An Ecological Study of Gunston Cove

2017

FINAL REPORT

December 2018

by

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Back of Title Page

Table of Contents

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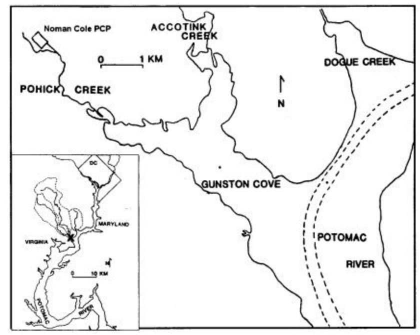
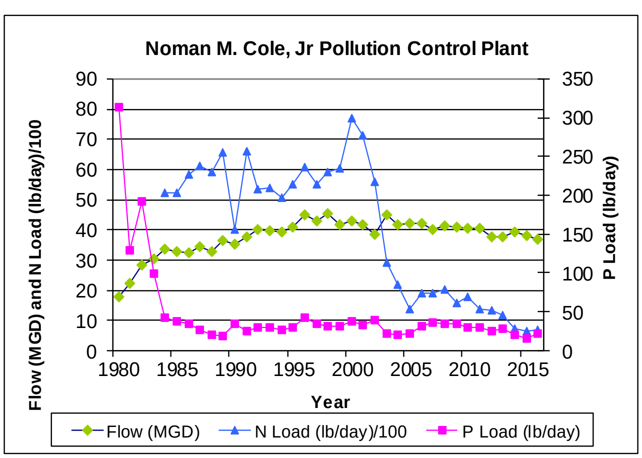
Executive Summary



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 2017 in the context of the entire data record.

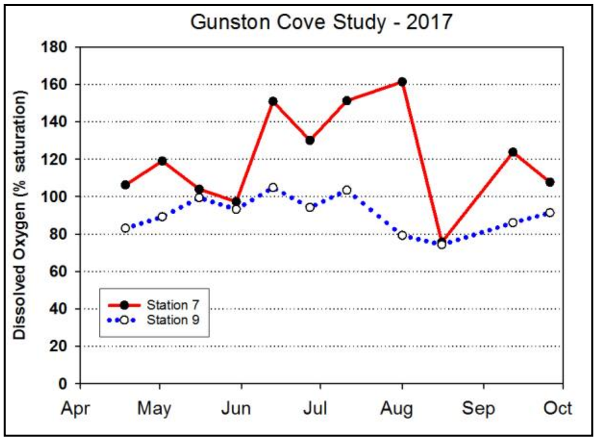
The Chesapeake Bay, of which the tidal Potomac River is a major subestuary, is the largest and most productive coastal system in the United States. The use of the bay as a fisheries and recreational resource has been threatened by overenrichment with nutrients which can cause nuisance algal blooms, hypoxia 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.

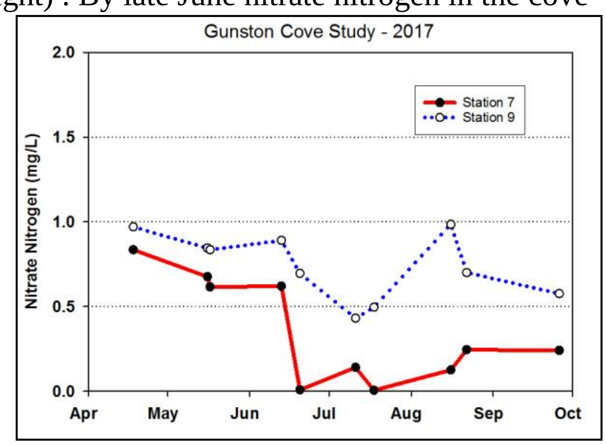
The ongoing ecological study reported here provides documentation of major improvements in water quality and biological resources which can be attributed to those efforts. Water quality improvements have been substantial in spite of the increasing population and volume of wastewater produced. The 35 year record of data 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.

The year 2017 was characterized by temperatures well above normal for April and June, but near normal the rest of the year. Monthly precipitation was well above normal in May and July, but close to normal in other months.

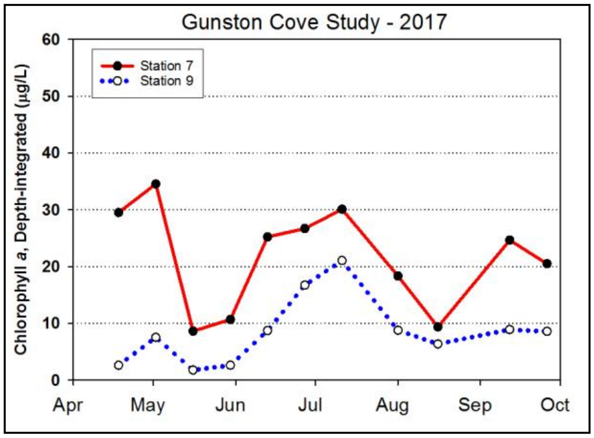


Mean water temperature was similar at the two stations with a pronounced dip in late May and a peak of nearly 30° in early July. Specific conductance declined substantially at both stations in the wake of the late May flow events. Dissolved oxygen saturation (DO) was normally substantially higher in the cove than in the river due to photosynthetic activity of phytoplankton and submersed aquatic vegetation (SAV) (figure at left). Field pH patterns mirrored those in DO: higher values in the cove than the river. Total alkalinity was generally higher in the river than in the cove and was fairly constant seasonally. Secchi disk transparency was quite constant over the year and did not attain values above 1 m, in contrast to recent years. Light attenuation coefficient and turbidity followed a similar pattern.

Ammonia nitrogen was consistently low in the study area during 2017, but all values were below the limits of detection making analysis of any temporal or spatial trends impossible. Nitrate values declined seasonally at both sites due to algal and plant uptake and possibly denitrification (figure to the right) . By late June nitrate nitrogen in the cove was below detection limits where it remained through the remainder of the year. River nitrate nitrogen levels reached a low of about 0.5 mg/L. Organic nitrogen exhibited substantial variability averaging somewhat higher in the cove over the year. Total phosphorus was similar at both sites and showed little seasonal change. Soluble reactive phosphorus was very low and consistently below detection limits in the cove and higher in the river. N to P ratio did not show a consistent seasonal pattern, but was lowest in the cove in late June at about 10 which is still indicative of P limitation of phytoplankton and SAV. BOD was generally

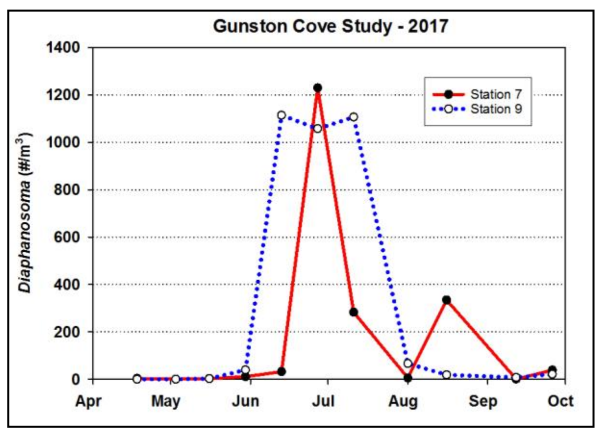


higher in the cove than in the river. TSS and VSS did not show strong spatial and temporal patterns.



In the cove algal populations as measured by chlorophyll *a* were consistently higher in the cove than in the river, but showed a similar seasonal pattern (figure to the left). Chlorophyll was unusually high in the cove in late April and early May. A decline was observed in late May followed by a resurgence in June and July at both stations with a maximum in mid-July at both stations. A decline was observed at both stations in late July and early August. Cell density tracked chlorophyll fairly well in the cove with maxima in May and July. Little seasonal change was observed in cell density in the river. Cell density in the cove was dominated by cyanobacteria, with *Oscillatoria, Merismopedia,* and *Anabaena* being the dominants. In the river, cyanobacteria dominanted in most months with diatoms being important in spring and early summer. Pennate diatoms and *Oscillatoria* were dominant. Phytoplankton biovolume was strongly weighted towards diatoms with *Melosira* and discoid centrics making the greatest contributions.

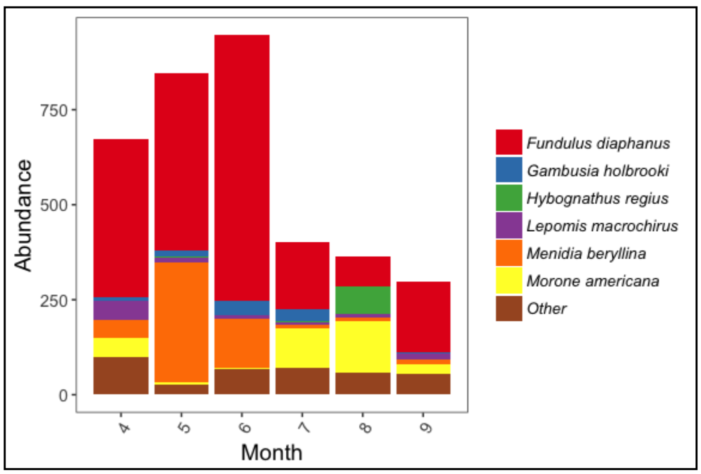
Rotifers continued to be the most numerous zooplankton in 2017. Rotifer densities were unusually high in early May in the cove, but were low in the river until later in the year. Another peak was observed in late June. *Brachionus* and *Keratella* shared dominance in both areas. *Bosmina*, a small cladoceran that was often common was present at low densities in 2017 except for the early May sample in the river where it was very abundant. *Diaphanosoma*, a larger cladoceran was found in both area at moderate densities peaking in the summer (figure to the right). Surprisingly, *Daphnia* was present at very low levels in 2017. *Leptodora* was moderately abundant in the cove and showed high abundance in mid June in the river. Copepod nauplii densities reached a distinct peak in the river in late June, but were variable in the cove. The calanoid copepod *Eurytemora* was very abundant in the river in June and July, but relatively rare in the cove. A second calanoid *Diaptomus* was found at much lower levels. Cyclopoid copepods had a strong maximum in the river in late June, but were rare in the cove.



In 2017 ichthyoplankton was dominated by clupeids, most of which were Alewife, Gizzard Shad, and Blueback Herring, and to a lesser extent Hickory Shad, and American Shad. White Perch was found in relatively high densities as well. *Morone* species (White Perch and Striped Bass) were mostly found in the Potomac mainstem, confirming their affinity for open water. Other taxa were found in very low densities similar to the previous year. The highest density of fish larvae occurred at the start of May, which was driven by a high density of Clupeid larvae in combination with relative density of other larvae. The non-clupeid larval density was highest in spring and declines from there, while clupeid density saw two distinct peaks (at the beginning of May and June).

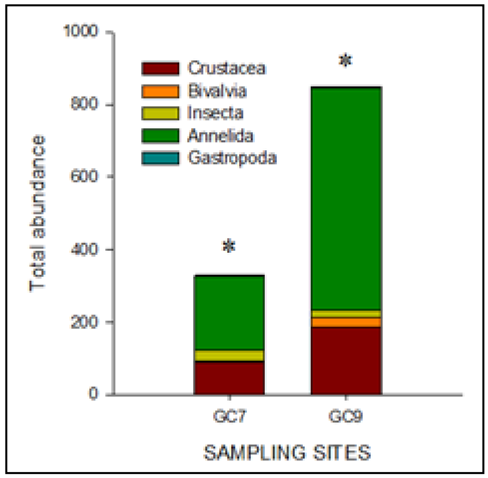
In trawls, White Perch (*Morone americana*) dominated with 71.27% of the catch, distantly followed by the still abundant taxa Spottail Shiner (*Notropis hudsonius*) and several species of sunfish. White Perch was by far the most abundant species and was found in all months at all stations, with peak abundance in July. Sunfishes were found throughout the year as well. Other numerically abundant taxa included Tessellated Darter, Yellow Perch, Banded Killifish, and Goldfish. Blue Catfish was collected with the trawl again this year, this time two in the mainstem, and two in the cove. We collected one native catfish (Brown Bullhead) within Gunston Cove. Almost all specimens of White Perch, sunfish, and Spottail Shiner were collected at station 7, which is our trawl station most representative of Gunston Cove.

In seines, the most abundant species was Banded Killifish (*Fundulus diaphanus*). Banded Killifish was far more abundant in seines than in trawls (figure to the left), 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). The abundance peak of Banded Killifish was in early June. Other taxa with high abundances were Inland Silverside (Menidia beryline) and White Perch (*Morone americana*).



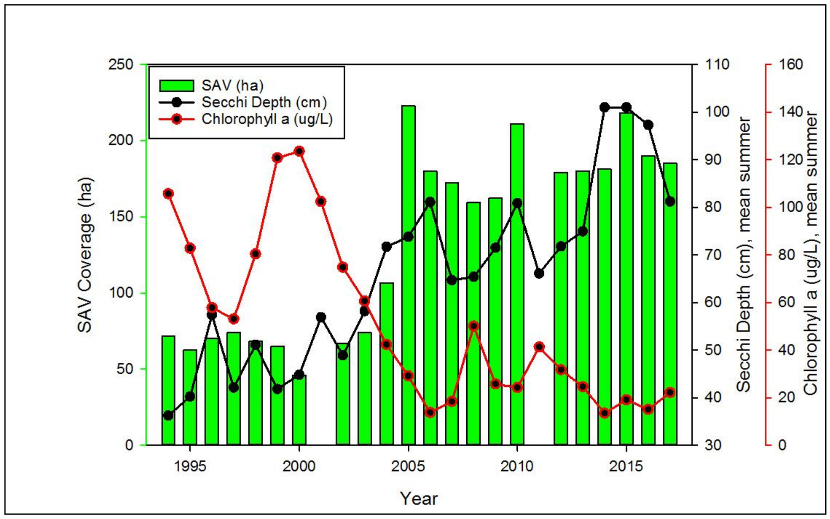
Fyke nets were part of the sampling regime again in 2017. The total catch of the fyke nets is smaller than the other gears, but still represents an interesting contribution to the total catch because the composition of the catch is different than the trawls and seines. Sunfishes were the most dominant taxa, with Banded Killifish as the second most abundant species. Sunfishes that could be identified to the species level were represented in order of abundance by Pumpkinseed, Bluegill, Redear Sunfish, and Bluespotted Sunfish. Fish abundance was highest in July. Overall catches were lowest in May, when SAV was still absent or sparse. Like last year, we found very few native catfishes in the fyke nets this year (one Brown Bullhead).

The coverage of submersed aquatic vegetation (SAV) in 2017 was similar to recent years. Mapping of the SAV coverage by species revealed that a native aquatic plant, *Najas guadalupensis* (common water-nymph), was the most frequently encountered plant and had the highest density. The exotic plant *Hydrilla* also widespread, but less dense. *Najas minor* (minor naiad, non native) and *Certophyllum demersum* (coontail, native) were also frequently encountered. As in most previous years, oligochaetes were the most common invertebrates collected in ponar samples in 2017. Encouragingly, the second most abundant taxon at both stations was Crustacea, represented by amphipods (figure to the right). While these often had been abundant in the river, their significant levels in the cove was new in 2017. Chironomids in the cove and bivalves in the river were next in abundance. There were significantly more individuals at the river station.



In the anadromous creek survey (of fish migrating from salt water to spawn in fresh water), Alewife was the dominant species in both larval and adult collections in both Pohick and Accotink Creeks. In the hoop net sets, 90 Alewife, 24 Blueback Herring, and 5 Hickery Shad adults were collected. While these numbers were lower than observed in 2016 and, especially 2015, they are still in the middle range of previous years. In a notable sign of recovery Pohick Creek, which was totally devoid of spawning fish in the early years of the study, now typically harbors more spawners than Accotink Creek. In fact, almost all of the Blueback Herring and Hickory Shad spawning was in Pohick Creek.

Two special studies were commissioned in 2017, both concerned with benthic macroinvertebrates. These reports were included as separate chapters at the end of this full annual report. One involved development of a benthic index of biotic integrity for the tidal freshwater Potomac River. Progress was made in compiling a complete list of potential macroinvertebrate taxa and features of their ecology like pollution tolerance which are required for index development. Additional data needs such as reference site data were identified. The second special report compiled relevant information on the status and diversity of native freshwater mussels in the tidal freshwater Potomac River. This lays the ground for enhanced efforts to sample these valuable indicator organisms.



