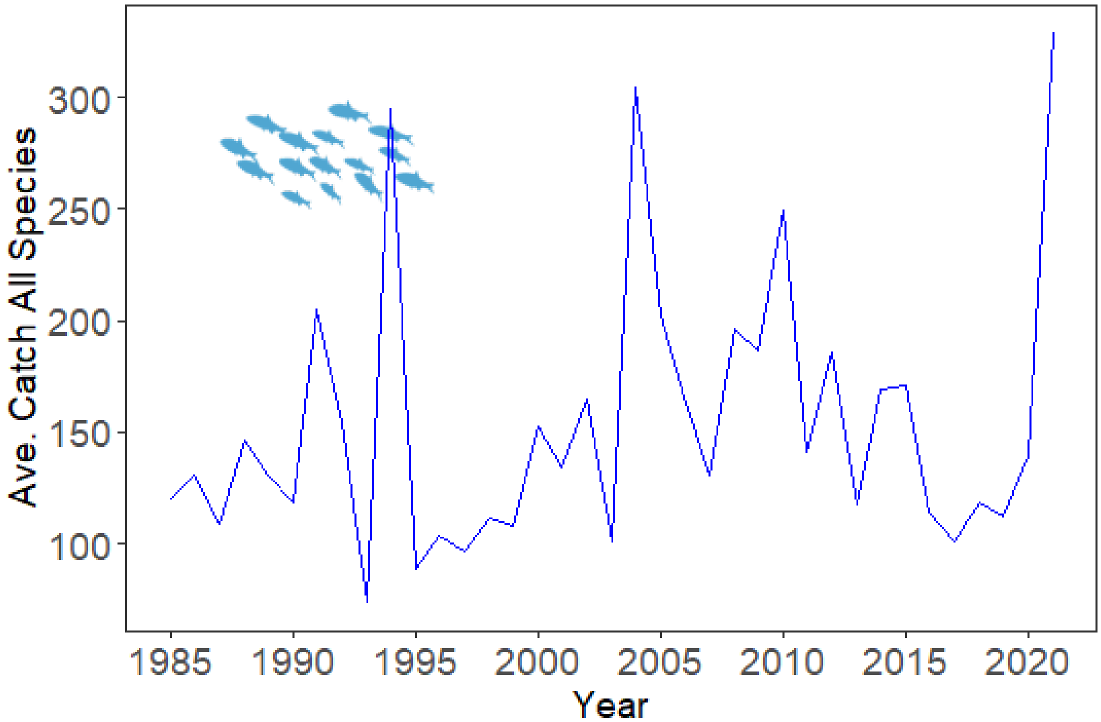



Figure 171. Seines. Annual Average over Stations 4, 4A, 6, and 11. All Species. 1985-2020.

Banded Killifish and White Perch have been the dominant species in seine samples throughout the survey. In 2021, the general trend of decreasing White Perch catches and increasing Banded Killifish catches over the period of record continued (Figures 159 and 160). However, both Banded Killifish and White Perch CPUE increased in 2021 when compared with 2020 and 2019. The decrease in White Perch seen in seine catches is indication of the shifted ecosystem state to an SAV dominated system, since Banded Killifish prefers SAV habitat, while White Perch prefers open water. The decreasing trend in white Perch, and increasing trend in Banded Killifish, seems to be leveling out, especially considering that both species CPUE tracked together this year. This could be indicative of a new stable state in the relative contribution of these two species. Subsequent years will determine whether this is indeed the case.

The relative success of Banded Killifish is coincidentally (rather than functionally related) to declines in White Perch as these species show very little overlap in ecological and life history characteristics. Instead, as mentioned above, prominent increases in mean catch rates of Banded Killifish are associated with development of SAV in the cove since 2000. The SAV provides refuge for Banded Killifish adults and juveniles and may enhance feeding opportunities with epifaunal prey items. Essentially, the habitat of White Perch in Gunston Cove has decreased, while the habitat of Banded Killifish has increased. However, White Perch does reside in SAV covered areas as well, just in lower numbers

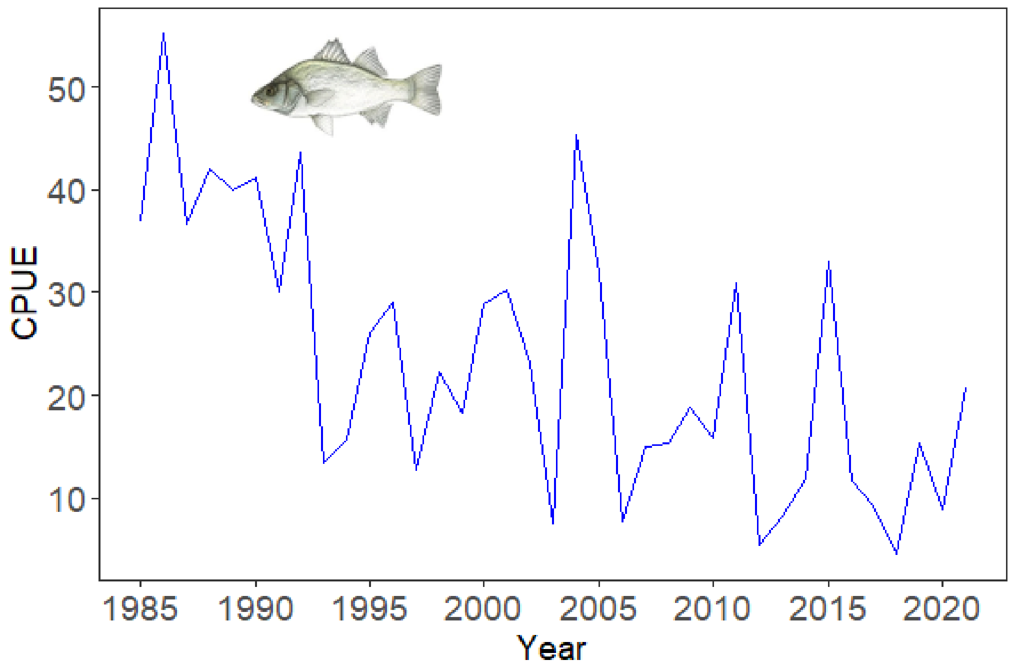



Figure 172. Seines. Annual Average Stations 4, 4A, 6, and 11. *Morone americana*. 1985-2020.

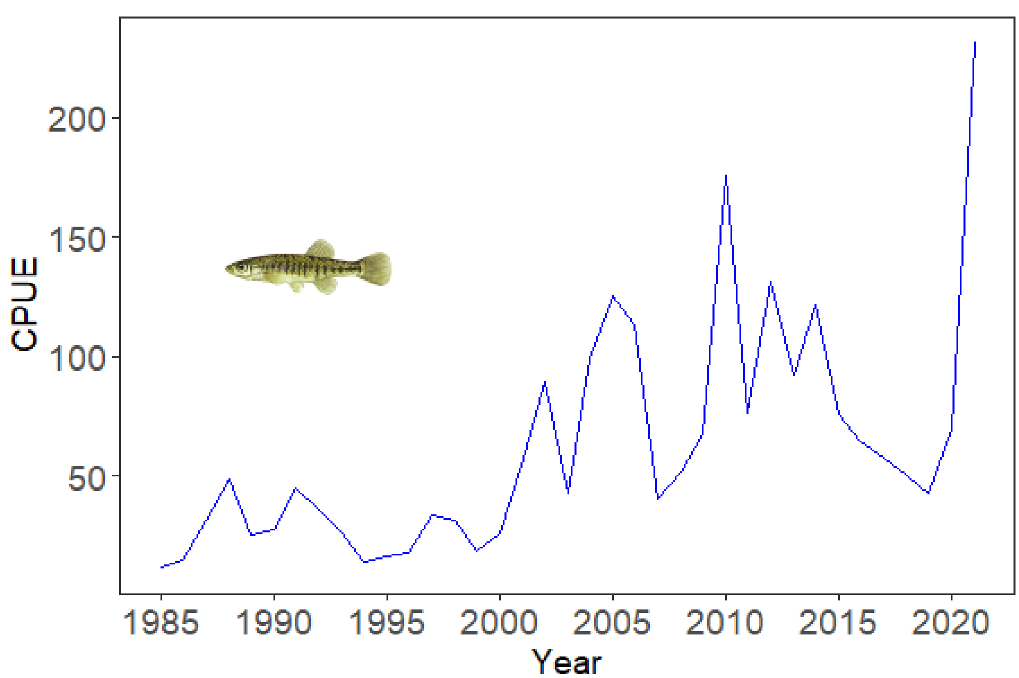



Figure 173. Seines. Annual Average Stations 4, 4A, 6, and 11. *Fundulus diaphanus*. 1985-2020.

Mean annual catch rates for river herring (Alewife and Blueback Herring) have exhibited sporadic peaks related to the capture of a large schools of fish (exceeding 200 for Alewife and approaching 100 individuals for Blueback Herring) in single hauls (Figure 161). Typically, less than 10 of either species were captured in a single sample. Both Alewife and Blueback Herring are listed as species of concern and have experienced declines throughout the Chesapeake Bay watershed. The moratorium on river herring since January 2012 has been put in place as an aid in the recovery. The moratorium (on fishing) may result in an increase in river herring over time. We added the category 'all Alosa sp.' to figure 161 in 2016 because a large portion of the Alosines cannot be identified to the species level. That revealed that Alosine abundances have been slightly higher since 2005 then just based on Alewife and Blueback Herring findings. For example, relatively high peaks in Alosines have been found in 2007, 2010, 2015, 2018, and 2019. In 2020 a declining trend started that has continued through 2021. Abundances are not sufficiently high that the stocks can be considered recovered. Continued monitoring will be key in determining the success of the moratorium. The high numbers of spawning adult river herring in 2015 in Pohick Creek, as described in the 2015 Anadromous Report, could signal the start of the recovery of these species. After lower abundances in 2016 and 2017, 2018 showed another peak for Alewife, indicating the large cohort of 2015 successfully returned to spawn (described in the 2018 Anadromous Report). Moderate levels of spawning adults were collected again in 2019, and 2020 could not be sampled because the spawning season of River herring occurred during the lockdown in response to the COVID-19 pandemic. In 2021, River Herring sampling commenced and our results are detailed in the Anadromous Report.

Owing to their affinity for marginal and littoral zone habitats, Spottail Shiner and Inland Silverside are consistently captured at moderate abundances throughout the course of the survey (Figure 162). Highest peaks occurred in 1999 and 2004 for Inland Silverside and Spottail Shiner respectively (Figure 162). After these high peaks, Inland Silverside remained relatively abundant with small peaks in 2006, 2008, 2012, 2017. In 2021, we recorded the highest abundances of Inland Silversides sine the 1999 peak. Spottail Shiner also increased in seine collections above their 2020 value.

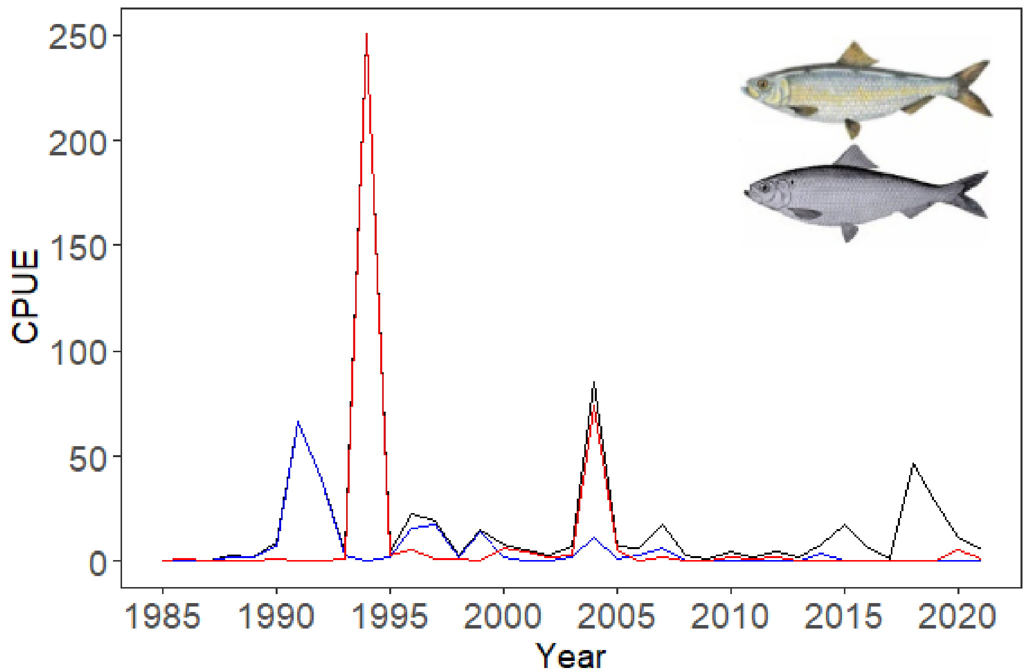



Figure 174. Seines. Annual Average over 4, 4A, 6, and 11 Stations. *Alosa aestivalis* (blue), *A. pseudoharengus* (red), and all *Alosa sp.* (black; *A. aestivalis*, *A. pseudoharengus*, *A. mediocris*, *A. sapidissima*, and unidentified Herring and Shad species). 1985-2020.