Data from 2017 generally reinforced the major trends which were reported in previous years. First, phytoplankton algae populations (which can cause nuisance algal blooms, hypoxia in stratified areas, and a decline of fisheries) in Gunston Cove have shown a clear pattern of declinee since 1989. Accompanying this decline have been more normal levels of pH and dissolved oxygen, and increased water clarity which are critical for a life-sustaining aquatic habitat. Data available through 2017 from Virginia Institute of Marine Science for SAV (submersed aquatic vegetation) assessment have indicated that the coverage by plants has remained at elevated levels observed since 2005 (green bars in figure below). The increased water clarity in the Cove has brought the rebound of SAV which provides increased habitat value for fish and fish food organisms. The SAV also filters nutrients and sediments and itself will inhibit the overgrowth of phytoplankton algae. This trend is undoubtedly the result of phosphorus removal practices at Noman M. Cole Pollution Control Plant which were initiated in the late 1970's (see first figure in Executive Summary). This lag period of 10-15 years between phosphorus control and phytoplankton decline has been observed in many freshwater systems resulting at least partially from sediment loading to the water column which can continue for a number of years. Gunston Cove is now an internationally recognized case study for ecosystem recovery due to the actions that were taken and the subsequent monitoring to validate the response.

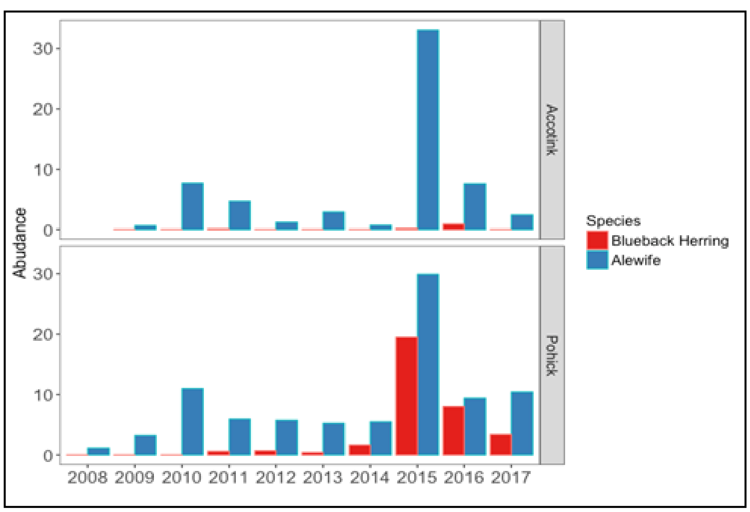
A second significant change in water quality documented by the study has been the removal of chlorine and ammonia from the Noman M. Cole, Jr. Pollution Control Plant effluent. A decline of over an order of magnitude in ammonia nitrogen has been observed in the Cove as compared to earlier years. The declines 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 changes 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 2017 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, and brown bullhead has decreased greatly in the Cove. Blue Catfish are regarded as rather voracious predators and may negatively affect the food web.

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 2017 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 and Banded Killifish in the SAV beds. In addition to SAV expansion, 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.

Juvenile anadromous species continue to be an important component of the fish assemblage in Gunston Cove. We have seen declines in “river herring” (a multispecies group that includes both Alewife and Blueback 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 stocks rebound. We reported last year that the larval abundances of the *Alosa* genus was high in 2014, possibly resulting in higher adult abundances in 2015. We indeed saw higher numbers of juvenile Blueback Herring and Alewife in trawls in 2015, but this was not repeated in 2016 or 2017.

The most direct indication we have of the status of river herring spawning populations is the anadromous study in Pohick and Accotink Creeks (which included Dogue Creek and Quantico Creek up to 2008). We witnessed a one to two orders of magnitude increase in catches from Accotink and Pohick Creeks of Alewife and Blueback Herring (the two species that are considered river herring) in 2015; 2016 and 2017 catches were somewhat lower, but still substantial (figure above). The shad moratorium has been in place in Virginia and neighboring states for four years, which means this is likely the first cohort protected by this moratorium for one full life cycle. Through meetings with the Technical Expert Working group (TEWG)



for river herring (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 in 2015; some surveyors even reported declines. Since the 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. Thus, the habitat in the Gunston Cove may be of suitable quality to support a larger spawning population now that reduced fishing pressure allows for more adults to return to their natal streams. Continued monitoring in years after this large spawning population was observed, will determine if this spawning season results in a successful year class, and if this is the first year of continued high river herring abundances.

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.

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 counts 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 nitrate and ammonia nitrogen. We recommend reviewing analytical protocols to try to lower detection limits for these two variables.
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. GMU's Potomac Environmental Research and Education Center instituted a continuous water quality monitoring site at Pohick Bay marina in May 2011. This program was suspended in 2014 due to ramp construction near the monitor, but we will consider reinstituting the program in 2017 should the County consider it valuable.
6. As river restoration continues, the benthic community including native mussels is showing signs of rejuvenation. We recommend that more use be made of the benthos in tracking recovery of the River. To that end we recommend that the initative to construct a Benthic Index of Biotic Integrity (B-IBI) for the tidal Potomac River be continued with the goal of having a trial index available by the end of the next contract.

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

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THE ONGOING AQUATIC MONITORING PROGRAM

FOR THE GUNSTON COVE AREA

OF THE TIDAL FRESHWATER POTOMAC RIVER

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to

Department of Public Works and Environmental Services
County of Fairfax, VA

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 Juan Reyes 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 are 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. Joris van der Ham headed up field fish collecting. Dr. Saiful Islam conducted phytoplankton counts. Thanks also go to C.J. Schlick, Beverly Bachman, Sammie Alexander, Chelsea Gray, Tabitha King, Casey Pehrson, Kristen Reck, Maziar Nourizadeh, Alex van Plantinga, Jessie Melton, Michael Rollins, Heather Nortz, Lisa McAnulty, Rachel Kelmartin, Julia Czarnecki, Mary Randolph, Lauren Atol-Patton, and Michael Cagle. Claire Buchanan served as a voluntary consultant on plankton identification. Roslyn Cress and Lisa Bair were vital in handling personnel and procurement functions.

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.

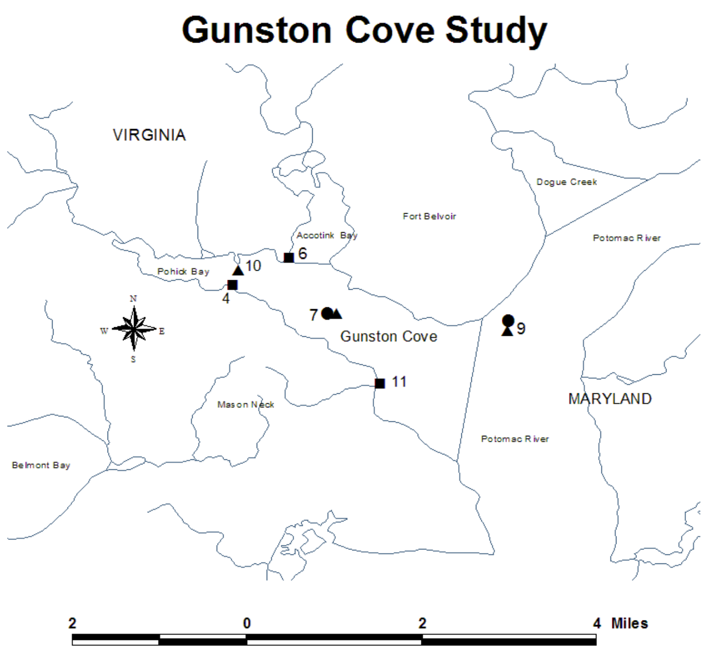


Figure 1a. Gunston Cove area of the Tidal Potomac River showing sampling stations. Circles (●) represent Plankton/Profile stations, triangles (▲) represent Fish Trawl stations, and squares (■) represent Fish Seine stations.

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

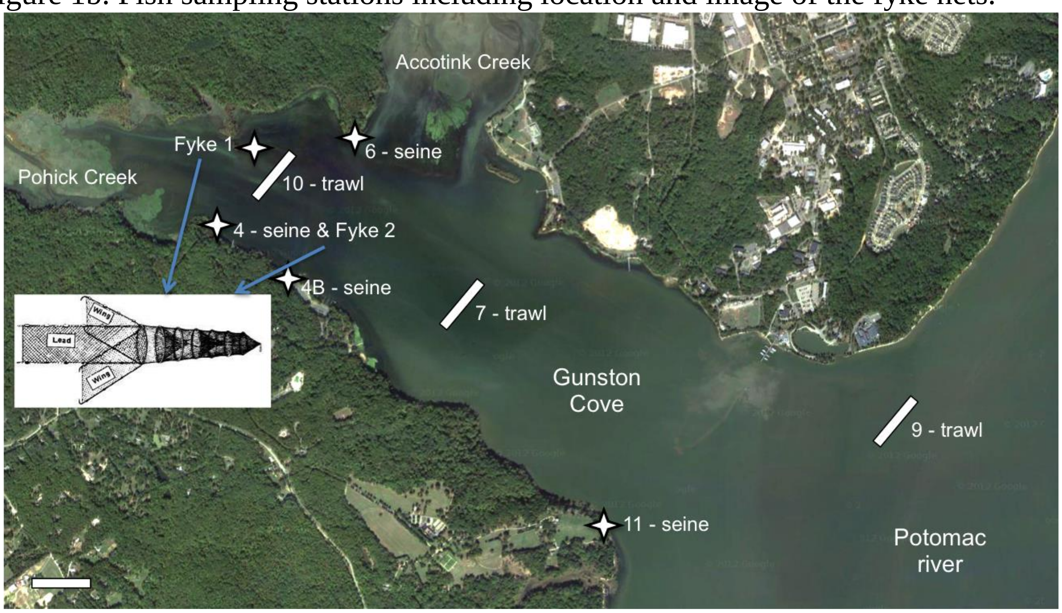


Table 1
Sampling Dates and Weather Data for 2017

	Type of Sampling					Avg Daily Temp (ºC)		Precipitation (cm)	
Date	G	F	T	S	Y	1-Day	3-Day	1-Day	3-Day
April 18	G	F				17.2	20.6	0	0.19
April 21			T	S		22.8	19.4	0.30	0.60
May 2	GB					22.2	23.5	0	T
May 12			T	S	Y	12.8	14.8	0.79	3.43
May 16	G	F				19.4	18.9	0	T
May 17		F*				25.0	21.1	0	0
May 23			T	S	Y	17.8	18.0	0.15	1.03
May 30	G					20.0	21.3	0.43	0.65
June 6			T	S	Y	22.2	23.0	0	T
June 13	G	F				29.4	28.9	0	0
June 20		F*	T	S	Y	26.1	27.4	T	1.36
June 27	GB					23.3	24.8	0.18	0.18
July 7			T	S	Y	27.8	26.5	0.03	4.01
July 11	GB	F				28.9	27.2	T	T
July 18		F*	T	S	Y	29.4	28.3	T	0.03
August 1	GB		T	S	Y	27.2	25.4	0	0
August 15			T	S	Y	26.1	25.4	0.43	0.43
August 16	G	F				27.8	26.1	0	0.43
August 22		F*				28.9	27.8	0	0.03
September 12	GB					22.2	19.6	0	0
September 19			T	S	Y	24.4	24.3	0	0
September 26	G	F				25.6	26.5	0	0

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. Except as indicated by asterisk, all samples collected by GMU personnel.
*Samples collected by Fairfax County Lab 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. On dates when water samples were not being collected for water quality analysis by the Fairfax County laboratory, benthic macroinvertebrate samples were collected. Three samples were collected at each site using a petite ponar grab. The bottom material was sieved through a 0.5 mm stainless steel sieve and resulting organisms were preserved in rose bengal formalin for lab analysis.

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 extracted in a ground glass tissue grinder to which 4 mL of dimethyl sulfoxide (DMSO) was added. The filter disintegrated in the DMSO and was ground for about 1 minute by rotating the grinder under moderate hand pressure. The ground suspension was transferred back to its scintillation vial by rinsing with 90% acetone. Ground samples were stored in the refrigerator overnight. Samples were removed from the refrigerator and centrifuged for 5 minutes to remove residual particulates.

Chlorophyll *a* concentration in the extracts was determined fluorometrically using a Turner Designs Model 10 field fluorometer configured for chlorophyll analysis as specified by the manufacturer. The instrument was calibrated using standards obtained from Turner Designs. Fluorescence was determined before and after acidification with 2 drops of 10% HCl. Chlorophyll *a* was calculated from the following equation which corrects for pheophytin interference:

Chlorophyll *a* (µg/L) = $F_s R_s (R_b - R_a)/(R_s - 1)$

where F_s=concentration per unit fluorescence for pure chlorophyll *a*
R_s=fluorescence before acid / fluorescence after acid for pure chlorophyll *a*
R_b=fluorescence of sample before acid
R_a=fluorescence of sample after acid

All chlorophyll analyses were completed within one month of sample collection.

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:

Zooplankton (#/L or #/m^3) = $NV_s/(V_cV_f)$

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, and setting fyke nets at stations fyke 1 and fyke 2 (Figure 1a and b). 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 and weather conditions are found in Table 1. Due to extensive SAV cover, station 10 could not be sampled in June, July, August and September of 2017.

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. 4B was added to the sampling stations since 2007 because extensive SAV growth interferes with sampling station 4 in late summer. Due to extensive SAV cover, station 4 could not be sampled in July, August and September of 2017.

Due to the permanent recovery of the SAV cover in station 4 and station 10, we adjusted our sampling regime in 2012, and have continued with this approach since then. Fyke nets are now set in station fyke 1 (near trawl station 10) and station fyke 2 (near seine station 4) during the entire sampling season. Setting fyke nets when seining and trawling is still possible will allow 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). Due to logistical issue, we did not set the fyke nets in April 2017.

After collection with various gear types, 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

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. Bottom samples were sieved on site through a 0.5 mm stainless steel sieve and preserved with rose bengal formalin. In the laboratory benthic samples 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.

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 - 2017

In 2017 air temperature was substantially above average in April and June, but near normal the remainder of the year (Table 2). July was the warmest month, with June being untypically warmer than August. There were 33 days with maximum temperature above 32.2°C (90°F) during 2017 which is near the median number over the last decade. Precipitation was well above normal during May and July, near normal in March, April and August, and below normal in the other months. The largest daily rainfall totals during the period of sampling was 8.41 cm on July 28. Over two days on July 22-23, 6.02 cm were observed. July exhibited mean discharge that was over twice the long-term average in Accotink Creek (Table 3). June and September average discharge was less than half the mean monthly value. May mean discharge was elevated in the river mainstem.

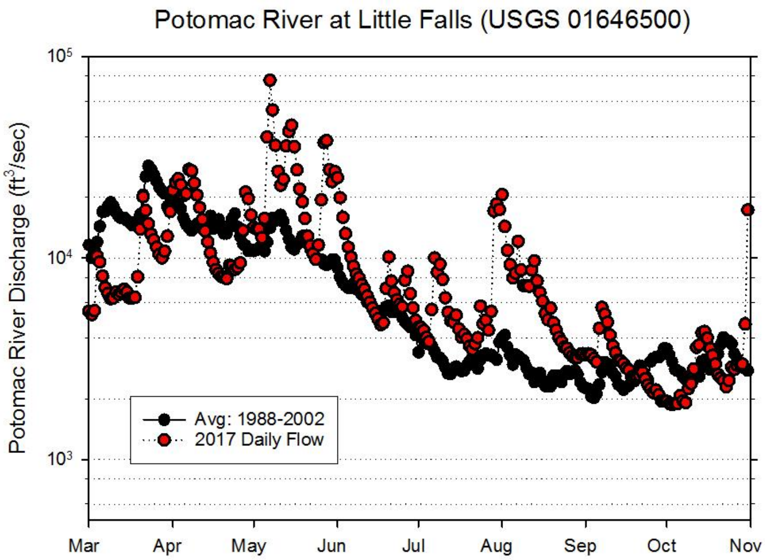
Table 2. Meteorological Data for 2017. National Airport. Monthly Summary.

MONTH	Air Temp (°C)		Precipitation (cm)	
March	8.4	(8.1)	8.1	(9.1)
April	18.2	(13.4)	6.7	(7.0)
May	18.8	(18.7)	14.1	(9.7)
June	25.5	(23.6)	2.9	(8.0)
July	27.7	(26.2)	23.3	(9.3)
August	25.1	(25.2)	11.6	(8.7)
September	22.8	(21.4)	3.7	(9.6)
October	---	(14.9)	---	(8.2)
November	---	(9.3)	---	(7.7)
December	---	(4.2)	---	(7.8)

Note: 2017 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.

Table 3. Monthly mean discharge at USGS Stations representing freshwater flow into the study area. (+) 2017 month > 2x Long Term Avg. (-) 2017 month < ½ Long Term Avg.

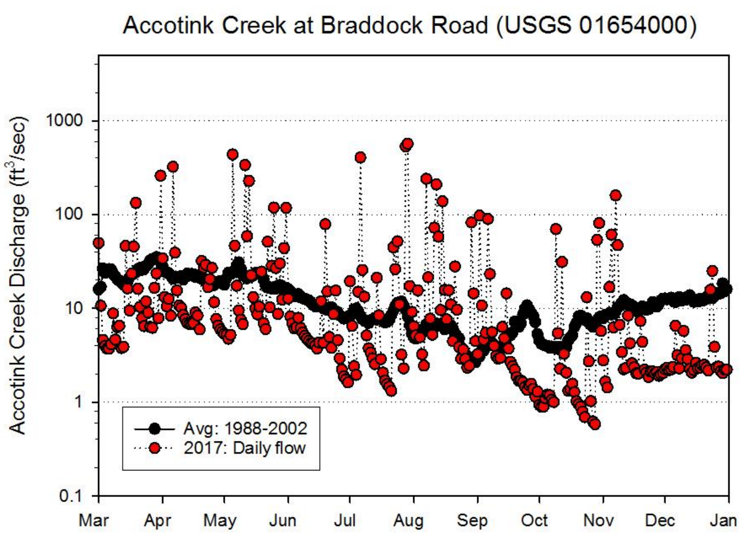
	Potomac River at Little Falls (cfs)		**Accotink Creek at Braddock Rd (cfs)**	
	2017	**Long Term Avg.**	**2017**	**Long Term Avg.**
March	9517 (-)	23600	24.8	42
April	15646	20400	24.4	36
May	26578	15000	55.3	34
June	8528	9030	8.4 (-)	28
July	6408	4820	58.4 (+)	22
August	6860	4550	32.6	22
September	3091	5040	10.2 (-)	27
October	3271	5930	9.4 (-)	19



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: 2017. Potomac River at Little Falls (USGS Data). Month tick is at the beginning of the month.

Potomac River discharge during 2017 was below normal during most of March and April (Table 3, Figure 2). From May through early June Potomac flows were consistently above the long-term mean. In July and August Potomac flows were consistently above average. Accotink Creek flows followed a similar pattern with most sampling months near normal (Figure 3). Throughout the year there were large, short lived flow peaks due to individual storms. A high incidence of these short-lived peaks occurred in 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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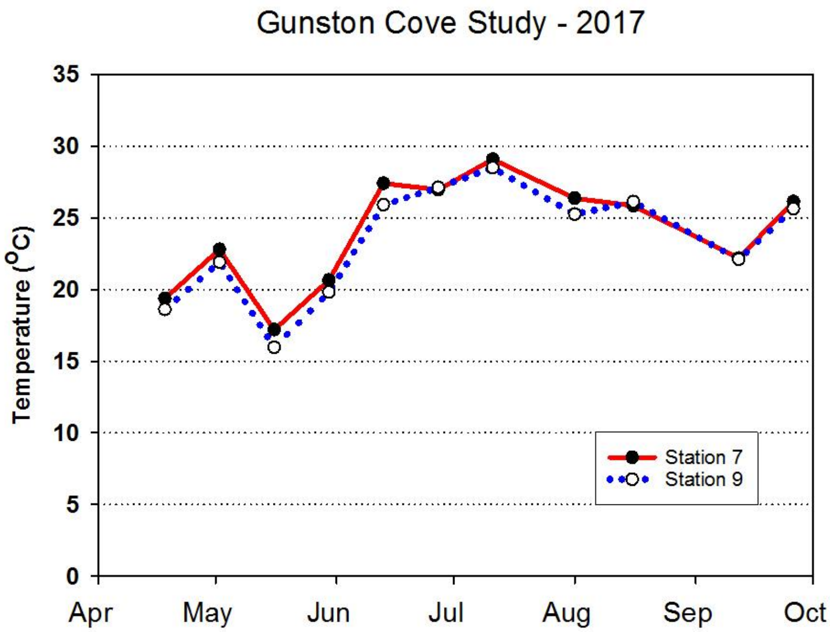
Figure 3. Mean Daily Discharge: 2017. Accotink Creek at Braddock Road (USGS Data).

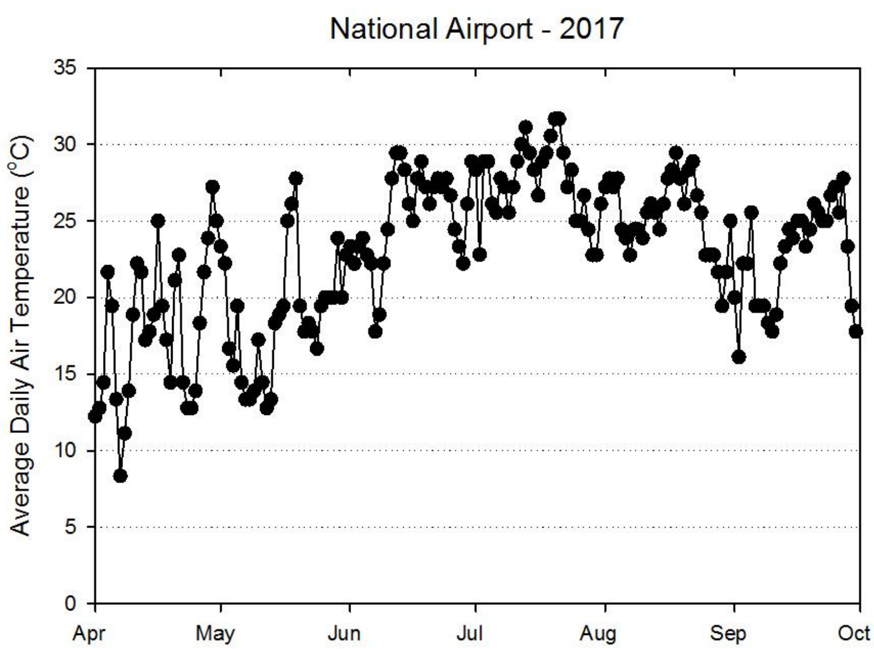
B. Physico-chemical Parameters – 2017



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.

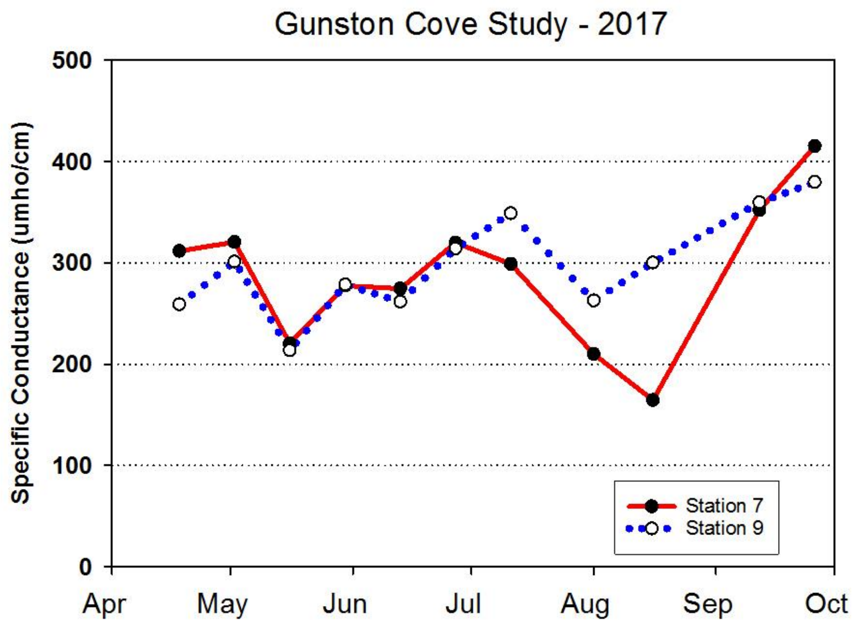
Figure 4. Water Temperature (^oC). GMU Field Data. Month tick is at first day of month.

In 2017, water temperature followed the typical seasonal pattern at both sites with the exception of a marked cooling in late May (Figure 4). Both sites approached 30°C in early July which was the warmest period for air temperature (Figure 5). For most of the summer, the two stations showed very similar water temperatures. Water temperature declined in early September, but rebounded in late September as did air temperature.



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.

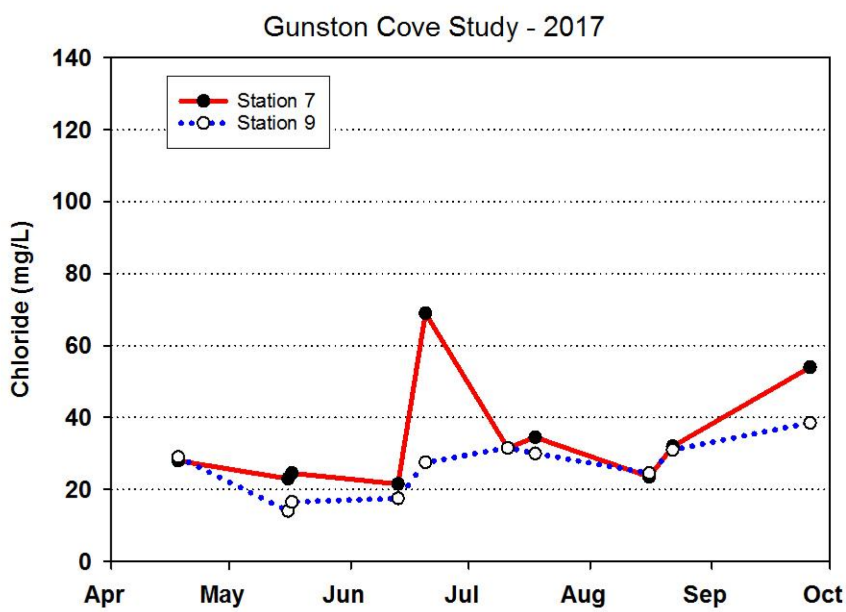
Figure 5. Average Daily Air Temperature (^oC) at Reagan National Airport.



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.

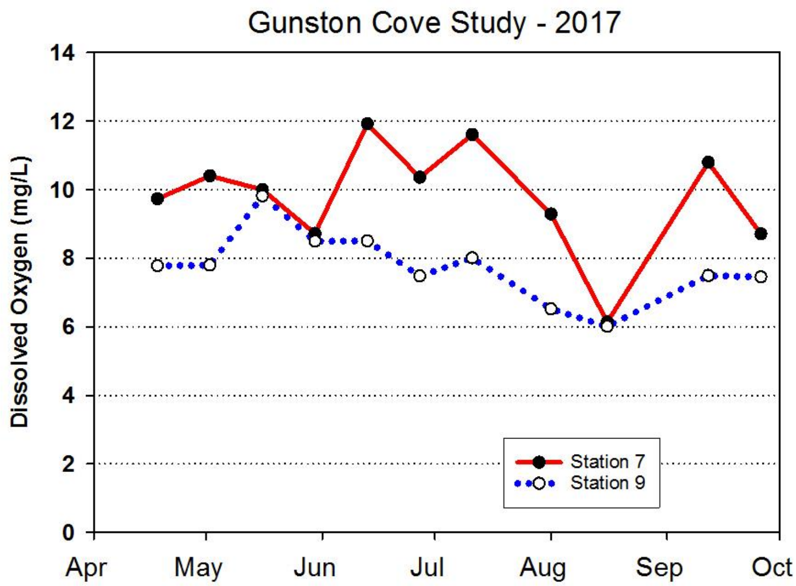
Figure 6. Specific Conductance (uS/cm). GMU Field Data. Month tick is at first day of month.

Specific conductance was generally around 300 uS/cm at both stations (Figure 6). A clear decline was observed in late May at both stations and in mid August in the cove. Both stations were increasing in September. Chloride ion was consistently slightly higher at Station 7 and exhibited a less marked seasonal pattern than did specific conductance (Figure 7). On one sample date in late June, chloride was clearly elevated only at Station 7.



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.

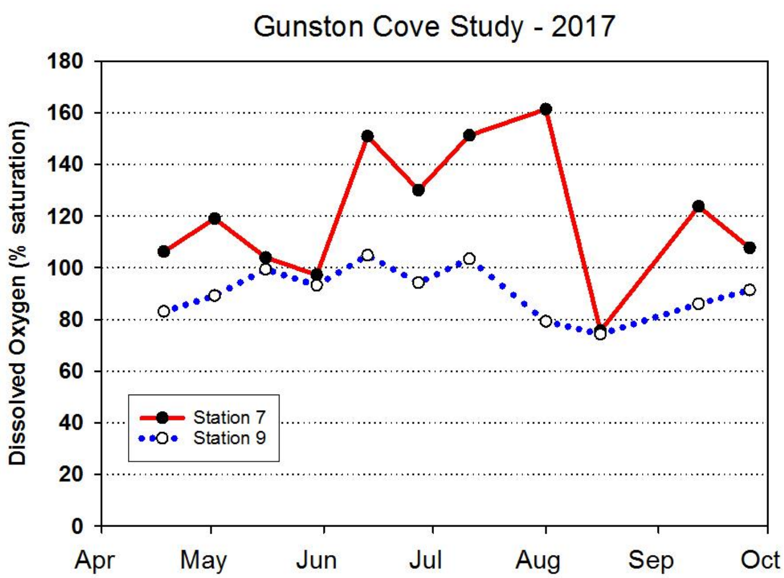
Figure 7. Chloride (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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 soluble at low temperatures.

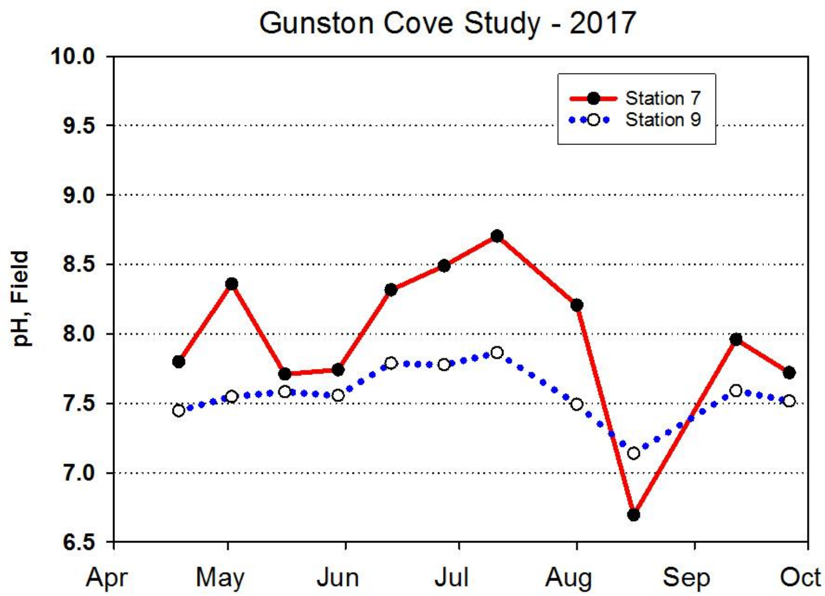
Figure 8. Dissolved Oxygen (mg/L). GMU Field Data. Month tick is at first day of month.

Dissolved oxygen showed substantial differences between the two stations for most of the year (Figure 8). On most dates the two sites diverged with Station 7 in Gunston Cove consistently exhibiting much higher values. Figure 9 shows that dissolved oxygen levels in the cove were often substantially above 100% 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. Elevated values in the cove in April and early May were probably attributable to phytoplankton while eleated values for the rest of the year were probably due to SAV.



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.