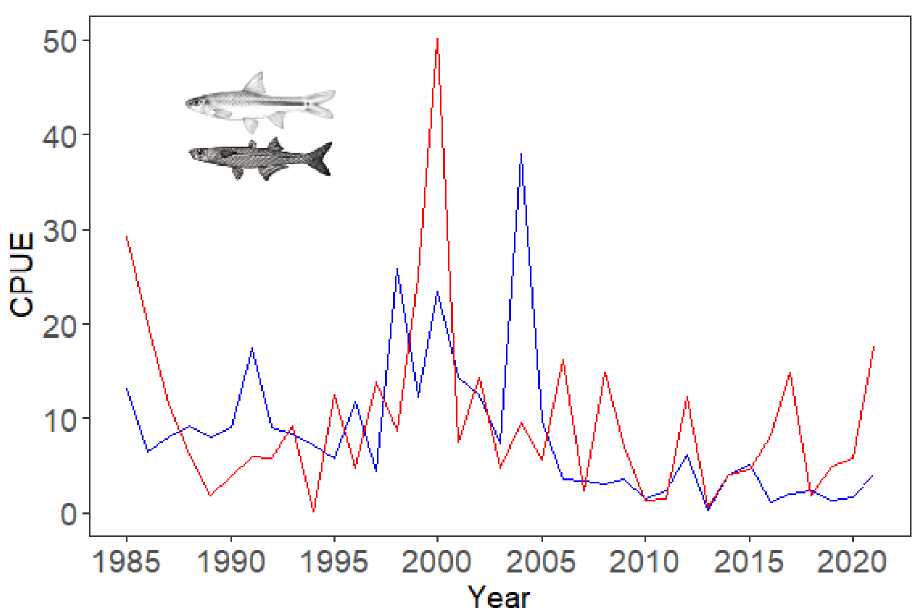



Figure 175. Seines. Annual Average over 4, 4A, 6, and 11 Stations. *Notropis hudsonius* (blue) and *Menidia beryllina* (red). 1985-2020.

**Fyke nets**

*Overall Patterns*

In 2012, fyke nets were added to the sampling gear near Station 4 (seine station where SAV interferes halfway during the sampling season) and Station 10 (trawl station where SAV interferes with sampling halfway during the sampling season). After very high abundance of sunfishes in the fyke nets in the first year (2012), the fyke net collections have seen moderate abundances evenly distributed over species that prefer SAV beds as habitat (Table 25, Figure 163). For the first three years of fyke net collections (2012-2014), White Perch was not among the dominant species in fyke nets. However, in 2015 White Perch was the second most dominant species in fyke net collections, and was present again in 2016 and 2017, indicating it was present within the SAV beds as well (Figure 164). In 2021, White Perch CPUE decreased to < 1, but individuals were still collected over SAV. A species consistently sampled at moderately high levels with the fyke nets is Banded Killifish, which benefits from extensive SAV beds as habitat (Figure 165). Similar to our seine catches, Banded Killifish CPUE also increased in Fyke nets this year above 2019 values. Fyke nets efficiently sample SAV beds, and are usually dominated by SAV-associated species like Banded Killifish and Sunfishes. Sunfish CPUE was similar to previous years (Figure 166). The state shift of the ecosystem to a SAV dominated system has resulted in a shift in the nekton community from open-water species to SAV-associated species. The number of sampling days per month where both fyke nets were set is shown in Table 26.

Inland Silverside typically have a variable record within the SAV-beds as represented by the fyke net catches; however, they were a common species this year exhibiting greater CPUE than Banded killifish. While inland silversides are not concentrated in SAV beds, they have remained moderately abundant throughout the Cove and the survey when all gear is considered.

After 2018 yielded in the lowest abundance in fyke nets for the period of record, catches were up to normal levels again in 2019 and continued increasing in 2021 (Table 25, Figure 163). This seems directly related to SAV cover, which was close to absent in 2018, but present in all other years since the period of record (2012-2021). Collections were dominated by sunfishes again in 2021, which is the species that is mostly represented with the fyke net collections. Like previous years, the relative contribution of species in fyke nets is different than collected with trawl or seine nets. The fyke nets mainly represents SAV-associated species such as several species of sunfishes. When the catch is low this seems associated with low SAV cover, since the fyke nets become relatively inefficient gear then due to their visibility and likely lower density of SAV associated species.

Table 28. Mean Catch per Fyke of Selected Adult and Juvenile Fishes at all Stations and all Months. 2012-2021.

| Year | All Species | Sunfish | Banded Killifish | Inland Silverside | Tesselated Darter | Brown Bullhead | Largemouth Bass | Goldfish |
|---|---|---|---|---|---|---|---|---|
| 2021 | 74.7 | 29.6 | 16.7 | 22.7 | 1.7 | 0.1 | 0.0 | 3.0 |
| 2019 | 48.3 | 30.3 | 13.9 | 0.4 | 0.7 | 0.0 | 0.1 | 0.4 |
| 2018 | 5.2 | 3.1 | 0.0 | 0.7 | 0.5 | 0.1 | 0.0 | 0.0 |
| 2017 | 66.4 | 38.3 | 11.1 | 10.8 | 0.1 | 0.1 | 0.2 | 1.5 |
| 2016 | 22.8 | 14.7 | 5.3 | 1.0 | 0.0 | 0.0 | 0.5 | 0.0 |
| 2015 | 36.6 | 6.4 | 25.3 | 1.1 | 0.1 | 0.0 | 0.0 | 0.3 |
| 2014 | 60.4 | 12.4 | 39.3 | 0.1 | 0.3 | 2.3 | 0.0 | 0.1 |
| 2013 | 25.3 | 6.1 | 16.8 | 0.7 | 0.1 | 0.0 | 0.0 | 0.2 |
| 2012 | 120.0 | 85.0 | 25.0 | 0.0 | 0.4 | 0.0 | 2.9 | 4.3 |

Table 26. The number of fykes in each month at Station Fyke 1 and Fyke 2 in each year. 2012-2021.

| Year | Station | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|
| 2021 | Fyke1 | 0 | 1 | 0 | 1 | 2 | 1 |
| 2021 | Fyke2 | 0 | 1 | 1 | 1 | 2 | 1 |
| 2019 | Fyke1 | 0 | 2 | 2 | 2 | 2 | 1 |
| 2019 | Fyke2 | 0 | 2 | 2 | 2 | 2 | 1 |
| 2018 | Fyke1 | 1 | 2 | 2 | 2 | 2 | 1 |
| 2018 | Fyke2 | 1 | 2 | 2 | 2 | 2 | 1 |
| 2017 | Fyke1 | 0 | 2 | 2 | 2 | 2 | 1 |
| 2017 | Fyke2 | 0 | 2 | 2 | 2 | 2 | 1 |
| 2016 | Fyke1 | 1 | 2 | 2 | 2 | 2 | 1 |
| 2016 | Fyke2 | 1 | 2 | 2 | 2 | 2 | 1 |
| 2015 | Fyke1 | 1 | 2 | 1 | 2 | 2 | 1 |
| 2015 | Fyke2 | 1 | 2 | 1 | 2 | 2 | 1 |
| 2014 | Fyke1 | 1 | 2 | 2 | 2 | 2 | 1 |
| 2014 | Fyke2 | 1 | 2 | 2 | 2 | 2 | 1 |
| 2013 | Fyke1 | 0 | 2 | 2 | 2 | 2 | 1 |
| 2013 | Fyke2 | 0 | 2 | 2 | 2 | 2 | 1 |
| 2012 | Fyke1 | 0 | 0 | 1 | 2 | 2 | 1 |
| 2012 | Fyke2 | 0 | 0 | 1 | 2 | 2 | 1 |

Other species that are collected with the fyke nets include native catfishes, such as the Brown Bullhead (Figure 167). They are generally collected in low abundances with the fyke nets as well, and a single individual was collected in 2021. We did see a spike in Brown Bullhead abundance in 2014, signifying that they have not been extirpated by the invasive Blue Catfish. We consistently find the invasive Goldfish as well (Figure 168), which exhibited its highest abundance since fyke net employment this year. Largemouth Bass also benefits from extensive SAV cover to better ambush prey species. While it may generally be successful in avoiding our stationary gear, we do generally collect some Largemouth Bass specimens in low abundances; however, none were collected in 2021 (Figure 169).

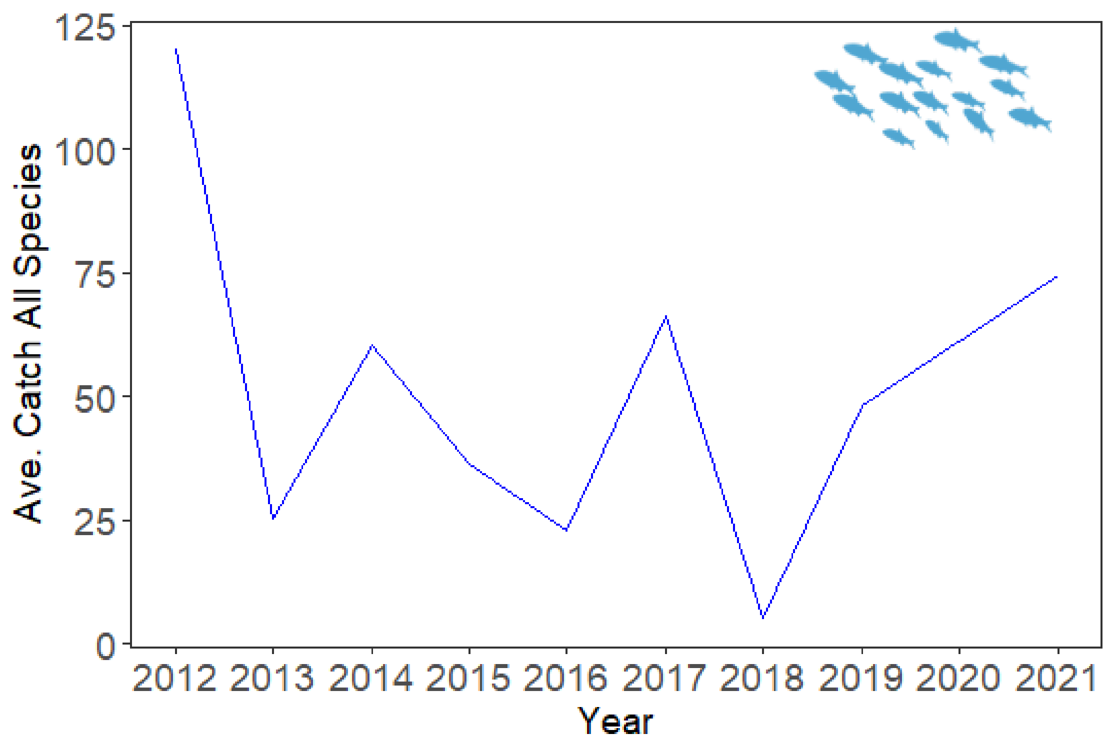



Figure 176. Fykes Annual Average over Stations Fyke 1 and Fyke 2. All Species. 2012-2021.

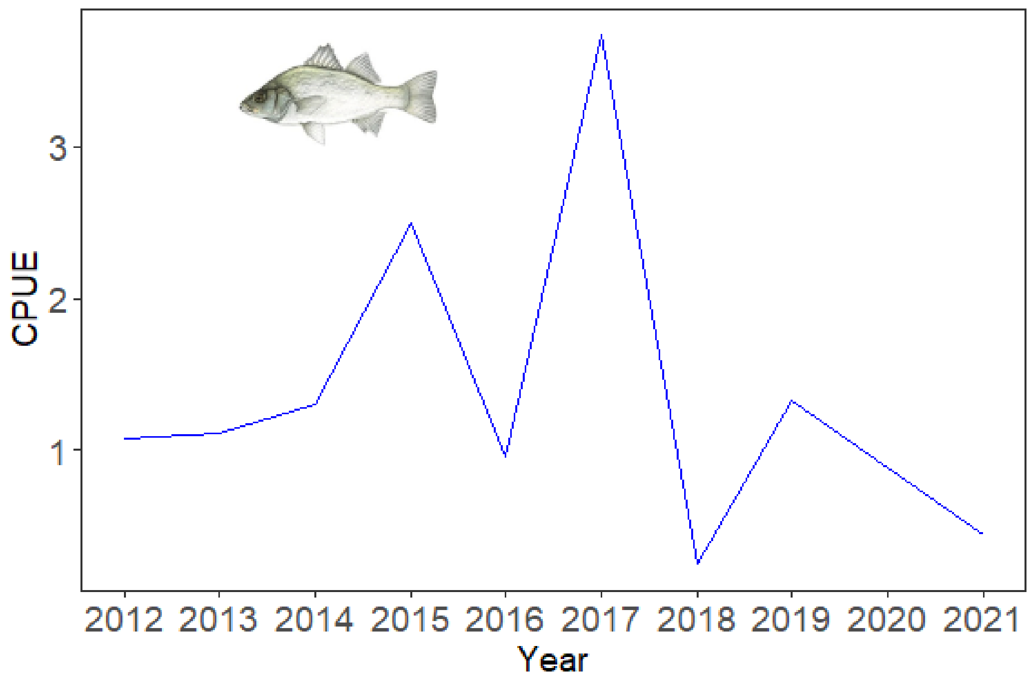



Figure 177. Fyke Annual Average Stations Fyke 1 and Fyke 2. *Morone americana*. 2012-2021.