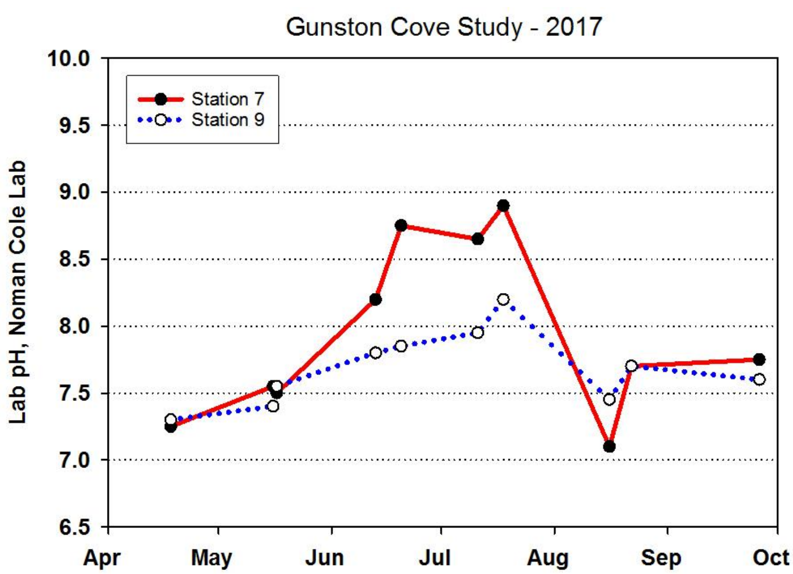
Figure 9. Dissolved Oxygen (% saturation). GMU Field Data. Month tick is at first day of month.



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 photosynthesis.

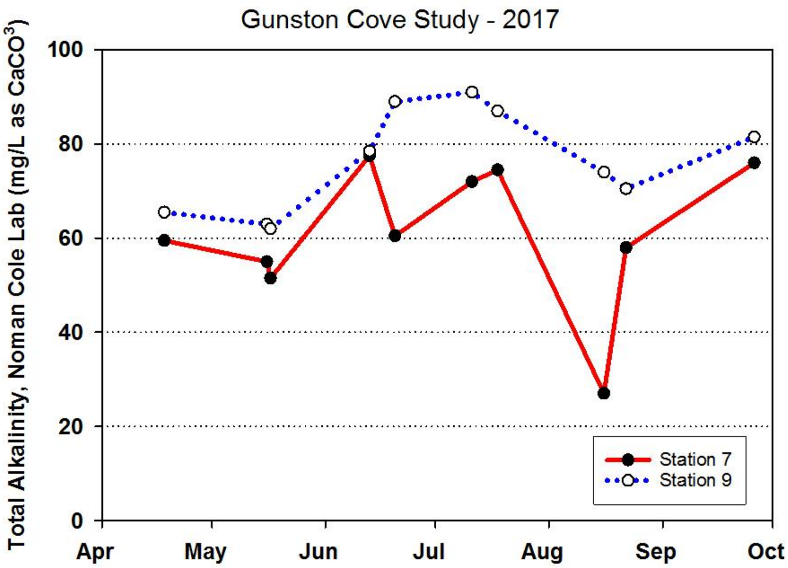
Figure 10. pH. GMU Field Data. Month tick is at first day of month.

Field pH was consistently greater in the cove than in the river again reflecting differences in photosynthetic activity (Figure 10). Times of elevated pH generally corresponded to those in dissolved oxygen. Lab pH was collected less frequently, but generally showed similar patterns (Figure 11). Of note is that both pH measurements showed a major decline in mid August as was also observed in dissolved oxygen.



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.

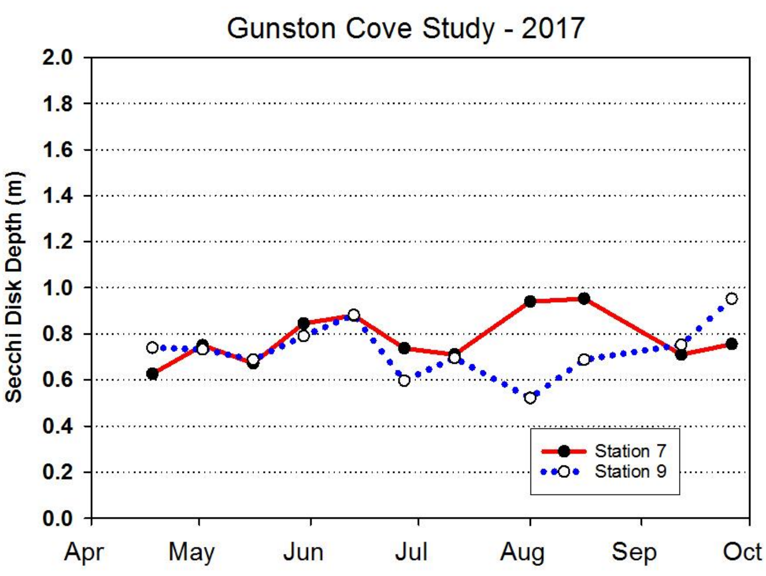
Figure 11. pH. Noman Cole Lab Data. Month tick is at first day of month.



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.

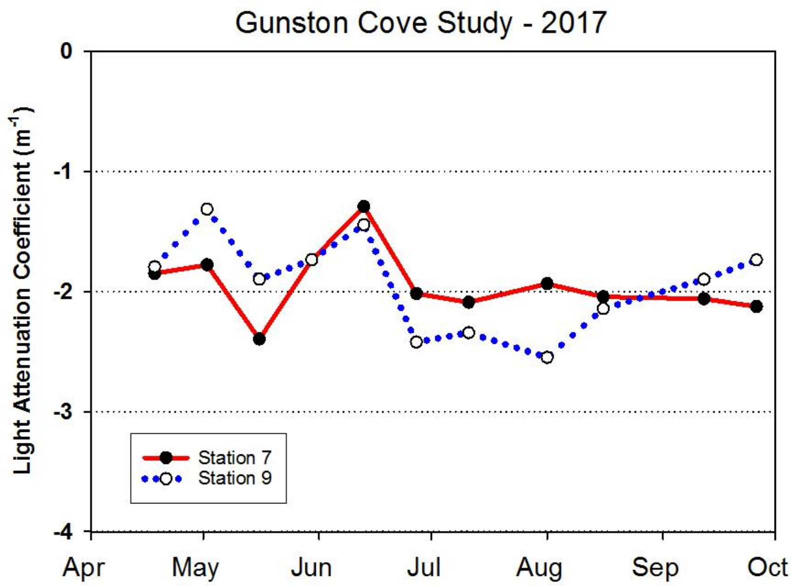
Figure 12. Total Alkalinity (mg/L as $CaCO_3$). Fairfax County Lab data. Month tick is at first day of month.

Total alkalinity was consistently higher in the river than in the cove by about 5-10 units (Figure 12). In mid August a strong decline was observed at Station 7 at a similar time as the declines in pH and dissolved oxygen. Water clarity as reflected by Secchi disk depth was generally similar at both sites, but in August was somewhat greater in the cove (Figure 13).



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 plants and algae.

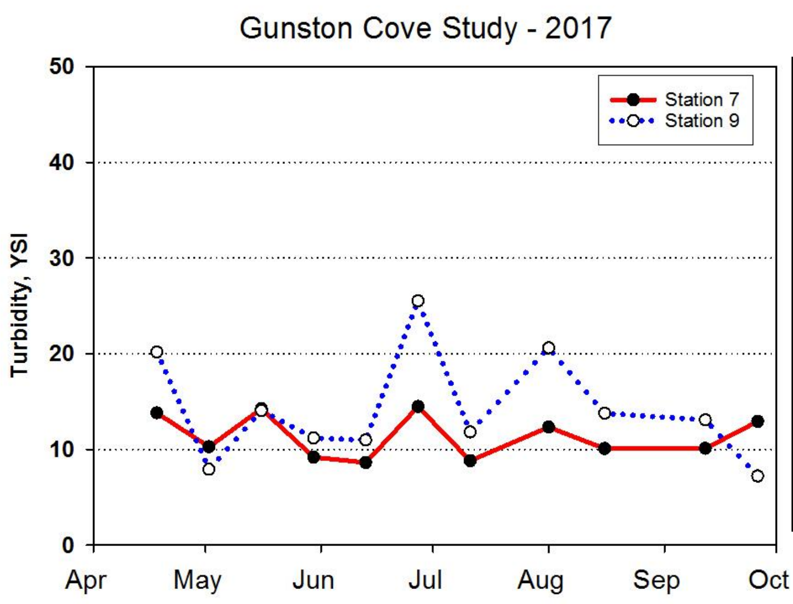
Figure 13. Secchi Disk Depth (m). GMU Field Data. Month tick is at first day of month.



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.

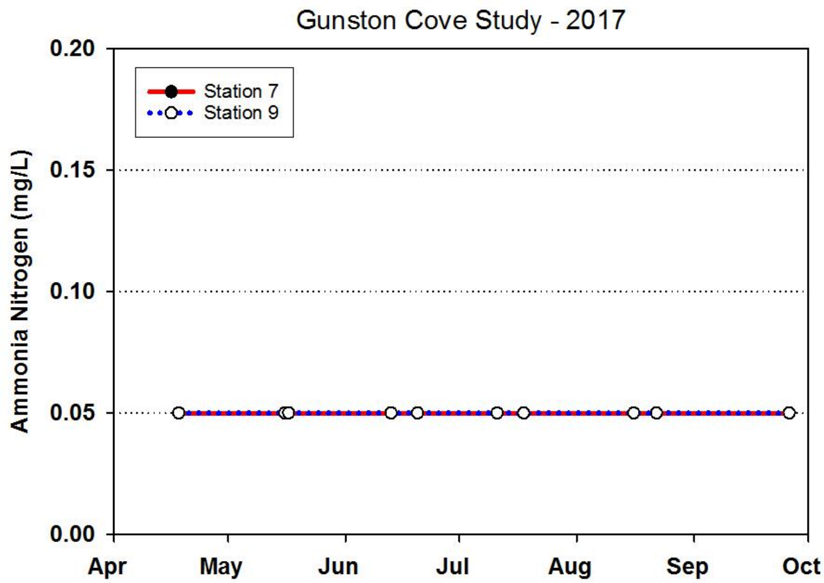
Figure 14. Light Attenuation Coefficient (m^{-1}). GMU Field Data. Month tick is at first day of month.

Light attenuation coefficient generally fell in the range -1.0 to -3.0 m^{-1} (Figure 14). Temporal and spatial trends were similar to those for Secchi depth. Turbidity was generally slightly lower in the cove than in the river (high turbidity corresponds to low transparency) (Figure 15).



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.

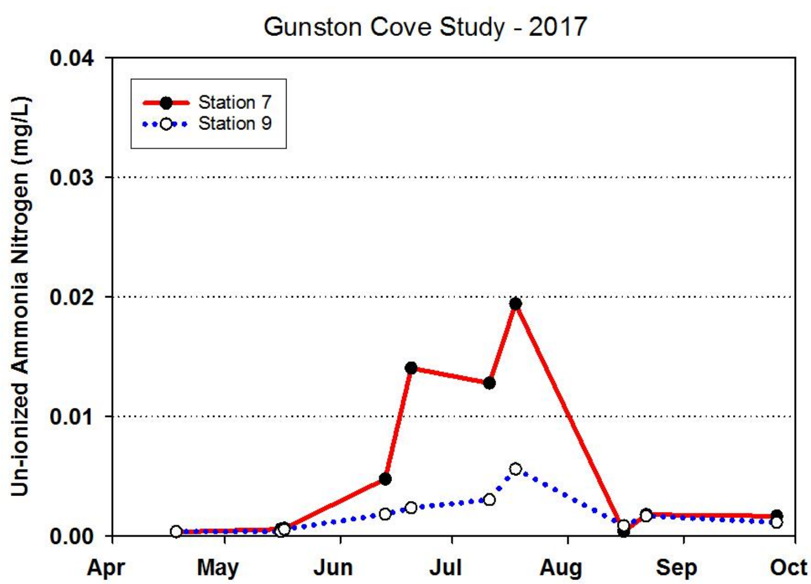
Figure 15. Turbidity (NTU). GMU Lab Data. Month tick is at first day of month.



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.

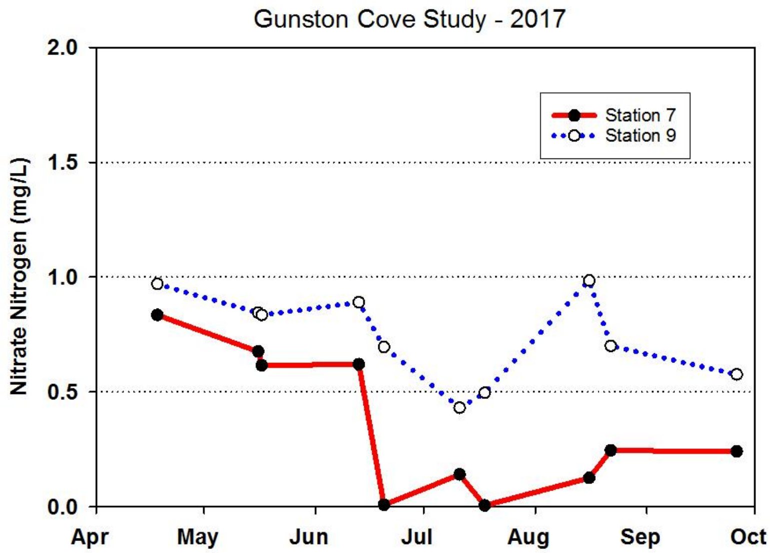
Figure 16. Ammonia Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month. (Limit of detection: 0.10 mg/L, LD values graphed as 0.05 mg/L)

Ammonia nitrogen was below detection limits in all samples reported in 2017 (Figure 16). Unfortunately, the detection limit at the Fairfax County Lab has increased substantially in the past two years from 0.01 mg/L to 0.1 mg/L. This has made it impossible to detect any further improvements in ammonia levels. Un-ionized ammonia was somewhat elevated in summer based on approximations of ammonia N (Figure 17). These values are subject to the same limitation as the ammonia nitrogen levels themselves.



Un-ionized ammonia nitrogen refers to ammonia gas (NH_3) dissolved in the water. This form is of interest because of its toxicity to aquatic life. The amount of un-ionized ammonia is a function of total ammonia, pH, and temperature. pH is especially important since as pH rises above 9, un-ionized ammonia rapidly increases. Un-ionized ammonia concentrations above 1 mg/L, well in excess of those observed here, are considered toxic to aquatic life.

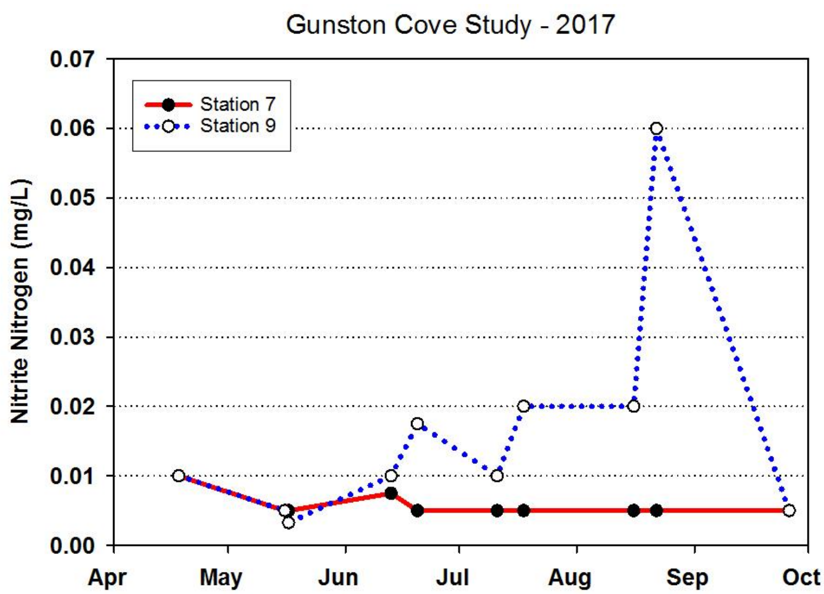
Figure 17. Un-ionized Ammonia Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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.

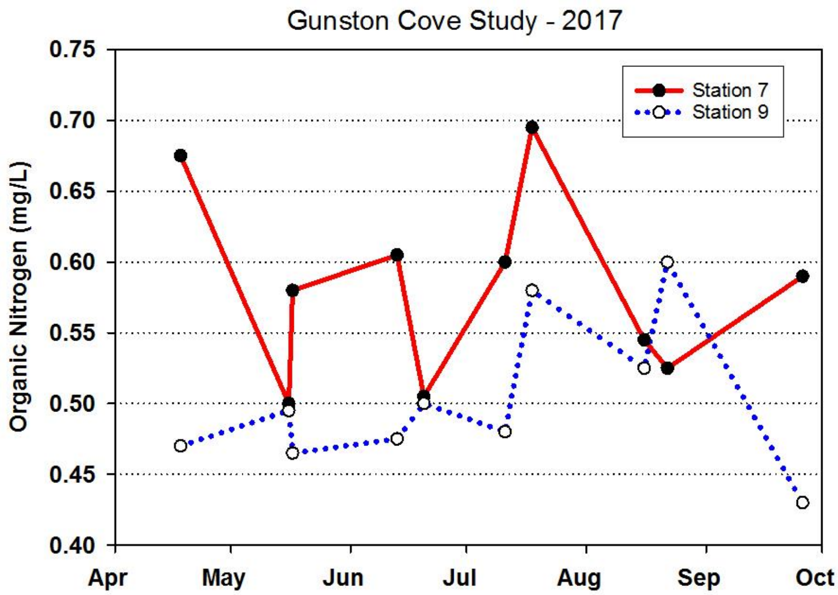
Figure 18. Nitrate Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month. (Limit of detection: 0.01 mg/L; LD values graphed as 0.005 mg/L)

Nitrate nitrogen levels were highest at both sites in early spring and declined during the summer (Figure 18). The decline was much quicker in the cove. This decline corresponded to the upswing in phytoplankton and SAV and was probably due to algal and SAV uptake. Nitrate essentially disappeared in the cove in midsummer. Nitrite nitrogen remained low throughout the year, often being below the limit of detection in the cove, but being consistently somewhat higher in the river (Figure 19). One exceptionally high value was reported in late August in the river.



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.

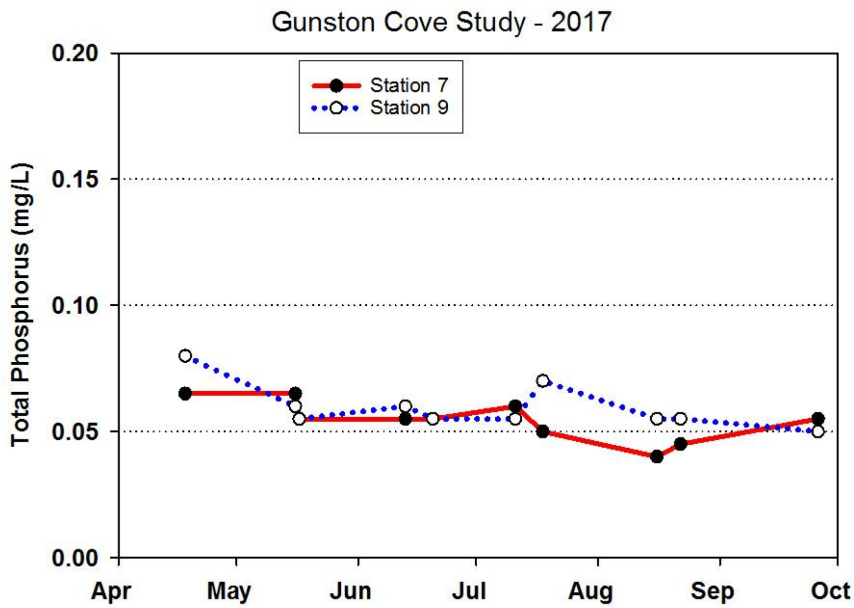
Figure 19. Nitrite Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month. (limit of detection = 0.01 mg/L).



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

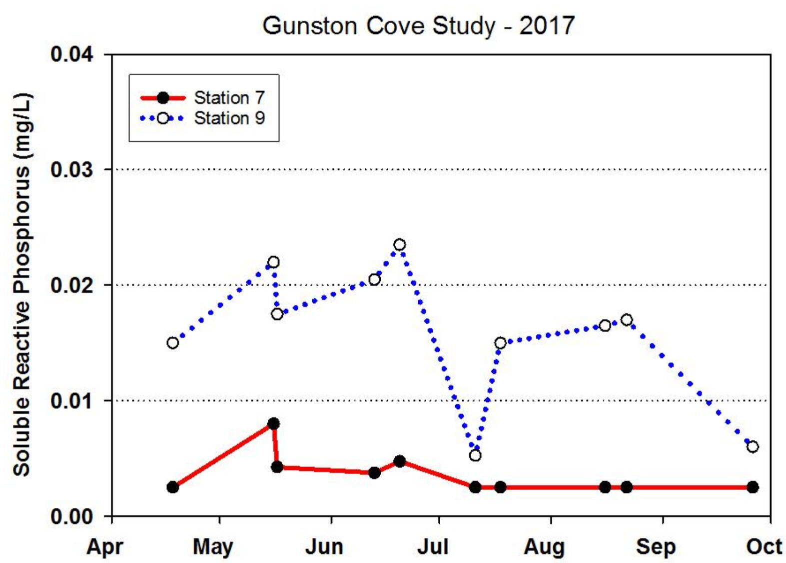
Organic nitrogen was quite variable in the cove with little seasonal pattern (Figure 20). In the river there appeared to be a seasonal increase through late August and a decline in September.



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.

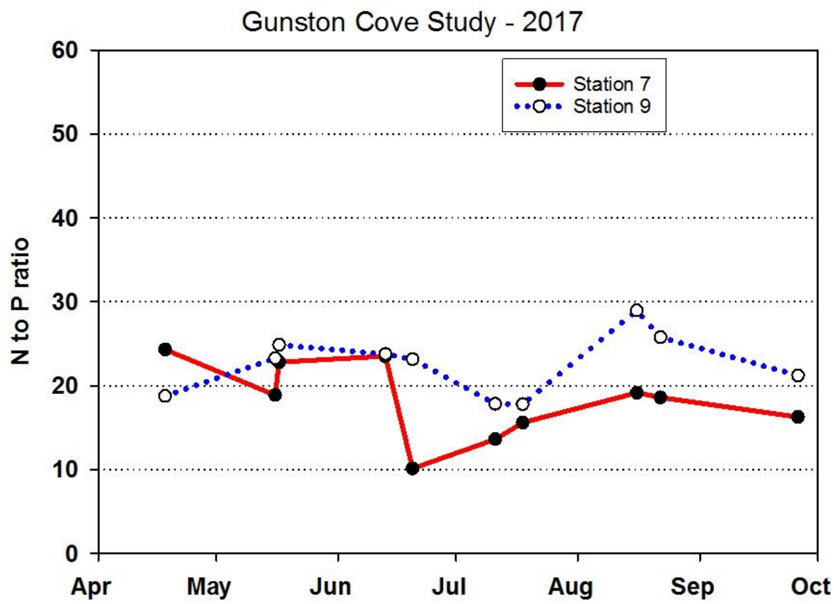
Figure 21. Total Phosphorus (mg/L). Fairfax County Lab Data. Month tick is at first day of month. (Limit of detection: 0.03 mg/L)

Total phosphorus was similar at both sites on almost all dates and showed very little seasonal variation (Figure 21). Soluble reactive phosphorus was consistently higher in the river while being quite low in almost all cove samples (Figure 22).



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.

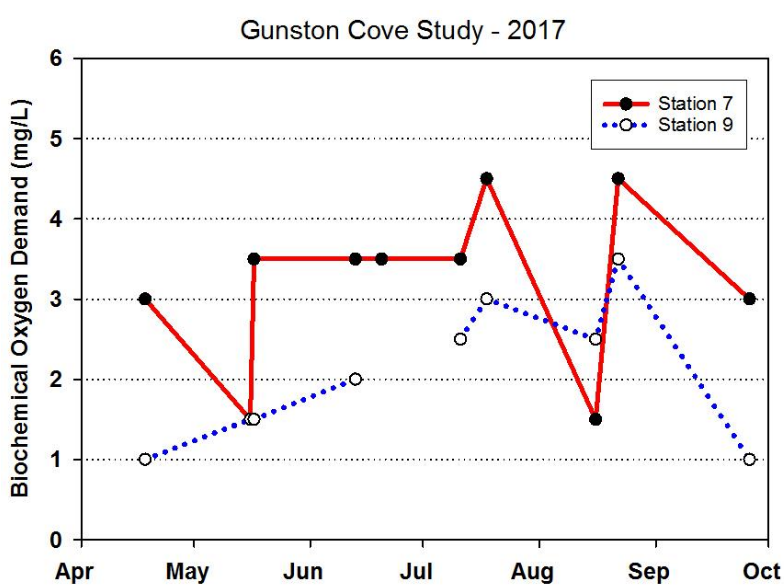
Figure 22. Soluble Reactive Phosphorus (mg/L). Fairfax County Lab Data. Month tick is at first day of month. (Limit of detection = 0.005 mg/L)



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.

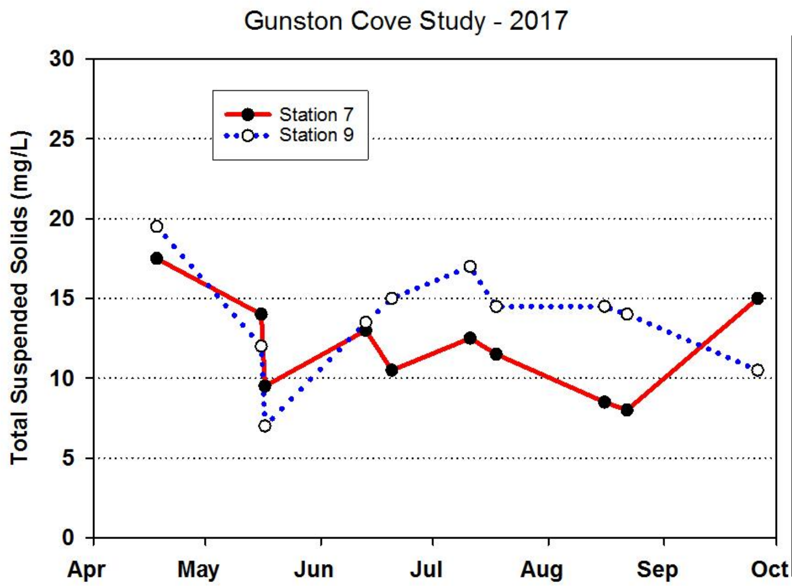
Figure 23. N/P Ratio (by mass). Fairfax County Lab Data. Month tick is at first day of month.

N/P ratio exhibited little seasonal pattern at either sites (Figure 23). Values bottomed out at about 10 in late June in the cove approaching N limitation. Values in the river remained generally above 20 throughout the year. Biochemical oxygen demand (BOD) was consistently higher in the cove than in the river (Figure 24). Values in the cove did not show much seasonal change, but exhibited a gradual seasonal increased in the river.



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

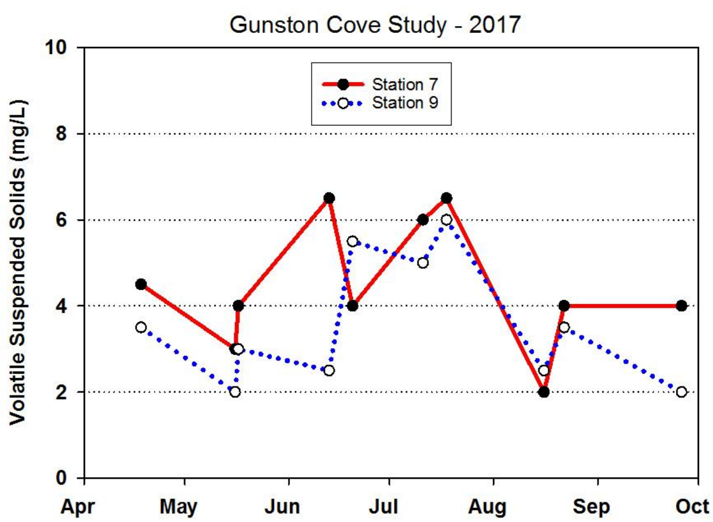
Figure 24. Biochemical Oxygen Demand (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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

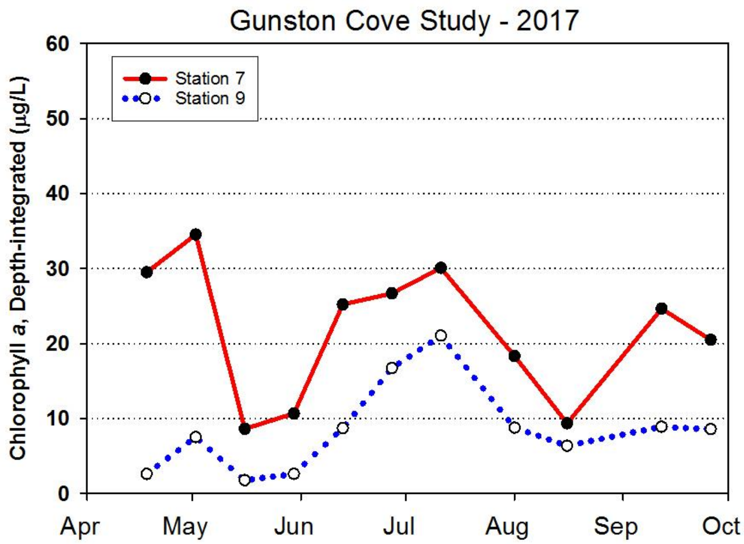
Total suspended solids was generally in the range 10-20 mg/L at both stations (Figure 25). There was little seasonal pattern. Volatile suspended solids was generally higher in the cove in spring with little seasonal pattern (Figure 26).



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 26. Volatile Suspended Solids (mg/L). Fairfax County first day of month.

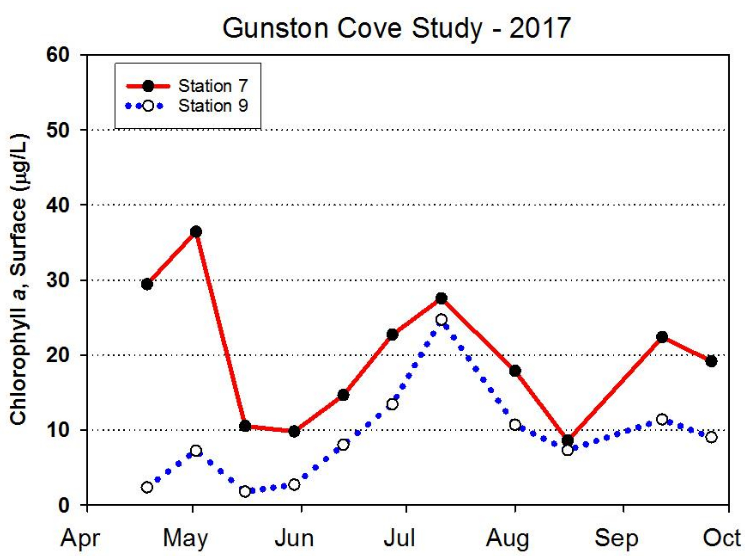
C. Phytoplankton -2017



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.

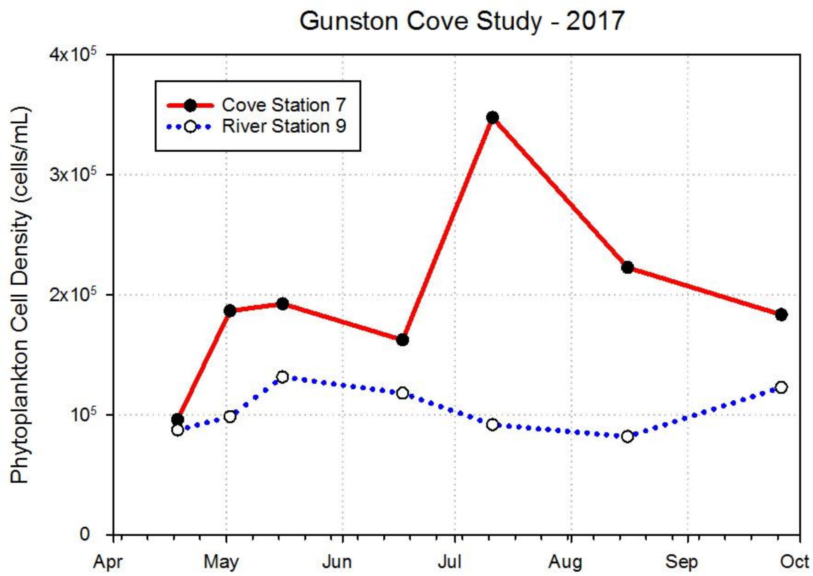
Figure 27. Chlorophyll *a* (ug/L). Depth-integrated. GMU Lab Data. Month tick is at the first day of month.

Chlorophyll *a* in the cove displayed a distinct seasonal pattern in 2017 (Figure 27). A strong peak was observed in the cove in early May flowed by a marked decline. A much weaker peak was found in the river. From late May through early July a general increase was observed in both cove and river to values of 20-30 ug/L. This was followed by a decline in to mid August and a subsequent increase in September. Depth-integrated and surface chlorophyll showed similar spatial and temporal patterns (Figure 28).



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.