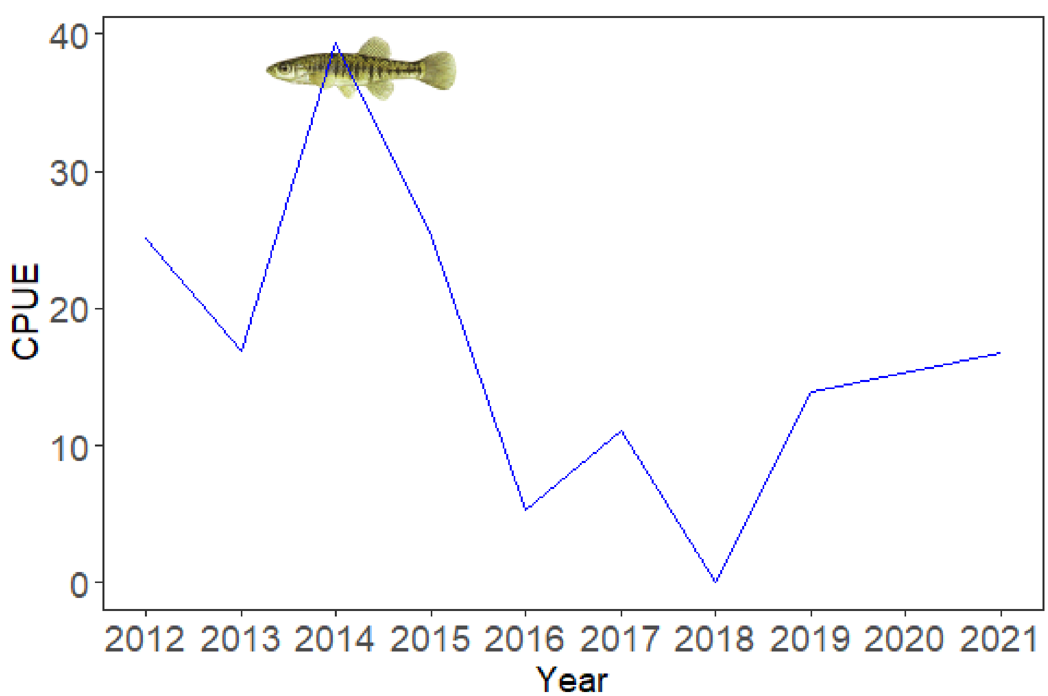



Figure 178. Fyke Annual Average Stations Fyke 1 and Fyke 2. *Fundulus diaphanus*. 2012-2021.

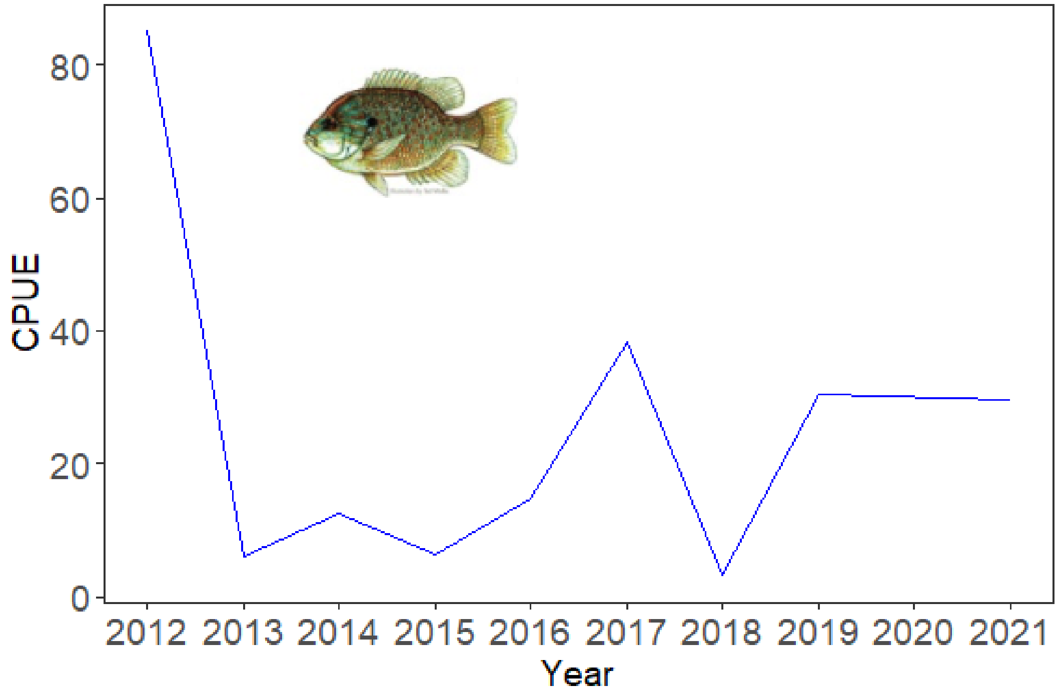



Figure 179. Fykes Annual Average over Fyke 1 and Fyke 2 Stations. All *Lepomis sp.* (blue). 2012-2021.

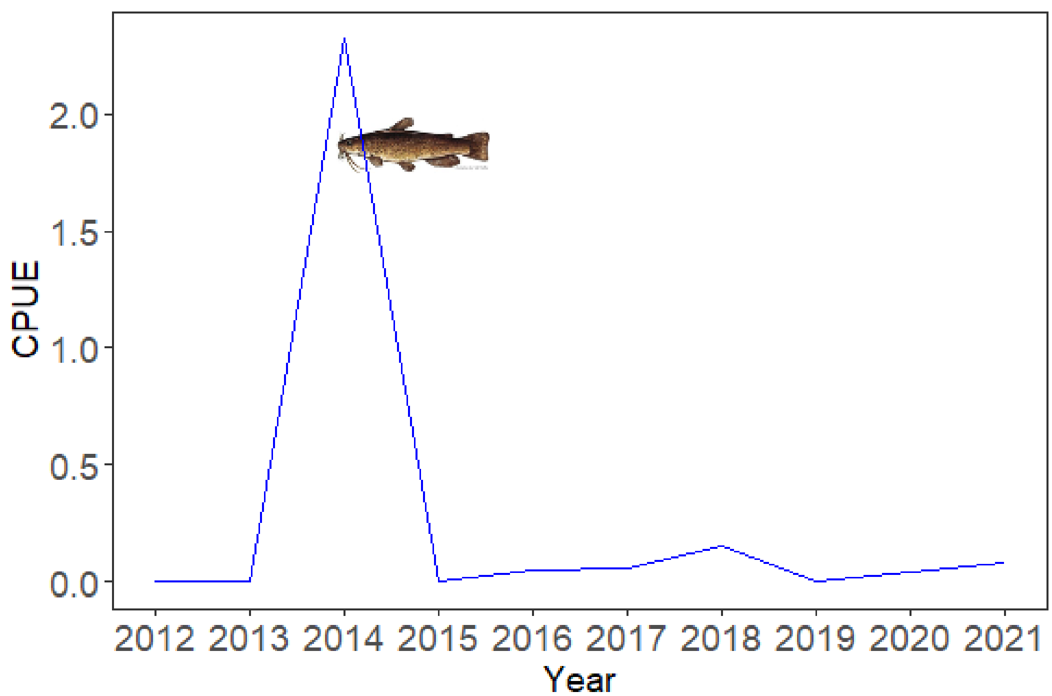



Figure 180. Fykes Annual Average over Fyke 1 and Fyke 2 Stations. *Ameiurus nebulosus* (blue). 2012-2021.

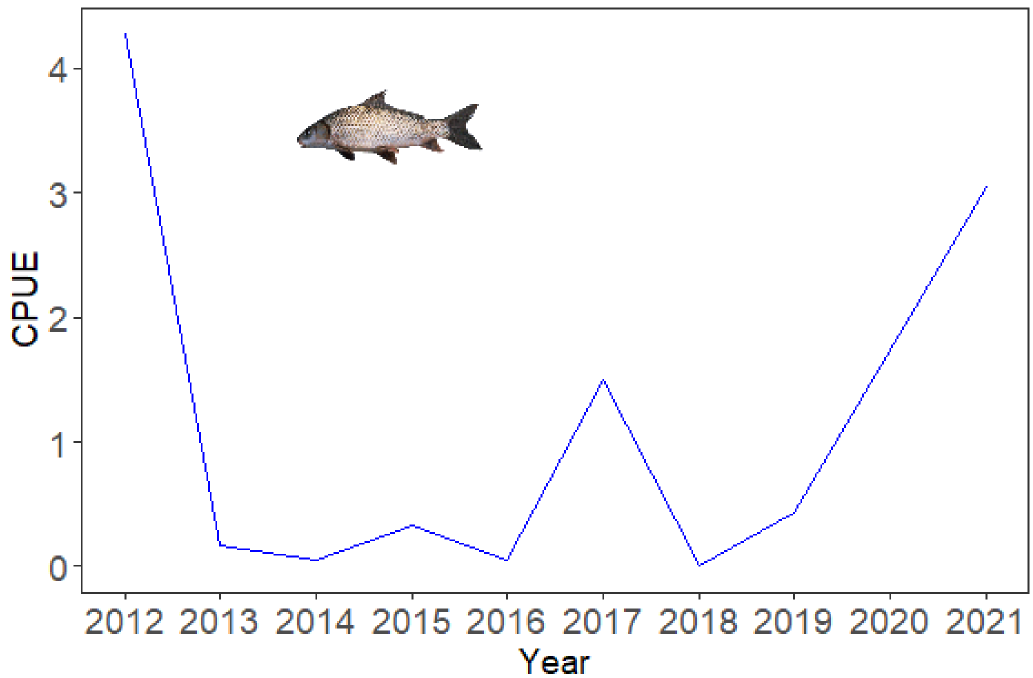



Figure 181. Fykes Annual Average over Fyke 1 and Fyke 2 Stations. *Carassius auratus* (blue). 2012-2021.

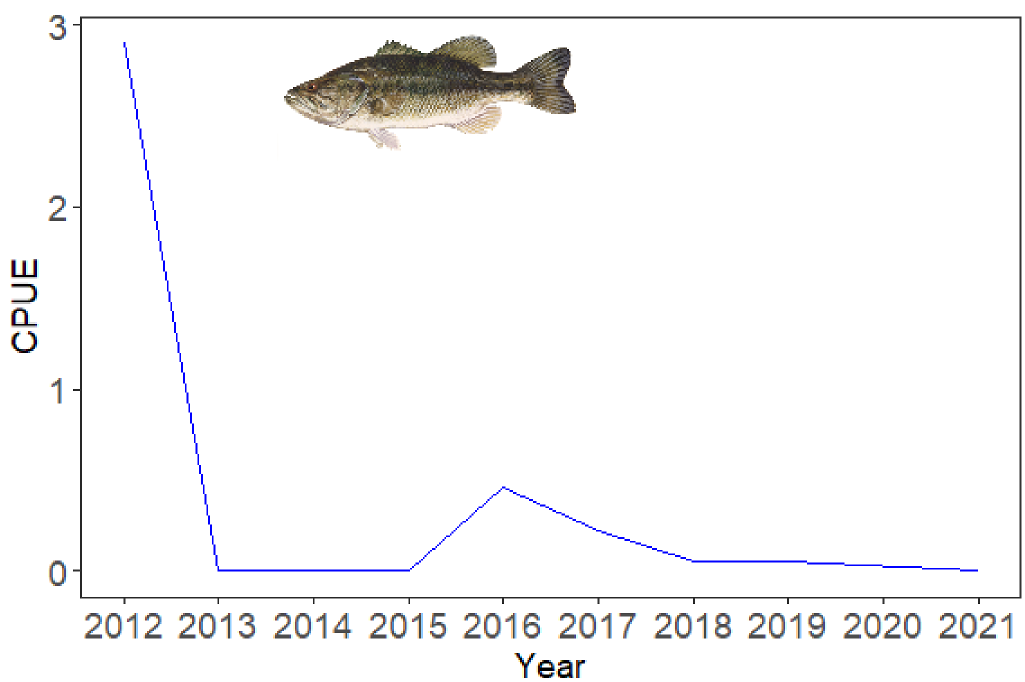



Figure 182. Fykes Annual Average over Fyke 1 and Fyke 2 Stations. *Micropterus salmoides* (blue). 2012-2021.

**Long-term Species Composition Changes**

The species composition and community structure are changing throughout the time of the survey as indicated by trawl and seine catches. The expansion of SAV beds in the inner cove seems to be driving some of these changes. The main trend related to increasing SAV beds is a decline in White Perch and an increase in Banded Killifish, especially in seine samples. A detailed multivariate analysis of the community structure shifts in the Gunston Cove fish community since the start of the Gunston Cove survey has recently been published (De Mutsert et al. 2017). Another community shift can be seen in the catfishes. Since the introduction of the invasive Blue Catfish in Gunston Cove in 2001, Blue Catfish has become prevalent in the trawl catches, while the abundances of other catfishes (Brown Bullhead, Channel Catfish, White Catfish) have been declining. The trend in Blue Catfish abundance is currently not increasing, and seems to have reached a plateau. Potentially, a new stable state has been achieved with high Blue Catfish abundances and low abundances of other catfishes. We do collect some Brown Bullhead specimens in the fyke nets, but abundances are low there as well, indicated by a single specimen in 2021. More fyke net collections or electrofishing samples are needed to determine if there is a spatial shift of Brown Bullhead towards SAV beds, which would not be unusual for this species that prefers vegetated habitat.

Another interesting community change is an increase in collections of Striped Bass. We only find Striped Bass in low numbers, but because of its high commercial and recreational value, it is worth mentioning. While Striped Bass is thought to occur in more saline waters, this semi-anadromous species does come up to tidal freshwater areas to spawn, and we find juvenile Striped Bass in our seine and trawl collections. Furthermore, resident freshwater Striped bass have been found and could occur within or near our study area.

Other observed long-term changes are the decline in Alewife and Blueback Herring. These declines are in concurrence with declines observed coast-wide, and do not have a local cause. It is a combination of declining suitable spawning habitat and overfishing (either targeted fishing that ended in 2012, or as bycatch of the menhaden fishery). Relative high abundances of juvenile Alosines in the trawl and seine samples in 2015, 2018 and 2019 were observed, but these numbers have since decreased back to low levels.

With the reported increases and decreases in species abundances it is interesting to evaluate the effect of these community structure changes on the overall diversity of the fish community. This is analyzed by calculating the Simpson's Index of Diversity for each year from 1984 to 2021 (Figure 170). In this index, calculated as $1\text{-}(\Sigma\ (ni/N)^2)$, the communities with higher diversity have higher values (approaching 1). The Simpson's Index of Diversity was 0.681 in 2021, which is lower than recent years but within the range of our study values. Calculating the index shows that the Cove represents a healthy and stable diversity. Gunston Cove harbors a diverse fish community. Overall, the fish species found in Gunston Cove are characteristic of Potomac River tributaries.

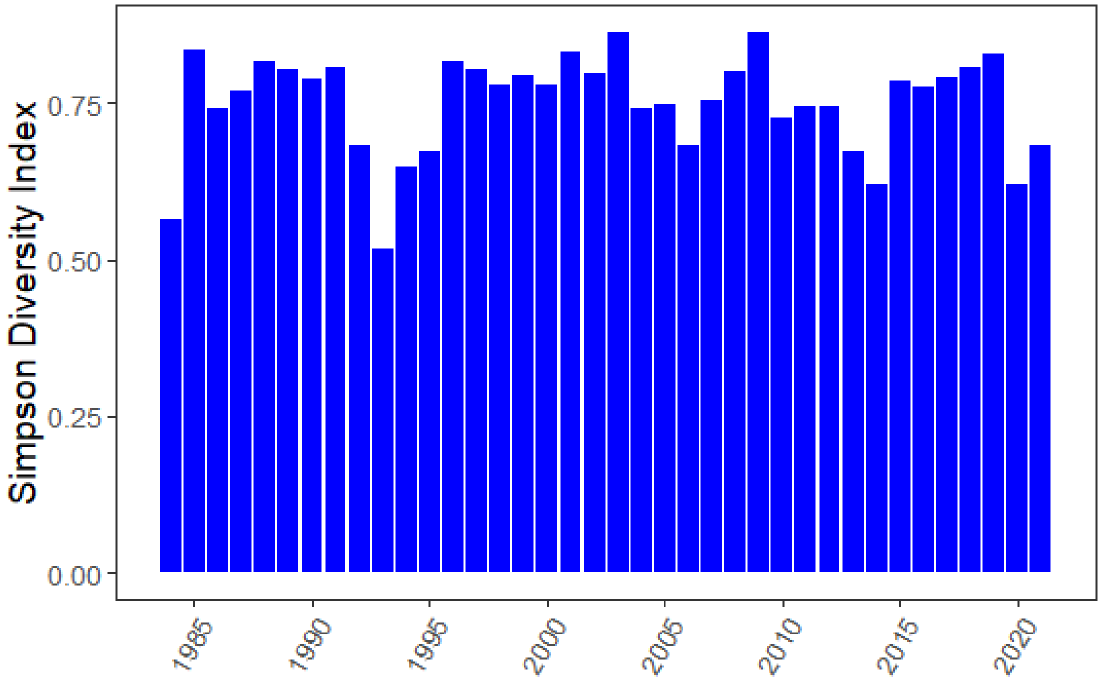



Figure 183. Simpson Diversity Index of fish species collected in Gunston Cove all years.

**Summary**

In 2021 ichthyoplankton was dominated by clupeids, most of which were Alewife, Blueback Herring, and Gizzard Shad, and to a lesser extent, American Shad, and Hickory Shad. White Perch was relatively dominant as well, with abundances similar to Blueback Herring. Inland Silversides were also found in relatively high densities. Other taxa were found in very low densities similar to previous years. Clupeid larvae showed a distinct peak in May, which follows the spring spawning run of herring and shad. Most clupeids are spawn from March –May, and are spawn closer to, or even further upstream from, the head of the tide. These larvae then drift down, and remain in tidal tributaries such as Gunston Cove until they are juvenile. They then usually remain several months as juveniles as well, and use Gunston Cove as a nursery.

The trawl, seine and fyke net collections continue to provide valuable information about long-term trends in the fish assemblage of Gunston Cove. The development of extensive beds of SAV over the past decade is providing more favorable conditions for Banded Killifish and several species of sunfish (Bluegill, Pumpkinseed, Redear Sunfish, Redbreast Sunfish, Bluespotted Sunfish, and Green Sunfish) among other species. Indeed, seine and trawl sampling has indicated a relative increase in some of these SAV-associated species. The abundance of some species such as White Perch are showing a decline (while relative abundance of White Perch in this area compared to other species than Banded Killifish remains high). This is likely due to a shift in nekton community structure as a result of the state shift of Gunston Cove to a SAV-dominated system. The shift in fish community structure was clearly linked to the shift in

SAV cover with a community structure analysis (De Mutsert et al. 2017). Interestingly, abundances of Banded Killifish and White Perch both increased in seine surveys this year, with the highest recorded catches of Banded Killifish since stud inception. The Simpson's Diversity Index calculated for all years showed that the changes in community structure did not result in significant increasing or decreasing trends in overall diversity in Gunston Cove, and that the diversity is relatively high and stable.

The SAV expansion has called for an addition to the sampling gear used in the survey, since both seines and trawls cannot be deployed where SAV beds are very dense. While drop ring sampling has been successfully used in Gunston Cove in previous years (Krauss and Jones, 2011), this was done in an additional study and is too labor-intensive to add to our semi-monthly sampling routine. In 2012, fyke nets were deployed to sample the SAV beds. The fyke nets proved to be an effective tool to sample the fish community within the vegetation. While fyke-nets do not provide a quantitative assessment of the density of species, it effectively provided a qualitative assessment of the species that reside in the SAV beds. The fyke nets collect mostly several species of sunfish and Banded Killifish, which are indeed species know to be associated with SAV. Reduced efficiency of fyke nets in a year with low SAV cover became clear in 2018, and the most likely reason for that is that fishes can see the nets when they are unobstructed by plants and successfully avoid this stationary gear. The abundance of specimens collected with fyke nets was up again in 2021, likely driven by the presence of extensive SAV beds.

Juvenile anadromous species continue to be an important component of the fish assemblage. We have seen declines in river herring since the mid 1990s, which is in concordance with other surveys around the Potomac and Chesapeake watersheds. In January 2012, a moratorium on river herring was put in effect to alleviate fishing pressure in an effort to help river herring stocks rebound. There were relatively high numbers of juvenile Blueback Herring, Alewife and other Alosines in trawls and seines in 2015. These abundances were lower again in 2016 and 2017, but the successful spawning cohort of 2015 (reported in more detail in the 2015 Anadromous Report) returned to spawn in 2018 as was hypothesized in previous reports (reported in more detail in the 2018 Anadromous Report). Unfortunately, since 2019, Alosine abundances have decreases returning to low levels. The continued monitoring of Gunston Cove since the complete closure of this fishery will help determine if the moratorium results in a recovery of Blueback Herring and Alewife. We have also noticed some aberrant growth trends in these species and plan to investigate these trends during future studies.

**G. Benthic Macroinvertebrates Trends: 1994-2021**

Benthic invertebrates have been monitored in a consistent fashion since 2009. Data from 2016-2021 are assembled below (Figure 184), and trends are generally consistent among years. The composition of the benthic macroinvertebrate community in the Potomac River mainstem (Station GC9) and Gunston Cove proper (Station GC7) seems to reflect mainly the texture of bottom substrates. In the cove at Station 7, the bottom sediments are fine and organic with anoxia just below the surface. These conditions favor chironomids and oligochaetes and are not very supportive of the other taxa found in the river. Interestingly, as submerged aquatic vegetation has become more established, gastropods are becoming more abundant and chironomids (midge larvae) are declining; however, this trend has not been consistent the past three years (2019, 2020, 2021) and there may be another change to the system. In the river, sediments are coarser and are comprised of a mixture of bivalve shells (mainly the invasive bivalve *Corbicula fluminea*) and sand/silt. This type of substrate supports a wider array of species, as supported by the data from this year and all previous years showing higher species diversity in the river versus cove.

Oligochaetes are generally the most abundant taxon at both stations across all years (Figure 184). However, if Annelids are removed and we examine the other dominant taxon groups, we see a few different trends in dominant taxa between the two sites across years (Figure 185). With Annelids removed, Gunston Cove proper (Station GC7) is dominated by the insect larvae of Chironomids (midges), while the Potomac River mainstem (Station GC9) is dominated by Gammarid amphipods. Amphipods have generally occurred sporadically at low levels in Gunston Cove proper (Station GC7). Chironomids are consistently found, but at lover levels at GC9. Isopods have been commonly found in the Potomac River mainstem (Station GC9) since 2010 and sporadically in Gunston Cove proper (Station GC7); they reached their highest densities in both sites in 2016. Turbellaria (flatworms) and Hirundinea (leeches) were found in low numbers sporadically at both sites and were present in several river samples since 2014, but none were found in 2021. Bivalves and Gastropods also occur in low numbers at both sites, with approximately the same average number of Gastropods across sites and years, although no Gastropods were recorded from either site in 2021. The Potomac River mainstem (Station GC9) has, on average, a higher abundance of Bivalves than GC7, mostly driven by the invasive Asian clam *Corbicula fluminea*. GC9 receives higher water flow and movement, which many species of Bivalvia require, and may help explain why there are higher abundances of Bivalvia located closer to the Potomac River. The consistent finding of even small numbers of taxa other than chironomids and oligochaetes in Gunston Cove proper (Station GC7) is encouraging and could be the result of improved water quality conditions in the cove.

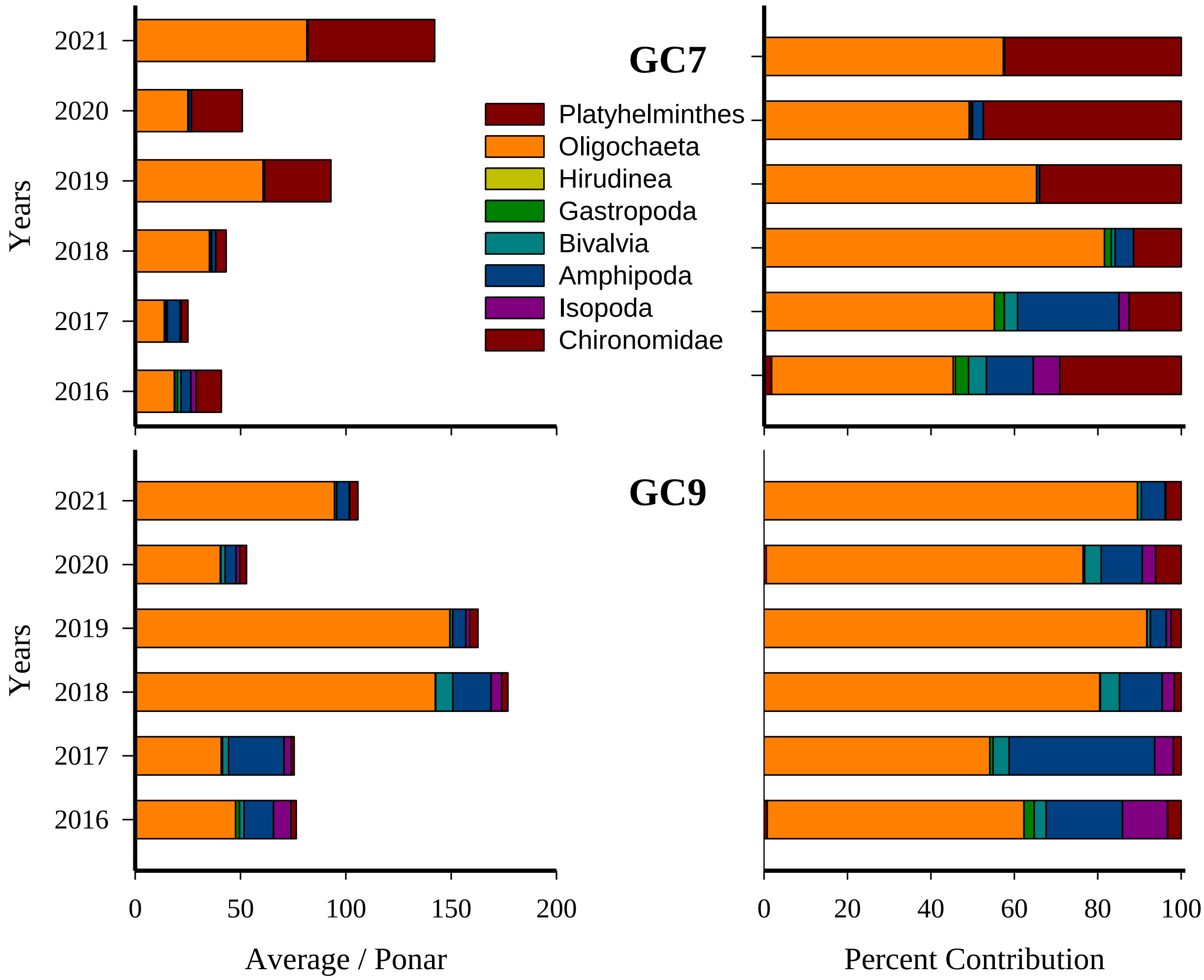



Figure 184. Average number per ponar sample (Left) and percent contribution (Right) of the eight dominant benthic invertebrate taxa in Gunston Cove embayment samples collected between 2016 and 2021 separated by site and year. Note the dominance of the Oligochaeta (worms).