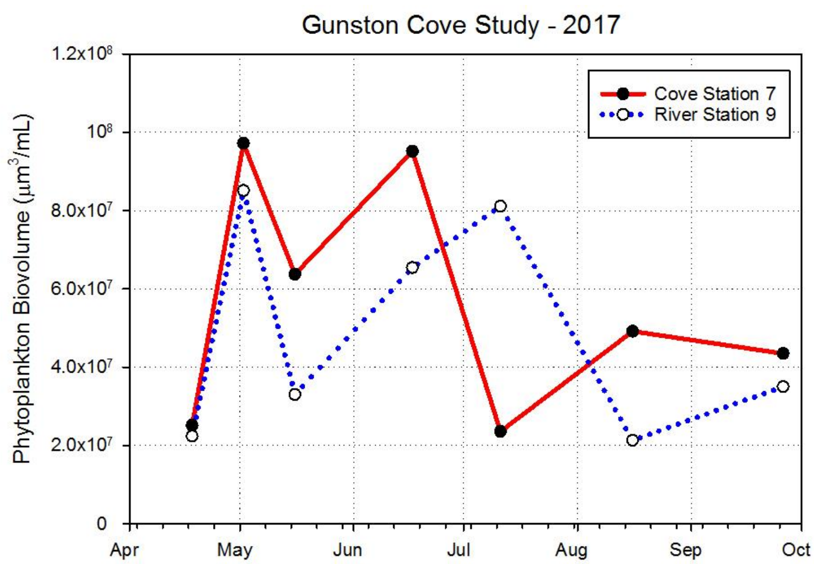
Figure 28. Chlorophyll *a* (ug/L). Surface. GMU Lab Data. Month tick is at first day of month.



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 cyanobacteria.

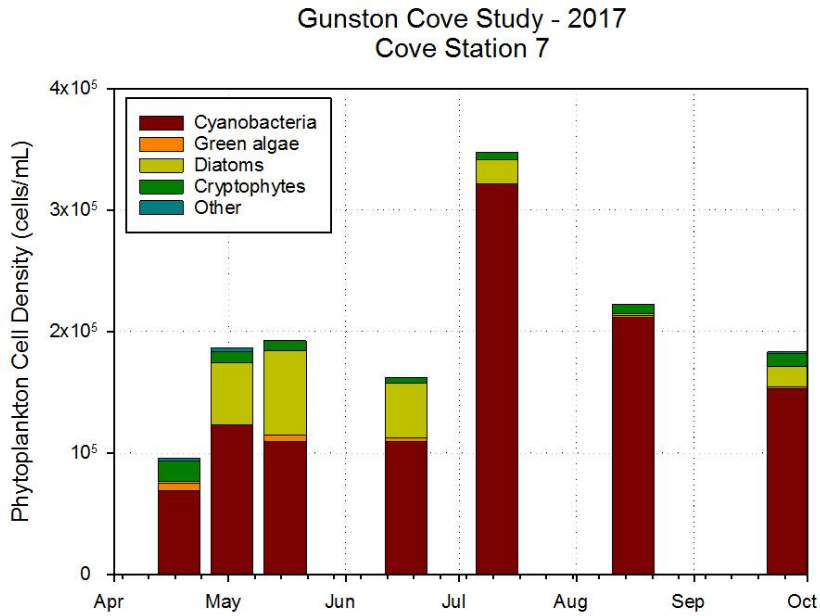
Figure 29. Phytoplankton Density (cells/mL).

In the cove phytoplankton density increased in early May and then again in July reaching a peak on the same date as chlorophyll (Figure 29). In the river there was little seasonal change in cell density although chlorophyll in the river reached a strong peak in early July. Total biovolume at both stations showed much variability between dates (Figure 30). Both stations exhibited a strong peak in early May. In the cove a second peak was observed in mid-June, while in the river the second peak was observed in early July.



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.

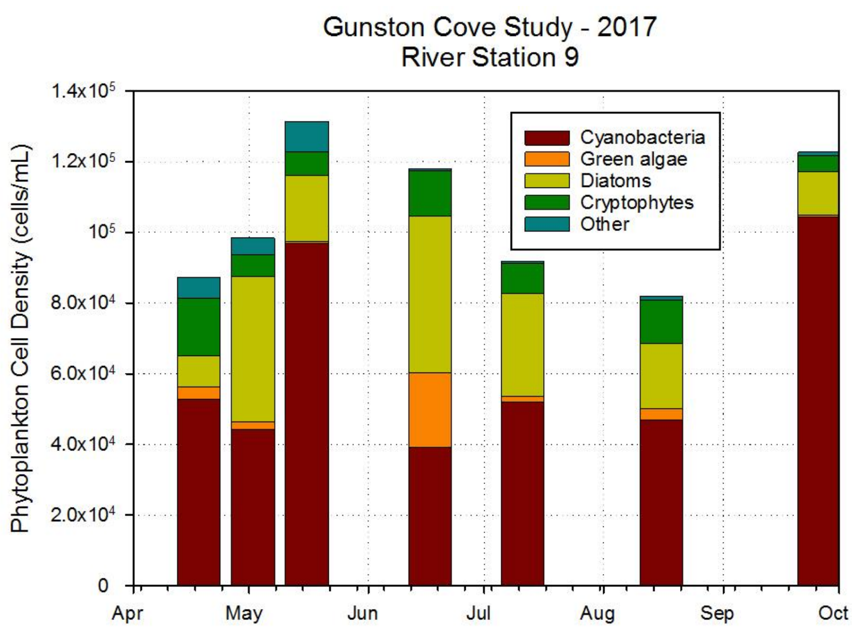
Figure 30. Phytoplankton Biovolume (um^3/mL).



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.

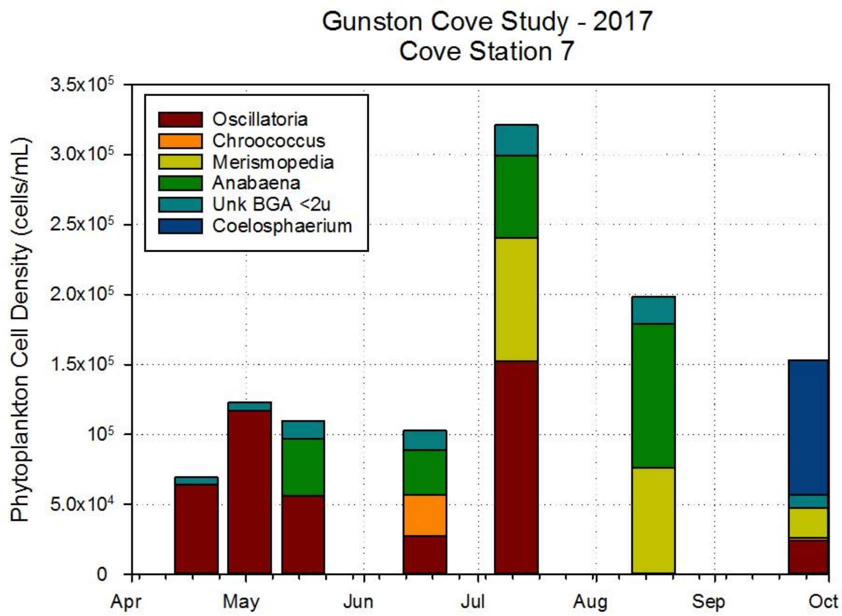
Figure 31. Phytoplankton Density by Major Group (cells/mL). Gunston Cove.

Phytoplankton density in the cove was dominated by cyanobacteria on all dates (Figure 31). Diatoms were found in significant numbers in May. In the river cyanobacteria were again the most numerous for virtually the entire year, but their dominance was less overwhelming (Figure 32). Diatoms shared dominance on two date: early May and mid June.



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 cove.

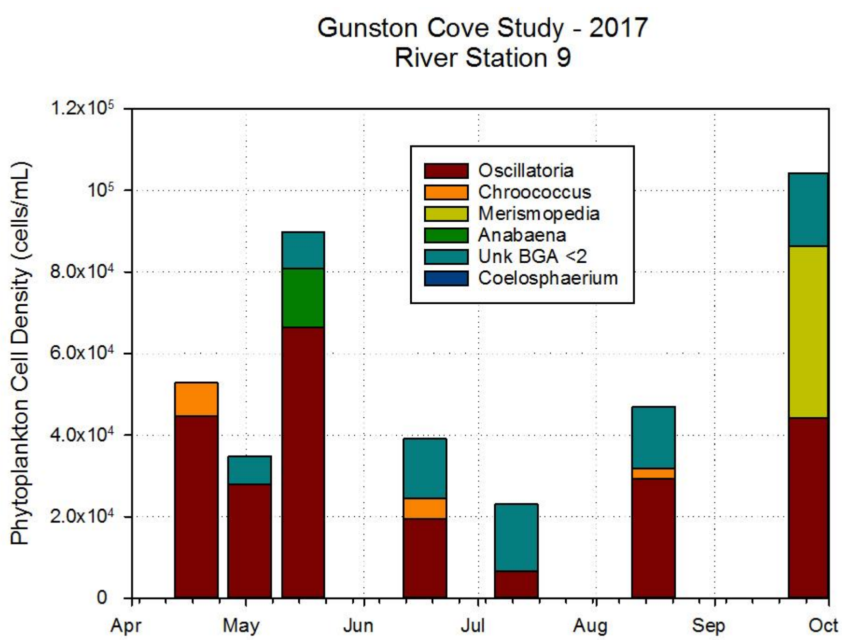
Figure 32. Phytoplankton Density by Major Group (cells/mL). River.

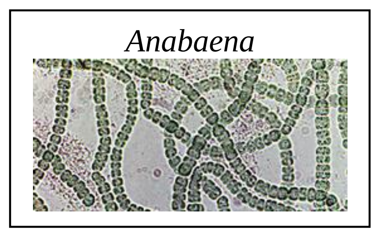


The dominant cyanobacteria on a numerical basis were:
Anabaena – a filament with bead-like cells & heterocysts
Microcystis – an irregular colony of spherical cells
Oscillatoria – a filament with cylindrical cells
Merismopedia -- a flat plate of cells in a rectangular arrangement
Chroococcus – individual spherical cells
Raphidiopsis – a filament of cylindrical cells

Figure 33. Phytoplankton Density by Dominant Cyanobacteria (cells/mL). Gunston Cove.

Oscillatoria was the most abundant cyanobacterium on most dates (Figure 33). In July *Anabaena* and *Merismopedia* were very important and in August they were dominant. In the river *Oscillatoria* was generally dominant with a strong showing from an unknown cyanobacterium on most dates (Figure 34). *Merismopedia* made a strong showing in late September.





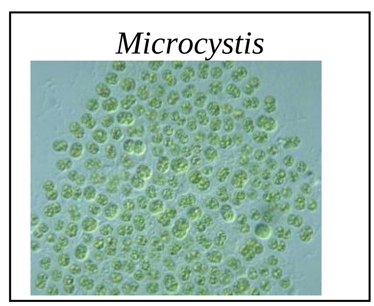
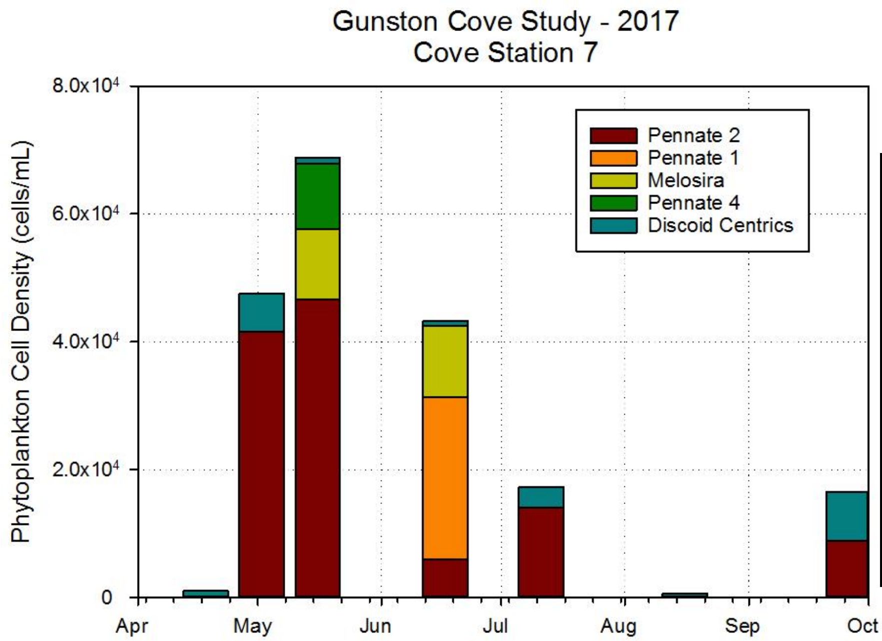


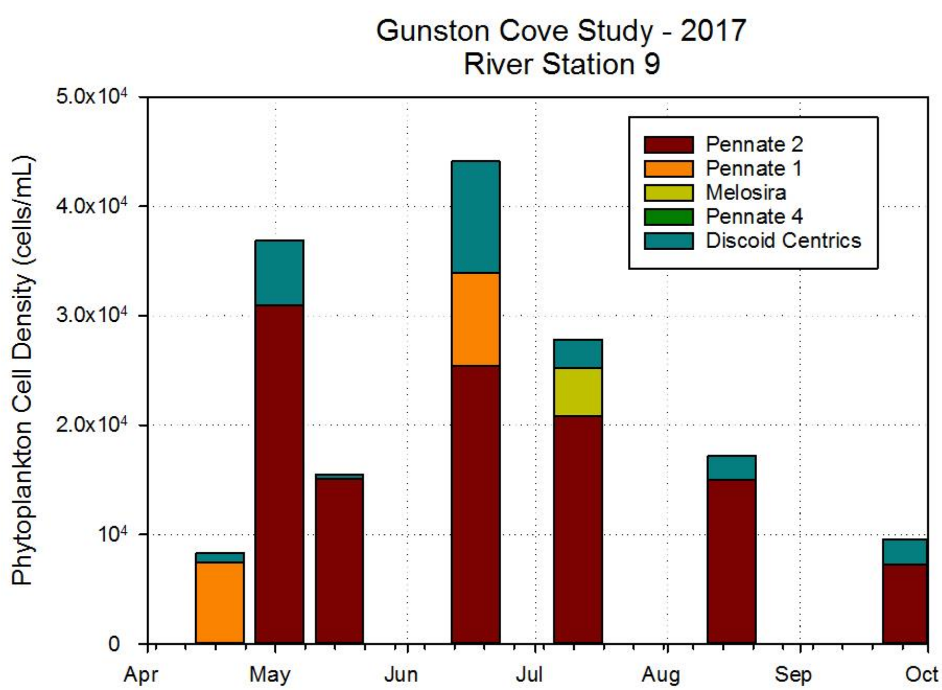
Figure 34. Phytoplankton Density by Dominant Cyanobacteria (cells/mL). River.



The most numerous diatoms in the phytoplankton were:
Melosira – a filamentous centric diatom
Centrics – discoid centric diatoms
Pennate 2 – a small pinnate diatom
Pennate 1 – a small pinnate diatom
Asterionella – a small pennate diatom that forms spoked - wheel colony

Figure 35. Phytoplankton Density by Dominant Diatoms (cells/mL). Gunston Cove.

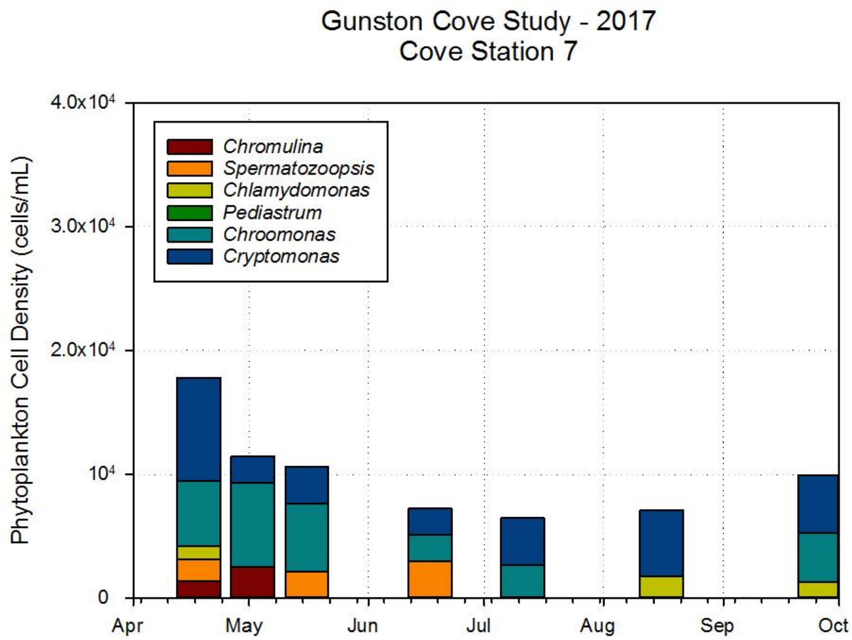
Diatom cell density was dominated by Pennate 2 in most samples from the cove station (Figure 35). Pennate 1 was very dominant in June. *Melosira* was observed in May and June. In the river a similar pattern was observed with the addition of substantial numbers of *Melosira* in summer and fall (Figure 36).