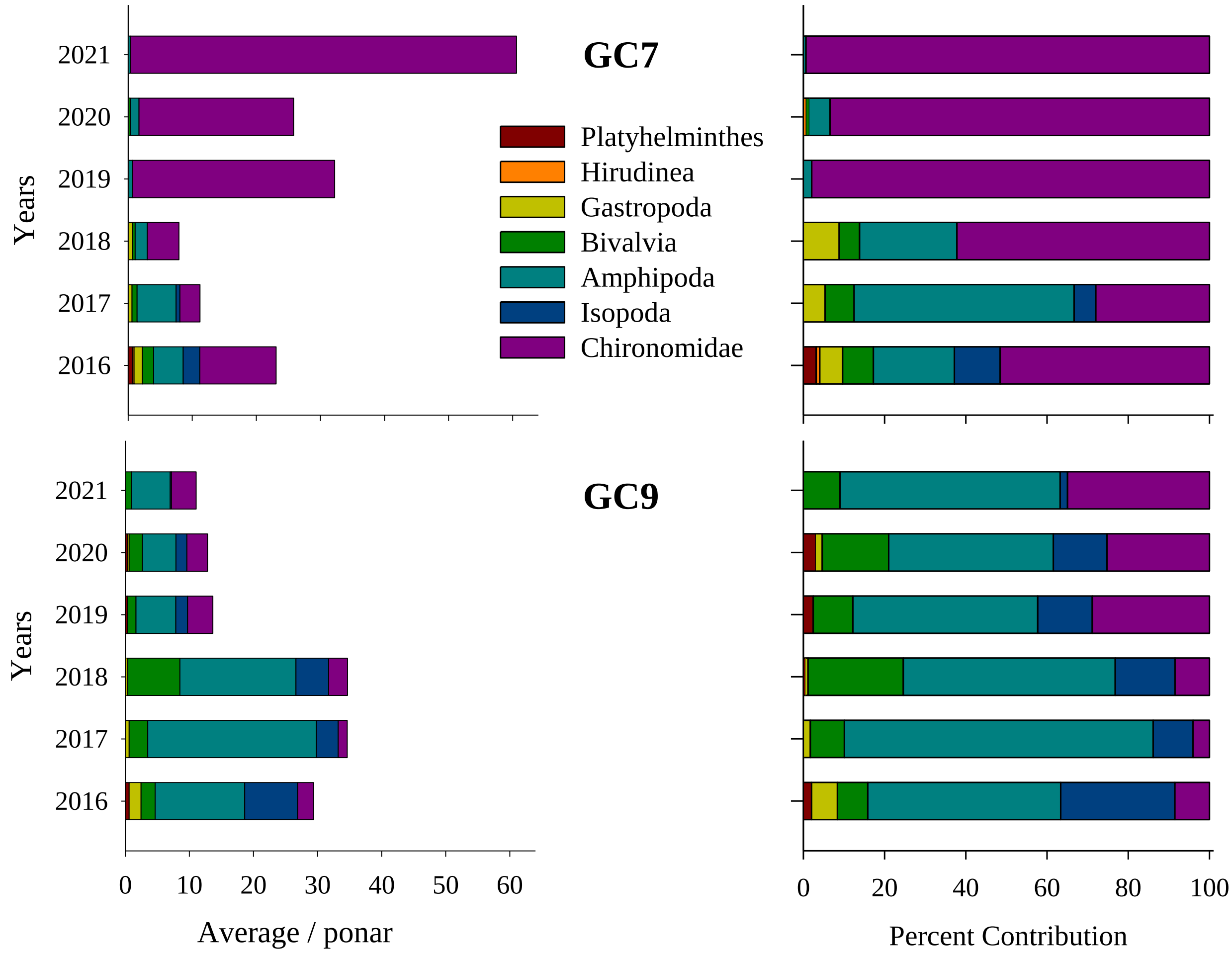



Figure 185. Without Oligochaeta, average number per ponar sample (Left) and percent contribution (Right) of the dominant benthic invertebrate taxa in Gunston Cove embayment samples collected between 2016 and 2021 separated by site and year.

**H. Submersed Aquatic Vegetation (SAV) Trends: 1994-2021**

A comprehensive set of annual surveys of submersed aquatic vegetation in the Gunston Cove area is available on the web at http://www.vims.edu/bio/sav/. This is part of an ongoing effort to document the status and trends of SAV as a measure of Bay recovery by conducting aerial mapping in early fall of each year. Maps of SAV coverage in the Gunston Cove area are available on the web site for the years 1994-2021 except for 2001, 2011, and 2018. Unfortunately, aerial mapping was not done in 2018 due to severe weather and poor imagery issues. Although the standardized data was not available, it was obvious that SAV was much reduced in 2018. In 2019 and 2020, average Secchi disk transparency increased to pre-2018 levels and SAV rebounded to near record levels (Figure 179). However, in 2021 SAV coverage declined somewhat apparently due to decreased water clarity reflected by a decrease in Secchi depth. Note the strong correlation between summer Secchi depth and SAV coverage (Fig. 180).

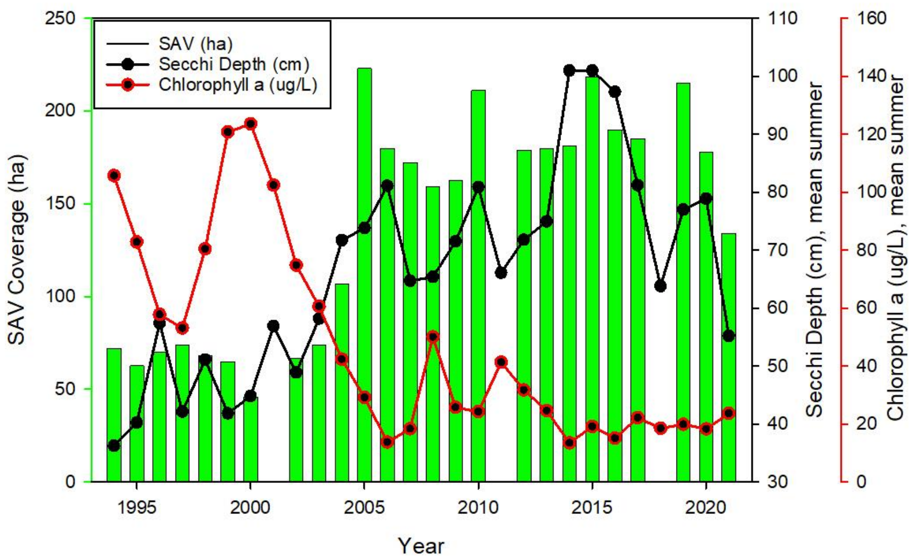



Figure 186. Gunston Cove SAV Coverage. Graphed with average summer (June-September) Depth-integrated Chlorophyll a (µg/L) and Secchi Depth (cm) measured at Station 7 in Gunston Cove.

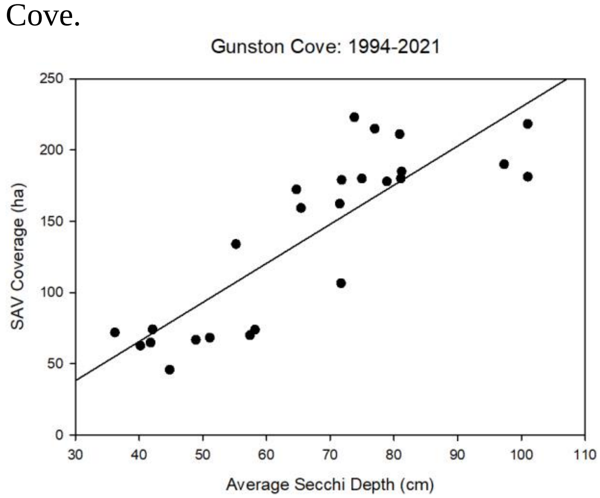



Figure 187. Correlation between Average Summer Secchi Depth (cm) and SAV Coverage (ha).

**LITERATURE CITED**


Bigelow, H.B. and W.C.Schroeder. 1953. Fishes of the Gulf of Maine. Fishery bulletin No. 74, Vol. 53. U.S. Government Printing Office. Washinton, D.C. 577 pp.

Carter, V., P.T. Gammon, and N.C. Bartow. 1983. Submersed Aquatic Plants of the Tidal Potomac River. Geological Survey Bulletin 1543. U.S. Geological Survey. 63 pp.

Chesapeake Bay Program. 2006 Ambient water quality criteria for dissolved oxygen, water clarity, and chlorophyll *a* for the Chesapeake Bay and its tidal tributaries. 2006 Addendum. Downloaded from Bay Program website 10/13/2006.

Cummings, H.S., W.C. Purdy, and H.P. Ritter. 1916. Investigations of the pollution and sanitary conditions of the Potomac watershed. Treasury Department, U.S. Public Health Service Hygienic Laboratory Bulletin 104. 231 pp.

Dahlberg, M.D. 1975. Guide to coastal fishes of Georgia and nearby states. University of Georgia Press. Athens, GA 187 pp.

De Mutsert, K., Sills, A., Schlick, C.J.C., and R.C. Jones. 2017. Successes of restoration and its effects on the fish community in a freshwater tidal embayment of the Potomac River, USA. Water 9(6), 421; doi:10.3390/w9060421

Douglass, R.R. 1999. A Field Guide to Atlantic Coast Fishes: North America (Peterson Field Guides). Houghton Mifflin Harcourt, Boston. 368 pp.

Eddy, S. and J.C. Underhill. 1978. How to know the freshwater fishes. 3rd Ed. W.C. Brown Co. Dubuque, IA. 215 pp.

Hildebrand and Schroeder. 1928. Fishes of the Chesapeake Bay. U.S. Bureau of Fisheries Bulletin 53, Part 1. Reprinted 1972. T.F.H. Publishing, Inc. Neptune, NJ. 388 pp.

Hogue, J.J, Jr., R.Wallus, and L.K. Kay. 1976. Preliminary guide to the identification of larval fishes in the Tennessee River. Technical Note B19. Tennessee Valley Authority. Knoxville, TN.

Huntley, M., K. Tande, and H.C. Eilertsen. 1987. On the trophic fate of *Phaeocystis pouchetii* (Hariot). Grazing rates of *Calanus hyperboreus* (Kroyer) on diatoms and different size categories of *Phaeocystis pouchetii*. J. Exp. Mar. Biol. Ecol. 110: 197-212.

Islam, S. 2001. Seasonal dynamics of micro-, nanno-, and picoplankton in the tidal freshwater Potomac River in and around Gunston Cove. Ph.Dissertation. George Mason University. 127 pp.

Jenkins, R.E. and N.M. Burkhead. 1994. The freshwater fishes of Virginia. American Fisheries Society. Washington, DC. 1080 pp.

Jones, P.W., F.D. Martin, and J.D. Hardy, Jr. 1978. Development of fishes of the Mid-Atlantic bight. Volumes I-VI. Fish and Wildlife Service, U.S. Department of the Interior. FWS/OBS-78/12.

Jones, R.C. 2020. Recovery of a Tidal Freshwater Embayment from Eutrophication: a Multidecadal Study. *Estuaries and Coasts*. Forthcoming in print. Available online at: https://link.springer.com/article/10.1007/s12237-020-00730-3

Kelso, D.W., R.C. Jones, and P.L. deFur. 1985. An ecological study of Gunston Cove - 1984-85. 206 pp.

Kraus, R.T. and R.C. Jones. 2011. Fish abundances in shoreline habitats and submerged aquatic vegetation in a tidal freshwater embayment of the Potomac River. Environmental Monitoring and Assessment. Online: DOI 10.1007/s10661-011-2192-6.

Lippson, A.J. and R.L. Moran. 1974. Manual for identification of early development stages of

fishes of the Potomac River estuary. Power Plant Siting Program, Maryland Department of Natural Resources. PPSP-MP-13.
Loos, J.J., W.S. Woolcott, and N.R. Foster. 1972. An ecologist's guide to the minnows of the freshwater drainage systems of the Chesapeake Bay area. Association of Southeastern Biologists Bulletin 19: 126-138.
Lund, J.W.G., C. Kipling, and E.C. LeCren. 1958. The inverted microscope method of estimation algal numbers and the statistical basis of estimations by counting. Hydrobiologia 11: 143-170.
Mansueti, A.J. and J.D. Hardy, Jr. 1967. Development of fishes of the Chesapeake Bay region: an atlas of egg, larvae and juvenile stages: Part 1. Natural Resources Institute. University of Maryland. 202 pp.
Merritt, R.W. and K.W. Cummins. 1984. An introduction to the aquatic insects of North America. 2nd edition. Kendall/Hunt Publishing Co., Dubuque, IA. 722 pp.
Page, L.M., and B.M. Burr. 1998. A Field Guide to Freshwater Fishes: North America North of Mexico (Peterson Field Guides). Houghton Mifflin Harcourt, Boston. 448 pp.
Pennack, R.W. 1978. Fresh-water invertebrates of the United States. 2nd ed. Wiley-Interscience. New York, NY.
Schloesser, R.W., M.C. Fabrizio, R.J. Latour, G.C. Garman, G.C., B. Greenlee, M. Groves and J. Gartland. 2011. Ecological role of blue catfish in Chesapeake Bay communities and implications for management. American Fisheries Society Symposium 77:369-382.
Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Bulletin 184. Fisheries Research Board of Canada. Ottawa, Canada. 966 pp.
Standard Methods for the Examination of Water and Wastewater. 1980. American Public Health Association, American Waterworks Association, Water Pollution Control Federation. 15th ed. 1134 pp.
Thorp, J.H. and A.P. Covich, eds. 1991. Ecology and classification of North American Freshwater Invertebrates. Academic Press. San Diego, CA. 911 pp.
Wetzel, R.G. 1983. Limnology. 2$^{nd}$ ed. Saunders. 767 pp.
Wetzel, R.G. and G.E. Likens. 1991. Limnological analyses. 2$^{nd}$ ed. Springer-Verlag. 391 pp.

# Anadromous Fish Survey of Pohick and Accotink Creeks 2021

Final Report
March 2021

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**Background**

The commercially valuable anadromous fishes in the herring family (Clupeidae) live as adults in the coastal ocean, but return to freshwater creeks and rivers to spawn. In the mid-Atlantic region, four species are present: American Shad, Blueback Herring, Alewife, and Hickory Shad.

The American Shad grows to be the largest and spawns in the shallow flats along the Potomac River channel. In the 1700s and early 1800s, incredibly large numbers of American Shad were caught each spring as they came up the river to spawn. The records from 1814-1824 of just one fishery located at Chapman’s Landing opposite Mason Neck, Virginia indicate that the annual catch varied from 27,939 to 180,755 American Shad (Massmann 1961). By 1982, the numbers caught in the entire river had dwindled so much that a moratorium was placed on both commercial and sport harvest of the species. In 1995, the Interstate Commission on the Potomac River Basin began a process of capturing ripe American Shad in gill nets off Dogue Creek and Fort Belvoir, stripping eggs from the females, and fertilizing the eggs with milt from males. The resulting young were raised in hatcheries for several days and then released, as fry, in the river below Great Falls (Cummins 2005). Through the 2002 season, over 15.8 million fry were released into the river, and by 2003 - the year after the restoration program ended - the population was judged strong enough to support a limited commercial fishery as bycatch in gill net fisheries. A replacement stocking program continued (Jim Cummins, pers. comm.), but was terminated in 2017 due to lack of recovery (https://www.dgif.virginia.gov/fishing/shad-restoration/).

Prior to the 1900s, spawning occurred in the river as high as Great Falls which is a natural barrier to upstream movement (Smith and Bean 1899). In recent years spawning has occurred mostly downriver between Piscataway Creek and Mason Neck (Lippson et al. 1979). We do not normally catch individuals of this species as adults, juveniles, or larvae. The adults are not caught because our trawls mostly sample fishes that stay near the bottom of the water column, and the American Shad remain in the river where the water column is deeper. The juveniles mostly remain in the channel also, but sporadically some juvenile American Shad are captured at our seine stations. Hickory Shad has similar spawning habitats and co-occurs with American Shad, but is less common than American Shad or river herring, and less is known about its life history. Coincident with the appearance of juvenile American Shad at our seine stations, we have also observed small numbers of juvenile Hickory Shad in recent years. Since 2010, we have been catching Hickory Shad adults in Pohick Creek and Accotink Creek.

Alewife and Blueback Herring, collectively called river herring, are commercially valuable, although typically less valuable than American Shad. In past centuries, their numbers were apparently even greater than those of the American Shad. Massmann (1961) reported that from 1814 to 1824, the annual catch at Chapman’s Landing ranged from 343,341 to 1,068,932 fish. The Alewife spawns in tributary creeks of the Potomac River and travels farther into these creeks than do the other species. Blueback Herring also enters creeks to spawn, but may also utilize downstream tidal embayments to spawn.

River herring were listed in 2006 by NOAA as species of concern due to widespread declining population indices. Population indices of river herring in the Potomac are available from seine surveys of juveniles conducted by MD-DNR. Juvenile catch rate indices are highly variable, but have been lower in the last decade for both species (Blueback Herring mean: 1998-2008=0.77 vs. 1959-1997=1.57; Alewife mean: 1998-2008=0.35 vs. 1959-1997=0.55). Since declines continued, a moratorium was established in January 2012, restricting all catches of Alewife and Blueback Herring (4VAC 20-1260-20). Causes of river herring decline are likely a combination of long-term spawning habitat degradation and high mortalities as a result of bycatch in the menhaden fishery. The establishment of a moratorium indicates that declines are widespread, and regular fishing regulations have not been sufficient to rebuild the stock. Using a moratorium to rebuild the stock is also an indication that the cause of the decline is largely unknown. Our monitoring of the river herring spawning population and density of larvae will aid in determining whether the moratorium is halting the decline in river herring abundance.

Another set of economically valuable fishes are the semi-anadromous White Perch and Striped Bass, which are sought after by both the commercial fishery and the sport-fishery. Both spawn in the Potomac River. Striped Bass spawn primarily in the river channel between Mason Neck and Maryland Point, while White Perch spawn primarily further upriver, from Mason Neck to Alexandria, and also in the adjacent tidal embayments (Lippson et al. 1979). Although spawning is concentrated in a relatively small region of the river, offspring produced there spread out to occupy habitats throughout the estuary. These juveniles generally spend the first few years of life in the estuary and may adopt a seasonal migratory pattern when mature. While most Striped Bass adults are migratory (spending non-reproductive periods in coastal seas), recent work indicates that a significant (albeit small) proportion of adults are resident in the estuaries.

Two other herring family species are semi-anadromous and spawn in the area of Gunston Cove. These are Gizzard Shad (*Dorosoma cepedianum*) and Threadfin Shad (*Dorosoma petenense*). They are very similar morphologically and ecologically, but in our collections, Threadfin Shad are found downriver of Mason Neck, and Gizzard Shad are found upriver of Mason Neck. Neither is commercially valuable, but both are important food sources of larger predatory fishes.

For several years, we have focused a monitoring program on the spawning of these species in Pohick Creek, Accotink Creek, and, less regularly, Dogue Creek. We have sampled for adult individuals each spring since 1988 and for eggs and larvae since 1992. After 16 years of using block nets to capture adults, we shifted in the spring of 2004 to visual observations and seine, dip-net, and cast-net collections. This change in procedures was done to allow more frequent monitoring of spawning activity and to try to determine the length of time the spawning continued. We had to drop Accotink Creek from our sampling in 2005, 2006, and 2007 because of security-related access controls at Fort Belvoir. Fortunately, access to historical sampling locations from Fort Belvoir was regained in 2008. The block net methodology was taken up again in 2008 and has been continued weekly from mid-March to mid-May each year since then. The creeks continuously sampled with this methodology during this period are Pohick Creek and Accotink Creek. Results from our 2021 sampling are presented below. Since the 2015 report, we have included a summary results of the adult abundances from 2008 to present, which shows the changes observed since the period of record that the same sampling methods were used.

## Introduction

Since 1988, George Mason University researchers have surveyed spawning river herring in Pohick Creek and adjacent tributaries of the Potomac River. The results have provided information on the annual occurrence and seasonal timing of spawning runs for Alewife (*Alosa pseudoharengus*) and Blueback Herring (*A. aestivalis*), but inferences on abundance have been limited for several reasons. The amount of effort to sample spawners has varied greatly between years and the methods have changed such that it is difficult to standardize the numbers captured or observed in order to understand annual fluctuations in abundance. River discharge was also not measured during some of the previous ichthyoplankton sampling. To maintain coherence with historical efforts while increasing the value of the data from surveys of Pohick and Accotink Creeks, we developed a modified protocol in 2008 with two main objectives: 1) quantify the magnitude of out drifting larvae and coincident creek discharge rate in order to calculate total larval production; 2) quantify seasonal spawning run timing, size distribution and sex ratio of adult river herring using block nets (a putatively non-selective gear used throughout the majority of the survey). These modifications were accomplished with little additional cost and provided results that are more comparable to assessments in other parts of the range of these species. After missing 2020 as a result of COVID-19, we have continued this sampling protocol in 2021 in Pohick and Accotink Creeks.

## Methods

We conducted weekly sampling trips from March 11 to May 12 in 2021. Sampling locations in each creek were located near the limit of tidal influence and as close as possible to historical locations. The sampling location in Accotink Creek was moved downstream a bit in 2014, which effectively moved the block net to an area before Accotink Creek splits into two branches, which reduces the number of anadromous fishes that could escape through an unsampled branch of the creek. In Pohick Creek the block net remained in the same location. On one day each week, we sampled ichthyoplankton by holding two conical plankton nets with a mouth diameter of 0.25 m and a square mesh size of 0.333 mm in the stream current for 10 minutes. A mechanical flow meter designed for low velocity measurements was suspended in the net opening and provided estimates of water volume filtered by the net. The number of rotations of the flow meter (Counts) attached to the net opening was multiplied by the low speed rotor constant based on the following equation provided by General Oceanics:

$$\text{Distance (m)} = \text{Difference in Counts*Rotor Constant (57560)/999999}$$

The distance could then be used to calculate volume based on the following equation provided by General Oceanics:

$$\text{Volume } (m^3) = ((3.14*(\text{Net Diameter } (0.25)2)/4)*\text{Distance}$$

Larval density (#/$m^3$) per species was calculated by dividing the number of individuals captured by the volume sampled. We collected 2 ichthyoplankton samples per week in each creek, and these were spaced out evenly along the stream cross-section. Coincident with plankton samples, we calculated stream discharge rate from measurements of stream cross-section area and current velocity using the following equation:

$$\text{Depth (m) x Width (m) x Velocity (m/s) = Discharge (m}^3\text{/s)}$$

Velocity was measured using a handheld digital flow meter that measures flow in cm/s, which had to be converted to m/s to calculate discharge. Both depth and current velocity were measured at 12 to 20 locations along the cross-section. During high rainfall events, block nets do not sample effectively and are dangerous to deploy and retrieve. Therefore, we completed larval sampling and creek profiles across all 10 weeks, but block nets were only set for six weeks (Table1).

Table 1. Sampling dates and procedures (Block Nets, Plankton Nets, and Creek Cross-Section [CS]) completed during each sampling event at each creek

| | Accotink | | | | Pohick | | | |
|---|---|---|---|---|---|---|---|---|
| **Date** | **Block** | **Plankton** | **CS** | **YSI** | **Block** | **Plankton** | **CS** | **YSI** |
| 3/11/2021 | Y | Y | Y | Y | Y | Y | Y | Y |
| 3/17/2021 | N | Y | Y | Y | N | Y | Y | Y |
| 3/25/2021 | N | Y | Y | Y | N | Y | Y | Y |
| 3/31/2021 | N | Y | Y | Y | N | Y | Y | Y |
| 4/8/2021 | Y | Y | Y | Y | Y | Y | Y | Y |
| 4/15/2021 | Y | Y | Y | Y | Y | Y | Y | Y |
| 4/22/2021 | Y | Y | Y | Y | Y | Y | Y | Y |
| 4/29/2021 | Y | Y | Y | Y | Y | Y | Y | Y |
| 5/6/2021 | N | Y | Y | Y | N | Y | Y | Y |
| 5/12/2021 | Y | Y | Y | Y | Y | Y | Y | Y |

The ichthyoplankton samples were preserved in 70% ethanol and transported to the GMU laboratory for identification and enumeration of fish larvae. Identification of larvae was accomplished with multiple taxonomic resources: primarily Lippson & Moran (1974), Jones et al. (1978), and Walsh et al. (2005). River herring (both species) have demersal eggs (tend to sink to the bottom) that are frequently adhesive. As this situation presents a significant bias, we made no attempts to quantify egg abundance in the samples. We were able to estimate total larval production (P) during the period of sampling by multiplying the larval density ($\#/m^{-3}$) with total discharge ($m^3$).

The two river herring species (Blueback Herring and Alewife) are remarkably similar during both larval and adult stages, and distinguishing larvae can be extraordinarily time consuming. While we reported only on Alewife up to 2014, we discovered that Blueback Herring sightings are common enough in our samples in recent years that they should be reported in this anadromous report, rather than Gizzard Shad, which is not an anadromous species. From the 2014 report on, the focus of this report is on the two true river herring species, Alewife and Blueback Herring, while presence of other clupeids (herring and shad species) such as Gizzard Shad will still be reported, but not analyzed to the detail of river herring.

The larval stages of the two *Dorosoma* species are also extremely difficult to distinguish. However, only Gizzard Shad comes this far upstream, while Threadfin Shad has not been found higher up in the Potomac watershed than Mason Neck. Due to the absence of juveniles in seine and trawl samples from the adjacent Gunston Cove and adjacent Potomac River, we disregarded the possibility that Threadfin Shad was present in our ichthyoplankton samples.

The block net was deployed once each week in the morning and retrieved the following morning (see Figure 1). All fish in the block net were identified, enumerated, and measured. Fish which were ripe enough to easily express eggs or sperm/semen/milt were noted in the field book and in the excel spreadsheet. This also determined their sex. Any river herring that had died were kept, while all other specimens were released. Fish that were released alive were only measured for standard length to reduce handling time and stress. Dead and dying fish were measured for standard length, fork length and total length. The dead fish were taken to the lab and dissected for ID and sex confirmation.