Melosira

Discoid Centrics

Figure 36. Phytoplankton Density by Dominant Diatoms (cells/mL). River.

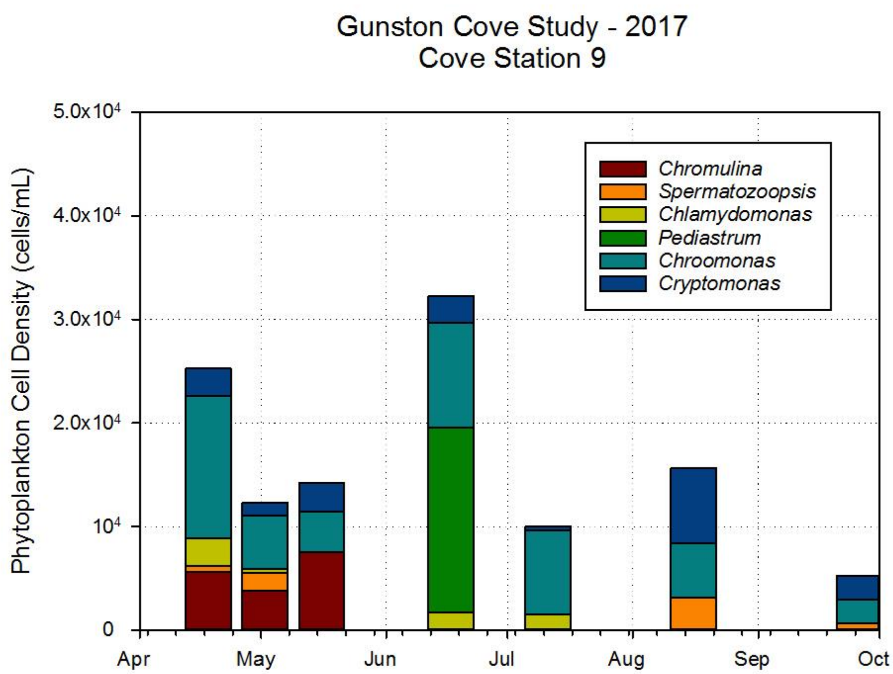


The most numerous phytoplankton among the cryptophytes, green algae and others were:

Cryptomonas – an ellipsoidal, flagellated unicell
Chroomonas – a flagellated cryptomonad unicell
Dictyosphaerium – colony of small green unicells
Selenastrum – single green algal cell as curved rod
Pediastrum – green algal colony
Botryococcus – single green coccoid cell

Figure 37. Phytoplankton Density (#/mL) by Dominant Other Taxa. Gunston Cove.

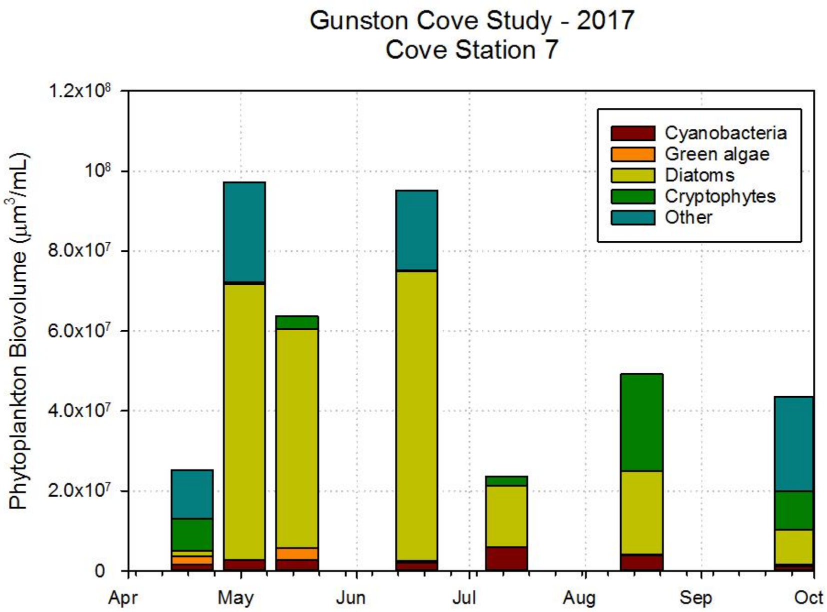
In the cove a number of other taxa were important, but between dates *Cryptomonas* and *Chroomonas* were generally the most abundant (Figure 37). In the river these two were again abundant on all dates. *Chromulina* was consistently important in the spring and Pediastrum made a showing in June (Figure 38).




Cryptomonas


Scenedesmus

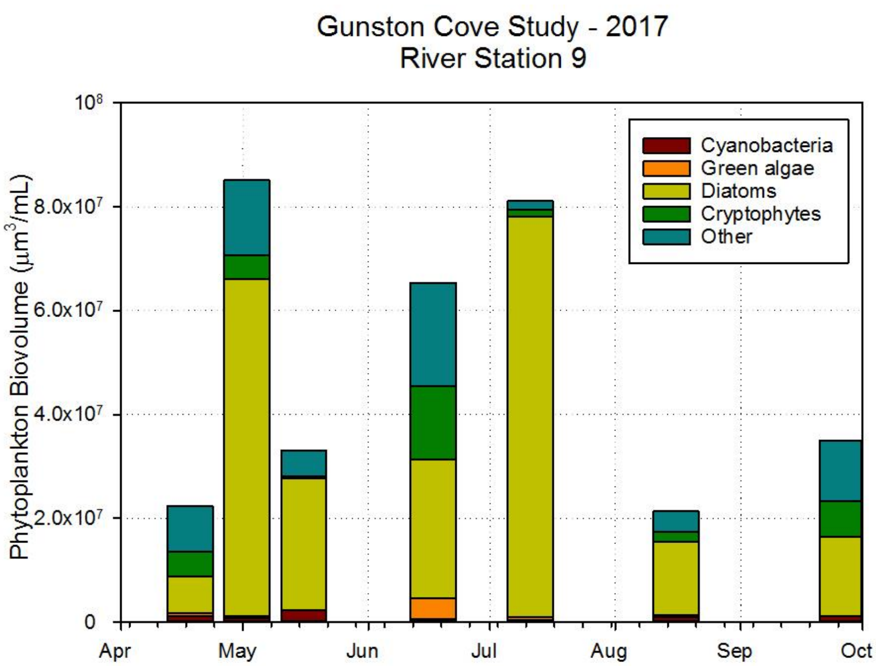
Figure 38. Phytoplankton Density (#/mL) by Dominant Other Taxa. River.



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

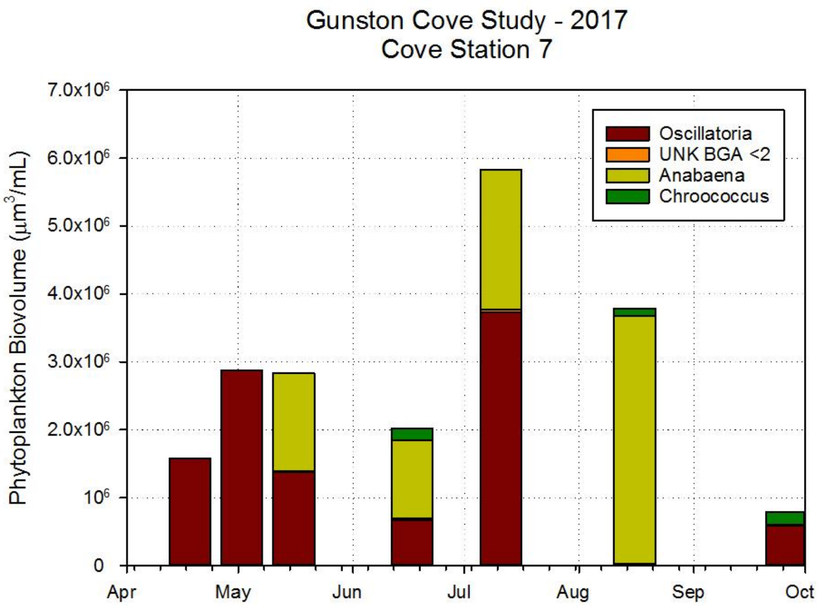
Figure 39. Phytoplankton Biovolume (um^3/mL) by Major Groups. Gunston Cove.

In the cove biovolume was strongly dominated by diatoms on most dates (Figure 39). Despite their greater cell density, cyanobacteria were much lower on all dates. Cryptophytes and Other algae were important on some dates. In the river, diatoms were again dominant in biovolume for most of the year (Figure 40).



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 40. Phytoplankton Biovolume (um^3/mL) by Major Groups. River.

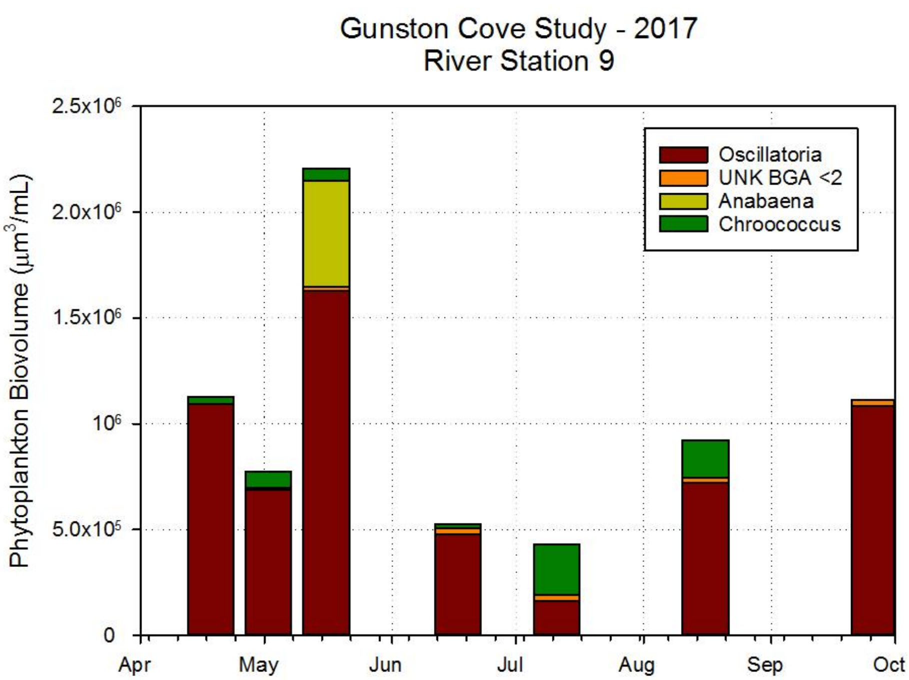


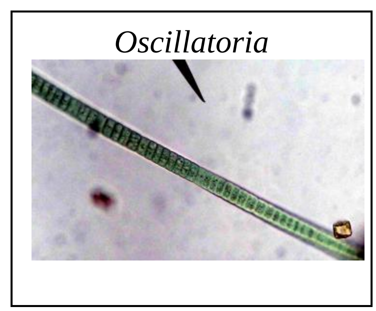
The dominant cyanobacteria on a biovolume basis were:

- *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 41. Phytoplankton Biovolume (um^3/mL) by Cyanobacteria Taxa. Gunston Cove.

Oscillatoria accounted for most of the cyanobacterial biovolume in the cove in spring and into the summer (Figure 41). *Anabaena* was also dominant in many samples in summer. In the river cyanobacteria were less abundant, but Oscillatoria was again the dominant (Figure 42). *Anabaena* was present in significant numbers only in late May.





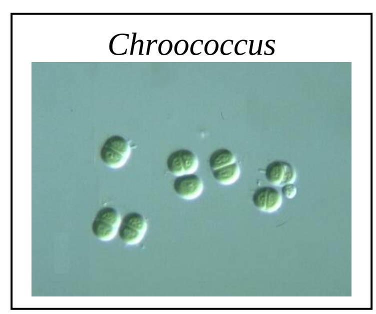
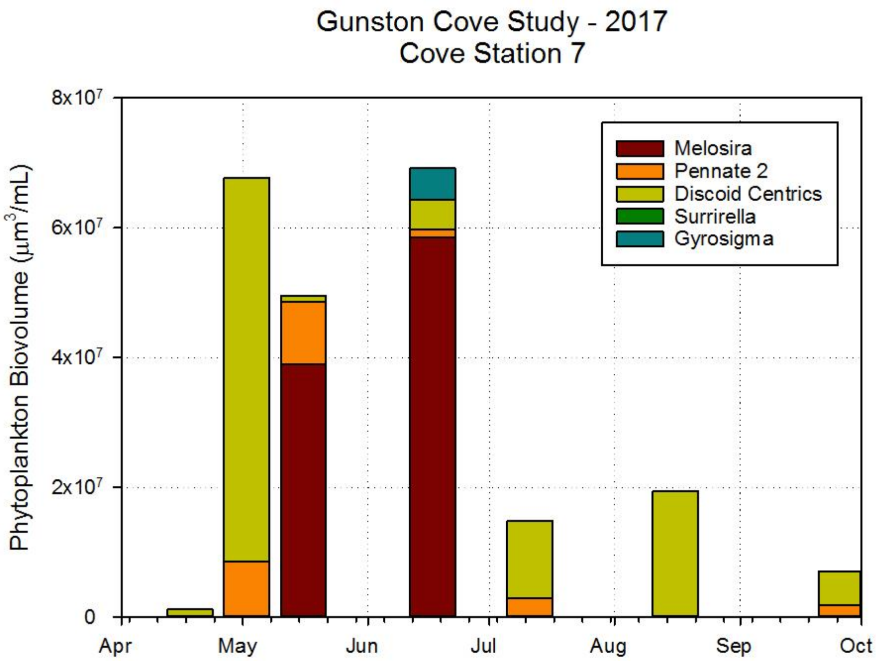


Figure 42. Phytoplankton Biovolume (um^3/mL) by Cyanobacterial Taxa. River.

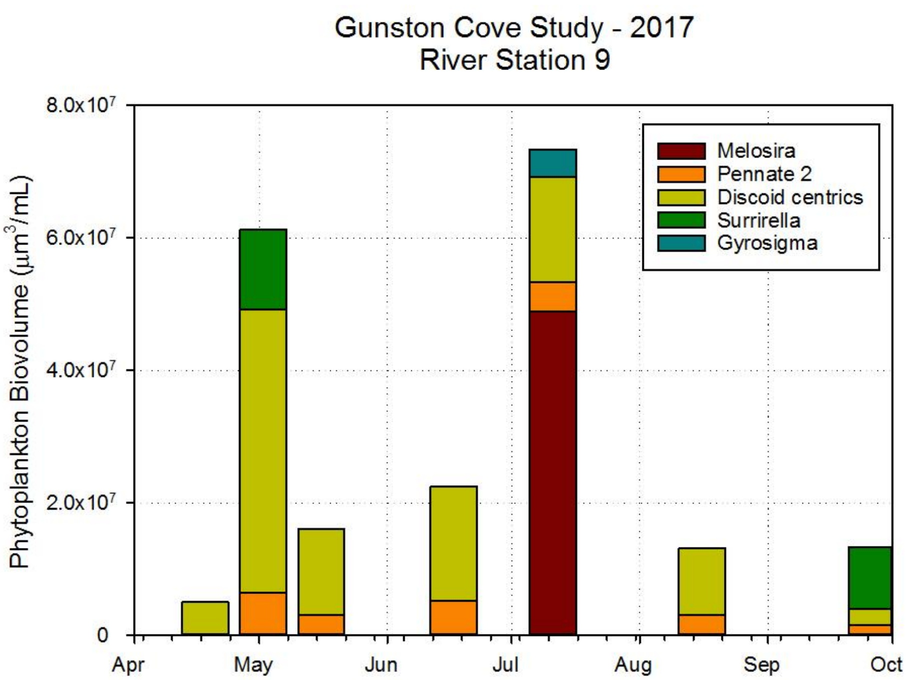


The most numerous diatoms in the phytoplankton were:

- *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 43. Phytoplankton Biovolume (um^3/mL) by Diatom Taxa. Gunston Cove.