We used a published regression of fecundity by size and observed sex ratios in our catches to estimate fecundity, and to cross-check whether spawner abundance estimated from adult catches is plausible when compared to number of larvae collected. The following regression to estimate fecundity was used, this regression estimates only eggs ready to be spawned, which gives a more accurate picture than total egg count would (Lake and Schmidt 1997):

$$\text{Egg \#} = -90{,}098 + 588.1(\text{TL mm})$$

We used data from specimens where both standard length and total length was estimated to convert standard length to total length in cases we had not measured total length. Our data resulted in the following conversion:

$$TL = 1.16SL + 6.$$

The regression had an $R^2$ of 0.97. Since the nets were set 24 hours per week for 6 (144 hours) out of the 10-week season (7 days * 10 weeks * 24 hours in a day = 1680 season hours), we approximated total abundance of spawning Alewife and Blueback Herring during the time of collection by extrapolating the mean catch per hour per species during the time the creeks were blocked of over the total collection period as follows:

$$\text{Total catch} / 144 \text{ hours} * 1680 \text{ hours} = \text{total abundance of spawners}$$

Our total collection period is a good approximation of the total time of the spawning run of Alewife. To determine the number of females we used the proportion of females in the catch for Alewife as well as Blueback Herring, since we are able to sex Blueback Herring as well.
We did not determine the abundance of spawners based on the amount of larvae collected. Alewife and Blueback Herring have fecundities of 60,000-120,000 eggs per female, and with the low numbers of larvae collected, we would grossly underestimate the abundance of spawning

fish. Eggs and larvae also suffer very high mortality rates, so it is unlikely that 60,000-120,000 larvae suspended in the total discharge of a creek amount to one spawning female. Instead the method described above was used.

In response to problems with animals tearing holes in our nets in earlier years, we have been consistently using a fence device that significantly reduces this problem. The device effectively excluded otters and similar destructive wildlife, but had slots that allowed up-running fish to be captured. The catch was primarily Clupeids with little or no bycatch of other species.

Figure 1. Block net deployed in Pohick creek. The top of the block net is exposed at both high and low tide to avoid drowning turtles, otters, or other air-breathing vertebrates. The hedging is angled downstream in order to funnel up-migrating herring into the opening of the net.

**Results**

Our creek sampling work in 2021 spanned a total of 10 weeks, during which we collected 40 ichthyoplankton samples, and 12 adult (block net) samples. In 2010, Hickory Shad (*Alosa mediocris*) was captured for the first time in the history of the survey, after which we have continued to observe Hickory Shad in our samples. Hickory Shad are known to spawn in the mainstem of the Potomac River, and although their ecology is poorly understood, populations of this species in several other systems have become extirpated or their status is the object of concern. This year we collected one adult Hickory Shad Accotink Creek and 18 adult Hickory Shad in Pohick Creek.

The abundance of confirmed *Alosa* larvae was lower than 2018 and 2019 at 230 individuals. The number of unidentified clupeid larvae was low (11 and 17 individuals in Accotink and Pohick respectively), which could be *Alosa* or *Dorosoma* (Gizzard Shad). Unidentified larvae are those too damaged to be identified to the species level, which usually occurs through a combination of high flow and high larval densities in the net. When flow and total larval abundance is lower (as was the case this year), we generally have fewer unidentified larvae. We also collected 13 identified Gizzard Shad larvae. We found that most *Alosa* larvae consisted of Alewife larvae, with fewer Blueback Herring and Hickory Shad present in similar abundances in each creek (Table 2).

Table 2. Clupeid larvae count and density (#/$m^3$), and adult counts and catch per unit effort over all dates (CPUE = number collected/total nets set [6]) from Accotink and Pohick creeks in 2021.

| | | | **Adult Count** | | | **Adult CPUE** | | |
|---|---|---|---|---|---|---|---|---|
| **Species** | **Larvae** | **Density** | **Female** | **Male** | **all** | **Female** | **Male** | **all** |
| *Accotink* | | | | | | | | |
| Blueback Herring | 2 | 0.22 | 0 | 3 | 6 | 0 | 0.50 | 1.00 |
| Hickory Shad | 1 | 0.04 | 0 | 0 | 1 | 0 | 0 | 0.17 |
| Alewife | 86 | 37.14 | 15 | 131 | 368 | 2.50 | 21.83 | 61.33 |
| Unidentified *Alosa* sp. | 6 | 0.50 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gizzard Shad | 9 | 1.06 | 2 | 3 | 19 | 0.33 | 0.50 | 3.17 |
| Mangled Clupeid | 11 | 0.79 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Pohick* | | | | | | | | |
| Blueback Herring | 11 | 0.41 | 0 | 15 | 22 | 0 | 2.50 | 3.67 |
| Hickory Shad | 9 | 0.25 | 5 | 2 | 18 | 0.83 | 0.33 | 3.00 |
| Alewife | 115 | 9.78 | 12 | 77 | 127 | 2.00 | 12.83 | 21.17 |
| Unidentified *Alosa* sp. | 0 | 0.00 | 0 | 0 | 4 | 0 | 0 | 0.67 |
| Gizzard Shad | 4 | 0.27 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mangled Clupeid | 17 | 0.78 | 0 | 0 | 0 | 0 | 0 | 0 |

We measured creek discharge at the same locations and times where ichthyoplankton samples were taken. The creeks showed similar discharge patterns this year (Figure 2), with consistently higher discharge in Pohick Creek than in Accotink Creek, similar to previous years. During the 70-day sampling period (which roughly coincides with the river herring spawning period), the total discharge was estimated to be on the order of 5.9 and 10.7 million cubic meters for Accotink and Pohick creeks, respectively (Table 3), which is higher than recent years.

Larval density of Alewife exhibited a peak in Accotink Creek the last week of April (Figure 3a), while densities in Pohick Creek remained consistent throughout the season (Figure 3a). Given the observed mean densities of larvae and the total discharge, the total production of

Alewife larvae was estimated at 11 million and 5.2 million for Accotink Creek and Pohick Creek, respectively (Table 3). Larval density of Blueback Herring exhibited a peak in Accotink Creek in mid-April and Pohick Creek the last week of April (Figure 3b). Blueback Herring larval density was much lower than Alewife as in previous years, leading to total larval production estimates of 60,000 and 200,000 for Accotink Creek and Pohick Creek, respectively, compared to production greater than 1 million in previous years.

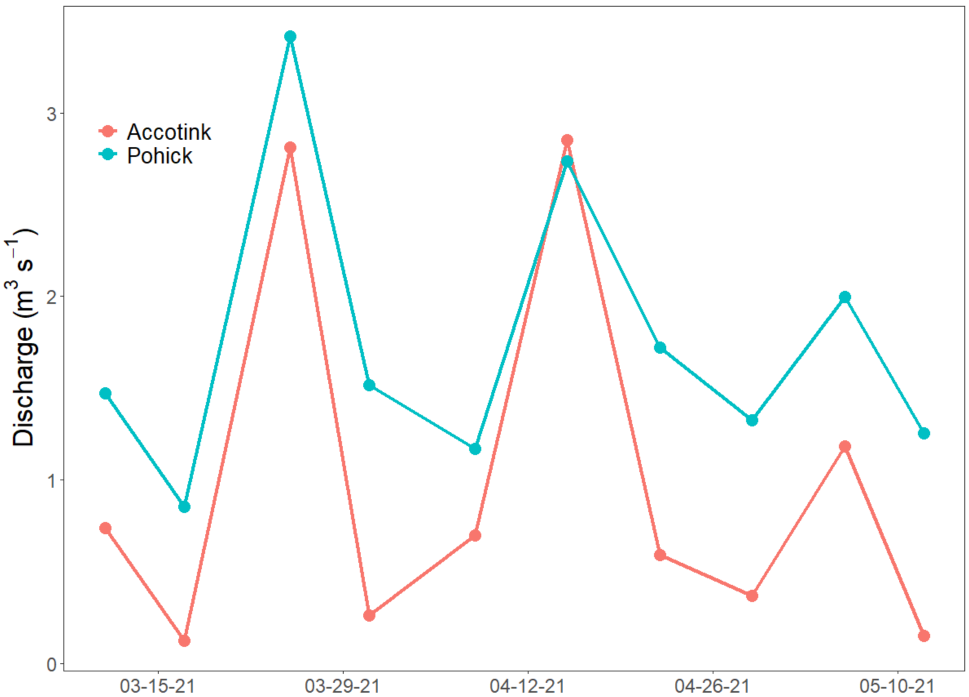


Figure 2. Discharge rate in $m^3$ $s^{-1}$ measured in Accotink and Pohick creeks during 2021.

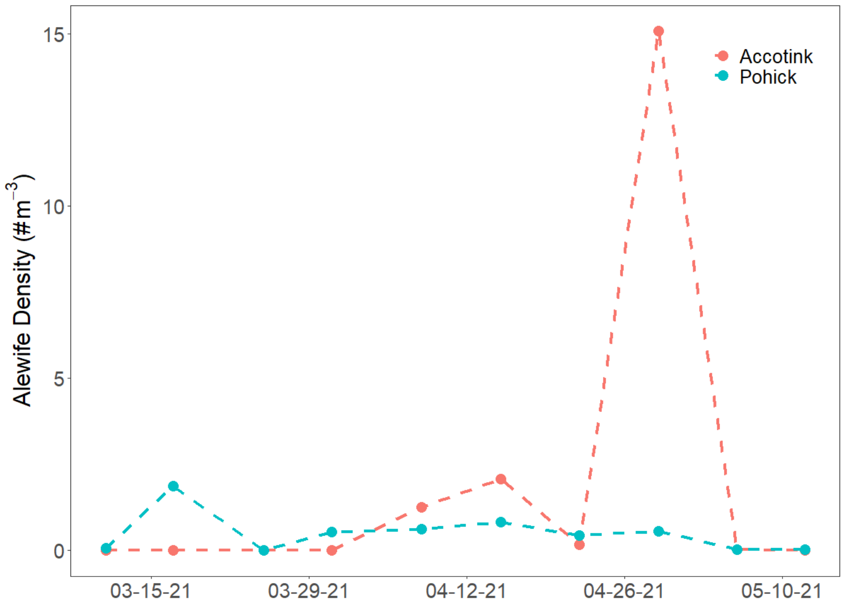


Figure 3a. Density of larval *Alosa pseudoharengus* observed in Accotink and Pohick Creek in 2021.

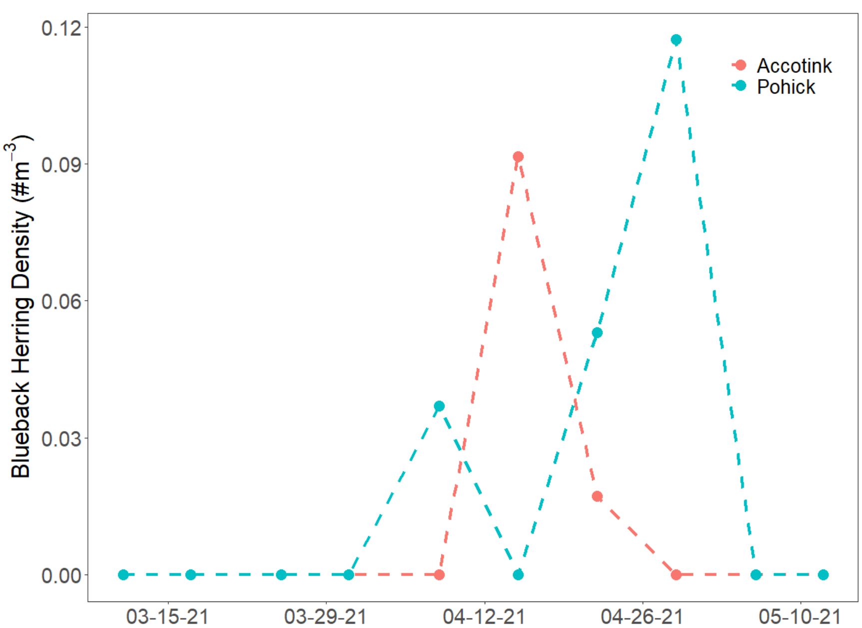


Figure 3b. Density of larval *Alosa aestivalis* observed in Accotink and Pohick Creek in 2021.

In the block nets, many Alewife were collected across both creeks (Accotink = 368, Pohick = 127, Table 2). This resulted in the highest CPUE we have recorded in Accotink Creek while using block nets (Table 4, Figure 4). In Pohick Creek this CPUE was the third highest ever recorded, with 2018 being the highest, followed by 2015. This high CPUE could be a result of fewer sampling events, but the total number of individuals is encouraging.  Blueback Herring were hardly collected this year, only 6 individuals were captured in Accotink Creek, and 22 in Pohick Creek (Table 3). We also did not collect a single female fish in either creek, so we could not estimate sex ratios or extrapolated female population numbers for this species. For Alewife, in both creeks higher numbers of male fish were collected. Skewed sex ratios in fish populations are common in *Alosa sp.* (Kissil 1974, Loesch and Lund JR 1977) and are not a problem as long as fecund females are present. The abundance of spawning Alewife was estimated to be 4,292 in Accotink Creek during the period of sampling, and 1,482 in Pohick Creek. Similar to the CPUE, this is much greater than previous years for Accotink Creek and similar to previous years for Pohick Creek. Overall, the estimated number of individual Blueback Herring were low, 70 and 257 spawners in Accotink and Pohick creeks respectively. Although these Blueback numbers are lower than recent years, they are still elevated above numbers at the start of the survey.

Table 3. Estimation of *Alosa pseudoharengus* and *A. aestivalis* fecundity and spawner abundance from Accotink and Pohick creeks during spring 2021. *Given that we did not collect any female Blueback Herring in ether creek, sex ratios and estimated female abundance could not be calculated this year for this species.

| Parameter | Accotink | Pohick |
|---|---|---|
| Mean discharge ($m^3s^{-1}$) | 0.977 | 1.746 |
| Minimum discharge ($m^3s^{-1}$) | 0.124 | 0.853 |
| Maximum discharge ($m^3s^{-1}$) | 2.853 | 3.419 |
| Total discharge, ($m^3$) | 5,909,117 | 10,561,880 |
| Mean Alewife larvae density ($m^3$) | 1.857 | 0.489 |
| Total Alewife Larval Production | 10,972,244 | 5,164,513 |
| Adult Alewife Mean Standard Length (mm) | 230.201 | 229.089 |
| Alewife Fecundity | 76,289 | 75,535 |
| Alewife Sex Ratio | 0.041 | 0.094 |
| Estimated number of female Alewife | 175 | 140 |
| Estimated total number of Alewife | 4,294 | 1,482 |
| Mean Blueback Herring larvae density ($m^3$) | 0.011 | 0.021 |
| Total Blueback Herring Larval Production | 64,308 | 218,924 |
| Adult Blueback Herring Mean Standard Length (mm) | 212.333 | 221.905 |
| Blueback Herring Fecundity | 64,181 | 70,667 |
| Blueback Herring Sex Ratio | 0* | 0* |
| Estimated number of female Blueback Herring | 0* | 0* |
| Estimated total number of Blueback Herring | 70 | 257 |

## Discussion

Summary 2019

We caught 495 adult Alewife and 28 adult Blueback Herring; we have positively identified Blueback Herring in this survey since 2011. We also collected 19 Hickory Shad. For Blueback Herring these numbers are much lower than usual and Hickory Shad numbers are consistent (Figure 4). Alewife numbers were the highest they have ever been in Accotink Creek and the third highest in Pohick Creek, but Blueback Herring abundances were low (Figure 4), potentially indicating a return to the low numbers prior to 2015. The estimated size of the spawning population of Alewife is 5,776 fishes in the Gunston Cove watershed in 2021, greater than recent years and driven by high abundances in Accotink Creek. Estimated Blueback Herring abundance was lower than recent years, but higher than what was observed prior to 2015. The fact that we missed many block net days early in the season may have biased our results. However, Blueback Herring prefer to spawn at higher temperatures than Alewife (Fay et al. 1983), so sampling later in the season should skew our catch to be Blueback dominated. The fact that we collected many more Alewife later in the season indicates that low Blueback Herring numbers was likely not an artifact of our sampling. The greater Alewife abundance in Accotink Creek may also be driven by temperature discrepancies among creeks. By receiving effluent for the Noman Cole pollution control plant, Pohick Creek is slightly warmer than Accotink Creek, making Accotink Creek the preferred spawning location for Alewife. This temperature difference may also be why more Blueback Herring were collected in Pohick Creek. A spawning population of Blueback Herring has been confirmed in this area since 2011, and we will continue to provide population parameters of Blueback Herring in our reports. A potential trend of earlier warmer temperatures in spring has moved Blueback Herring spawning season to overlap more with Alewife spawning season over time, which could explain why they did not find Blueback Herring during this time period in the past. This hypothesis warrants further investigation.

Trends through time

With a moratorium established in 2012 in Virginia, in conjunction with moratoria in other states connected to the North Atlantic at the same time or earlier, the order of magnitude increase in Alewife and Blueback Herring abundance three years after this occurrence (in 2015) could be a result of the moratorium. The moratorium prohibits the capture and/or possession of river herring (Alewife and Blueback Herring). The three-year delay coincides with the time it takes for river herring to mature, which means this is the first year a cohort has been protected under the moratoria for a complete life cycle. The lower numbers in 2016 and 2017 (while the moratoria wer still in effect), indicate that the high abundances in 2015 are not just an effect of the moratoria, but perhaps a combination of that and having a good year class in 2015. Since it takes about 3 years for river herring to return as spawning adults from the time they were spawn as ichthyoplankton, we were hopeful for a strong return in 2018. This indeed materialized for Alewife, which has continued this three-year cycle trend into 2021. This trend is especially apparent in Accotink Creek, with the highest CPUE ever recorded, and while the 2021 numbers are lower in Pohick Creek, they are still the third highest behind 2015 and 2018. Our missing observations earlier in the season may have led to decreased Alewife observations in Pohick Creek this year, especially considering it warms faster than Accotink Creek because of wastewater effluent. Blueback Herring numbers were much lower, and it appears that coastwide these populations did poorly in 2021 (personal communication with Virginia Alosa Taskforce). Although the numbers of Blueback were lower this year, they are still higher than what was collected a decade ago, indicating at least some improvement perhaps as a result of the moratorium.

Through meetings with the Technical Expert Working group for river herring (TEWG; http://www.greateratlantic.fisheries.noaa.gov/protected/riverherring/tewg/index.html), it has become clear that not all tributaries of the Chesapeake Bay, in Virginia and elsewhere, have seen increased abundances as we are seeing here; some surveyors even reported declines (De Mutsert, personal communication). Since the general historic decline in river herring was related both to overfishing and habitat degradation, it could be the case that habitat in those areas has not recovered sufficiently to support a larger spawning population now that fishing pressure is released. This while the habitat in the Gunston Cove watershed is of suitable quality to support a larger spawning population now that reduced fishing pressure allows for more adults to return to their natal streams. Additional stressors could play a role in the variable success so far of the moratoria; while targeted catch of river herring is prohibited, river herring is still a portion of by-catch, notably of offshore midwater trawl fisheries (Bethoney et al. 2014).

Table 4. The CPUE of four Clupeid species (Blueback Herring, Hickory Shad, Alewife, and Gizzard Shad) that occur in this area captured with block net during the spawning season.

| | **Accotink** | | | | **Pohick** | | | |
|---|---|---|---|---|---|---|---|---|
| **Year** | **Blueback** | **Hickory** | **Alewife** | **Gizzard** | **Blueback** | **Hickory** | **Alewife** | **Gizzard** |
| 2008 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.3 |
| 2009 | 0.0 | 0.0 | 0.6 | 0.1 | 0.0 | 0.0 | 3.3 | 0.2 |
| 2010 | 0.0 | 0.0 | 7.7 | 0.0 | 0.0 | 3.1 | 11.0 | 0.0 |
| 2011 | 0.1 | 1.3 | 5.2 | 4.7 | 0.6 | 0.6 | 6.0 | 2.2 |
| 2012 | 0.0 | 0.0 | 1.2 | 0.2 | 0.7 | 0.3 | 5.8 | 0.5 |
| 2013 | 0.0 | 0.1 | 2.9 | 0.2 | 0.4 | 0.0 | 5.3 | 1.7 |
| 2014 | 0.0 | 0.1 | 0.8 | 2.8 | 2.0 | 0.7 | 6.8 | 2.3 |
| 2015 | 0.2 | 0.0 | 37.9 | 6.8 | 61.3 | 20.9 | 59.5 | 13.0 |
| 2016 | 0.9 | 0.0 | 7.6 | 10.8 | 8.0 | 2.1 | 9.4 | 0.8 |
| 2017 | 0.0 | 0.0 | 2.4 | 0.3 | 3.4 | 0.7 | 10.4 | 0.9 |
| 2018 | 3.2 | 0.2 | 21.2 | 1.2 | 9.9 | 1.3 | 113.0 | 1.4 |
| 2019 | 3.2 | 0.0 | 7.0 | 5.0 | 13.8 | 1.6 | 20.1 | 3.6 |
| 2021 | 1.0 | 0.2 | 61.3 | 3.2 | 3.7 | 3.0 | 21.2 | 0.0 |

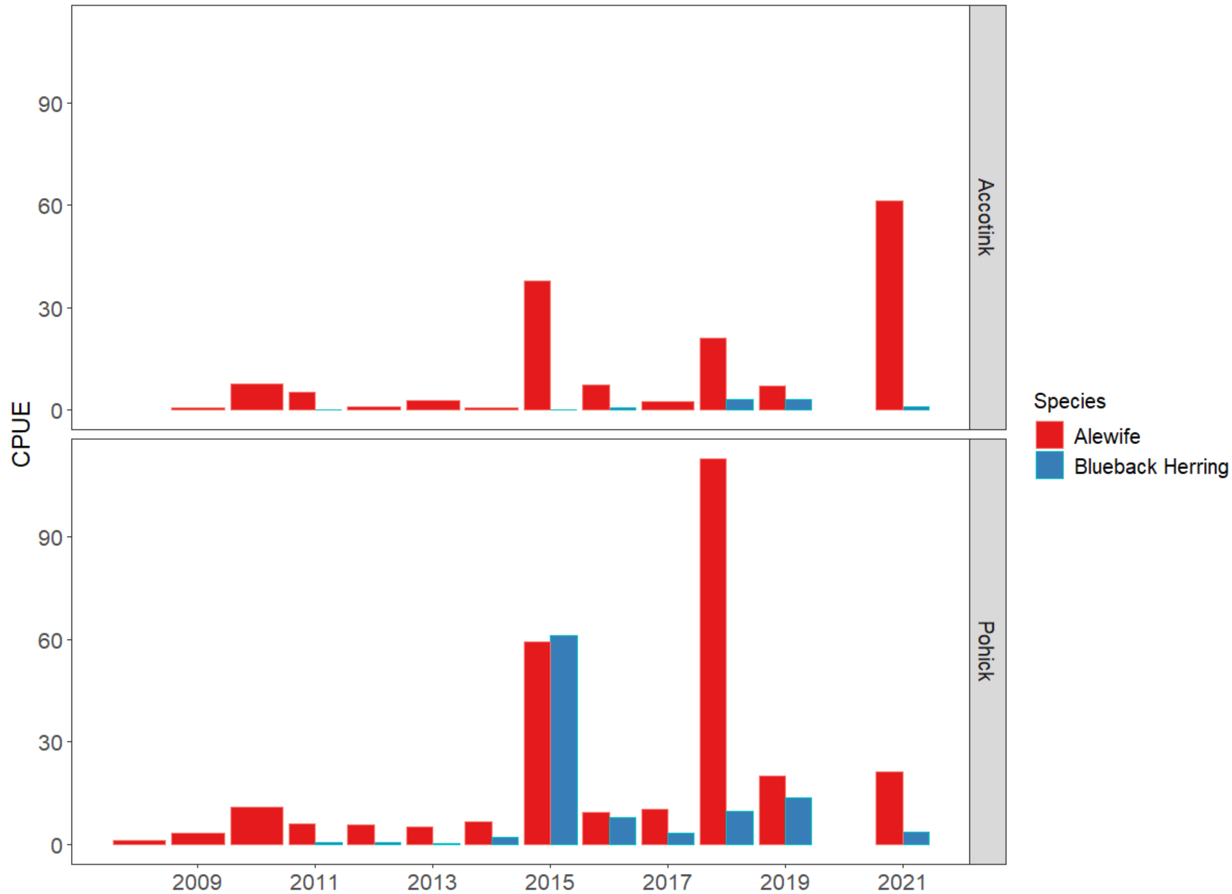


Figure 4. The CPUE (number of individuals per net sample) of *Alosa pseudoharengus* and *A. aestivalis* collected with the block net in each year.   Text

## Literature Cited

Bethoney, N. D., K. D. E. Stokesbury, B. P. Schondelmeier, W. S. Hoffman, and M. P. Armstrong. 2014. Characterization of River Herring Bycatch in the Northwest Atlantic Midwater Trawl Fisheries. North American Journal of Fisheries Management 34(4):828-838.

Cummins, J.D. 2005. The Potomac River American Shad restoration project. 2004 Summary Report. Interstate Commission on the Potomac River Basin Report No. 05-2. 6 + 3 p.

Fay, C. W., R. J. Neves, and G. B. Pardue. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (mid-Atlantic). U.S. Fish and Wildlife Service, Blacksburg, VA.

Jones, P. W., F. D. Martin, and J. D. Hardy, Jr. 1978. Development of fishes of the Mid-Atlantic Bight: an atlas of egg, larval, and juvenile stages, volume 1. Acipenseridae through Ictaluridae. U.S. Fish and Wildlife Service, FWS/OBS-78/12.

Kissil, G. W. 1974. Spawning of the Anadromous Alewife, Alosa pseudoharengus, in Bride Lake, Connecticut. Transactions of the American Fisheries Society 103:312–317.

Lake, T.R. and Schmidt. 1998. The relationship between fecundity of an Alewife (Alosa pseudoharengus) spawning population and egg productivity in Quassaic Creek, a Hudson River tributary (HRM 60) in Orange County, New York. Section II: 26 pp. In J.R. Waldman and W.C. Nieder (Eds). Final Reports of the Tibor T. Polgar Fellowship Program, 1997, Hudson River Foundation, NY.

Lippson, A. J., M. S. Haire, A. F. Holland, F. Jacobs, J. Jensen, R. L. Moran-Johnson, T. T. Polgar, and W. A. Richkus. 1979. Environmental atlas of the Potomac Estuary. Environmental Center, Martin Marietta Corp. 280 p.

Lippson, A. J., and R. L. Moran. 1974. Manual for the identification of early developmental stages of fishes of the Potomac River estuary. Maryland Department of Natural Resources, Baltimore.

Loesch, J. G., and W. A. Lund JR. 1977. A Contribution to the Life History of the Blueback Herring, Alosa aestivalis. Transactions of the American Fisheries Society 106:583–589.

Massmann, W.H. 1961. A Potomac River shad fishery, 1814 – 1824. Chesapeake Sci. 2 (1-2): 76-81.

NOAA (Department of Commerce). 2006. Endangered and Threatened Species; Revision of Species of Concern List, Candidate Species Definition, and Candidate Species List. Federal Register, Vol. 71, No. 200, Tuesday, October 17, 2006, pp. 61022-61025.

Smith, H.M., and B.A.Bean . 1899. List of fishes known to inhabit the waters of the District of Columbia and vicinity. U.S. Fish Commission Bulletin 18:179-187.

Walsh H.J., L.R Settle, and D.S. Peters. 2005. Early life history of Blueback Herring and Alewife in the lower Roanoke River, North Carolina. Transactions of the American Fisheries Society 134:910-926.