In the cove discoid centrics were dominant or made a significant showing on many dates (Figure 43). On the other dates in May and June, *Melosira* exhibited a strong peak in abundance. In the river discoid centrics were dominant for most of the year (Figure 44). On only one date in July, *Melosira* was dominant.



Melosira

Surirella

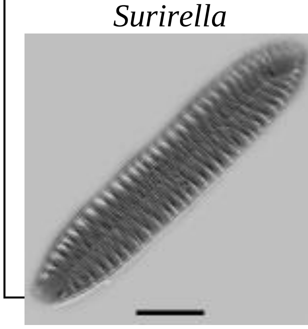
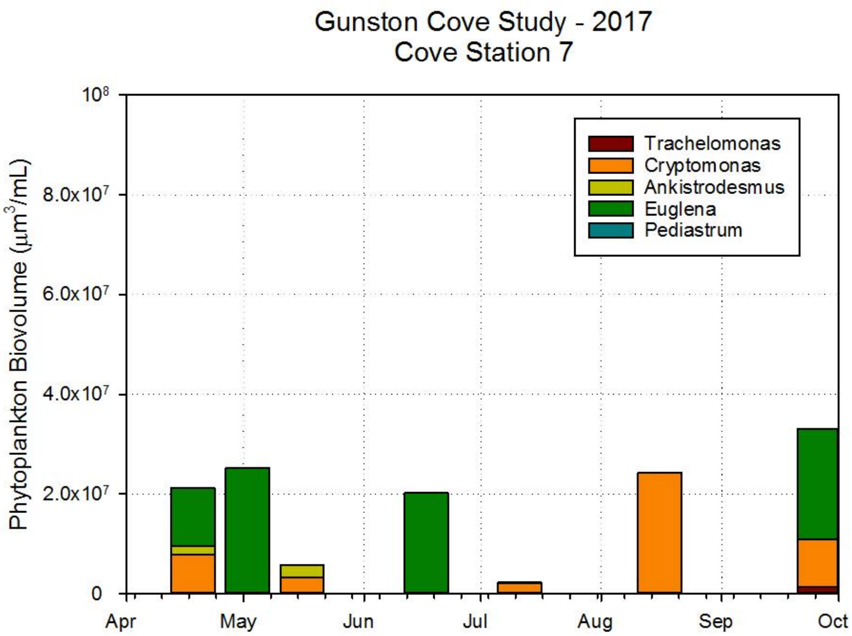


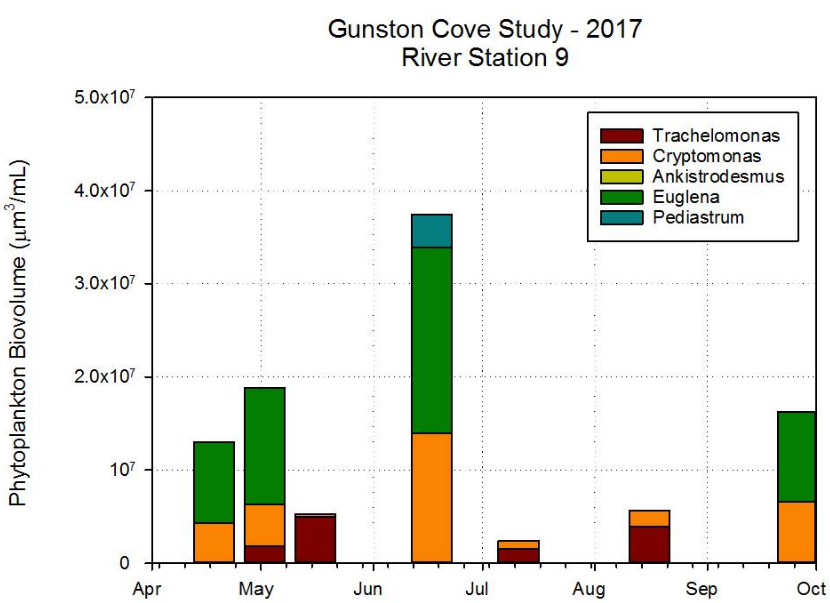
Figure 44. Phytoplankton Biovolume (um^3/mL) by Diatom Taxa. River.



The most numerous phyto-plankton 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 45. Phytoplankton Biovolume (um^3/mL) by Dominant Other Taxa. Gunston Cove.

A number of other taxa were present in the cove in 2017 and *Euglena* and *Cryptomonas* made strong contributions to biovolume on most dates (Figure 45). In the river *Cryptomonas*, *Euglena*, and *Trachelomonas* showing a marked presence on most dates (Figure 46).

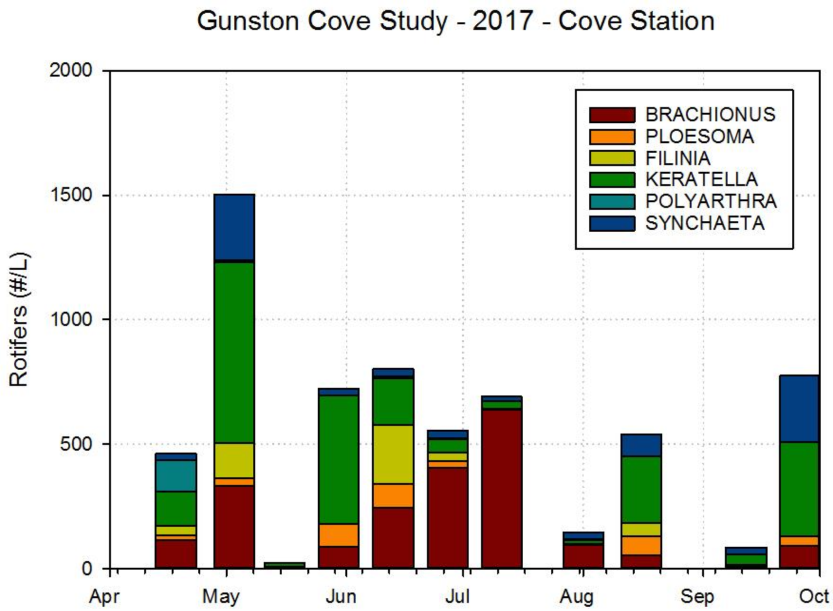


Cryptomonas

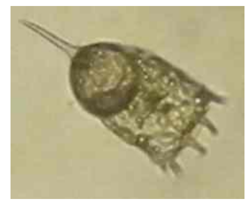
Euglena

Figure 46. Phytoplankton Biovolume (um^3/mL) by Dominant Other Taxa. River.

D. Zooplankton – 2017



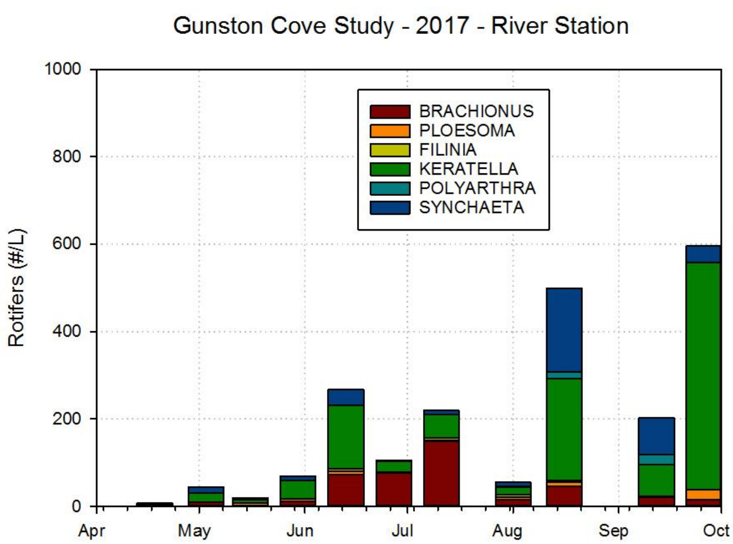
Brachionus (Sta 7, RCJ)



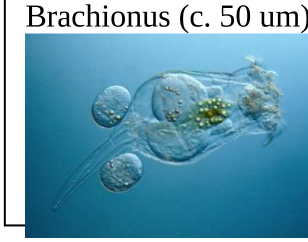
Keratella (Sta 7, RCJ)

Figure 47. Rotifer Density by Dominant Taxa (#/L). Cove.

In the cove, rotifers exhibited a strong presence in April and early May, declined in late May, and then increased again in June to an early summer peak (Figure 47). Subsequent peaks were seen in mid-August and late September. *Brachionus* and *Keratella* were most prominent for most of the year in the cove. In the river rotifers did not have a sping peak, but increased in summer reaching a maximum in mid-August (Figure 48). *Keratella* was dominant on most dates and co-dominant on other dates.



Brachionus (c. 50 um)



Conochilidae

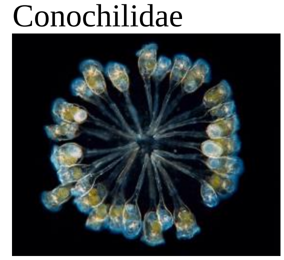


Figure 48. Rotifer Density by Dominant Taxa (#/L). River.

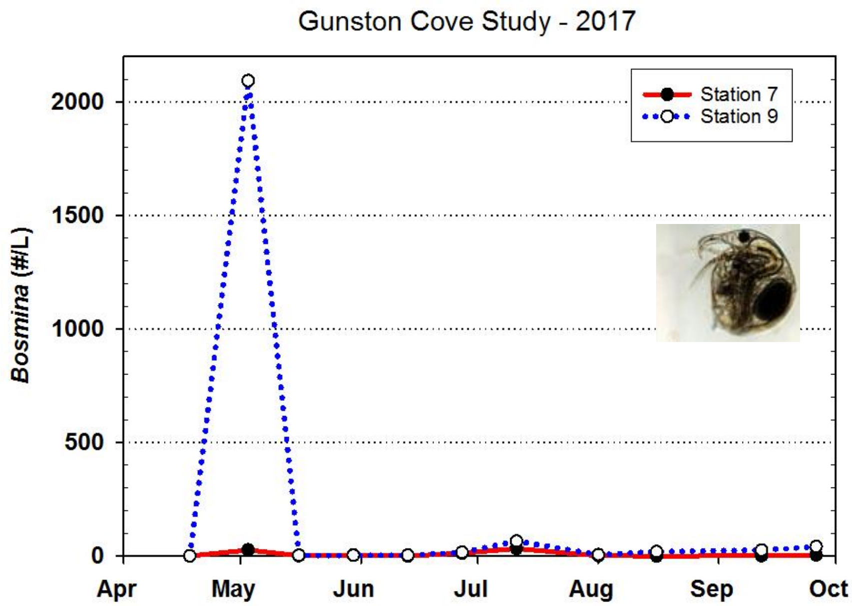


Figure 49. *Bosmina* Density by Station (#/L).

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 2017 the small cladoceran *Bosmina* was present in many samples, but at much reduced levels (Figure 49). The exception was in early May in the river where it exceeded 2000/L. *Diaphanosoma*, typically the most abundant larger cladoceran in the study area, was present at appreciable levels in 2017, reaching a maximum of over 1000 per m^3 in late June and early July at both stations (Figure 50).

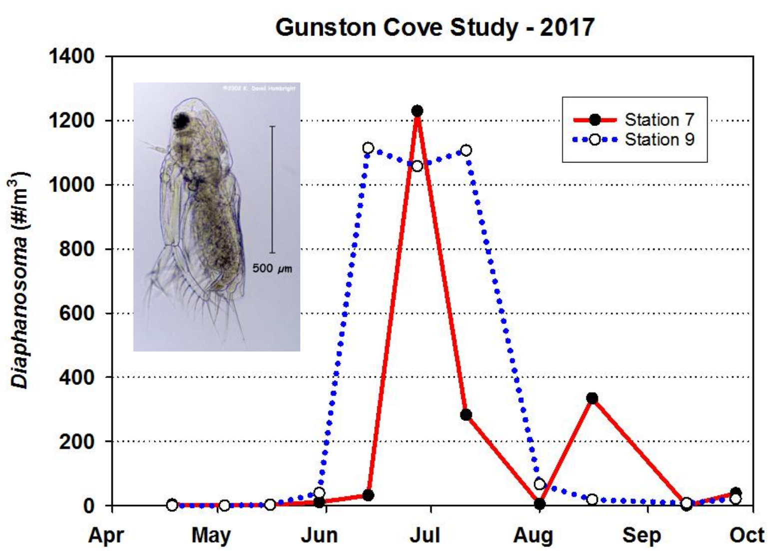
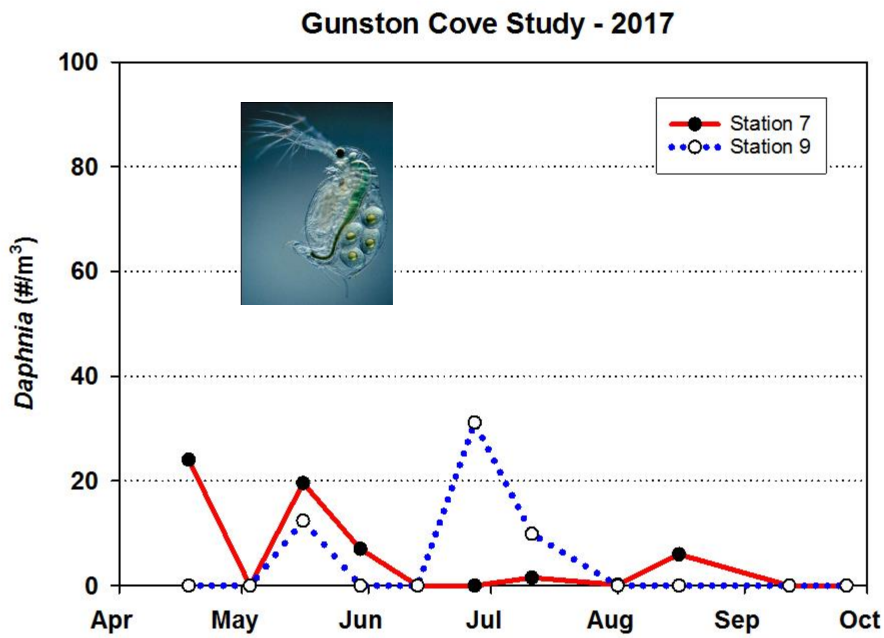


Figure 50. *Diaphanosoma* Density by Station (#/m^3).

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 spring.

Figure 51. *Daphnia* Density by Station (#/m^3).

In 2017 *Daphnia* exhibited very low values, typically below 30/m^3 (Figure 51). *Camptocercus* was generally quite low except for a high density of nearly 600/m^3 in late August (Figure 52).

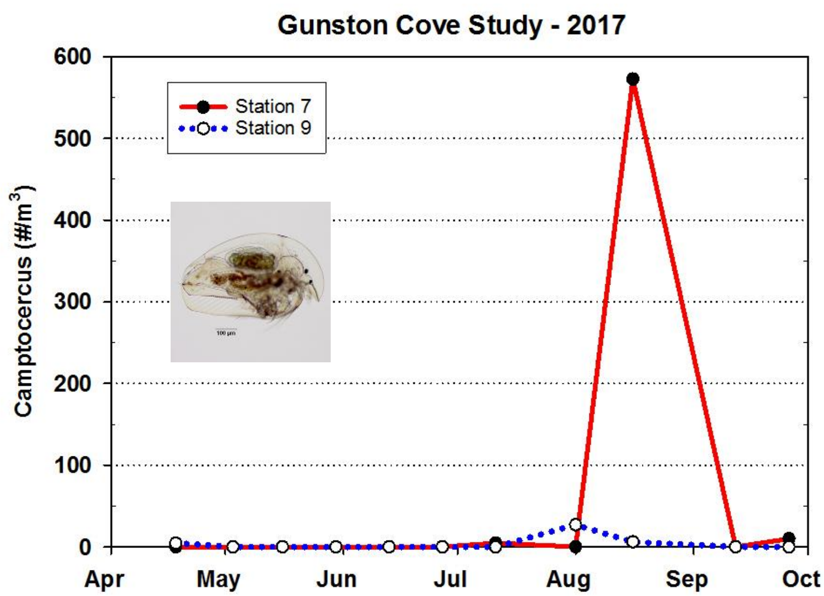
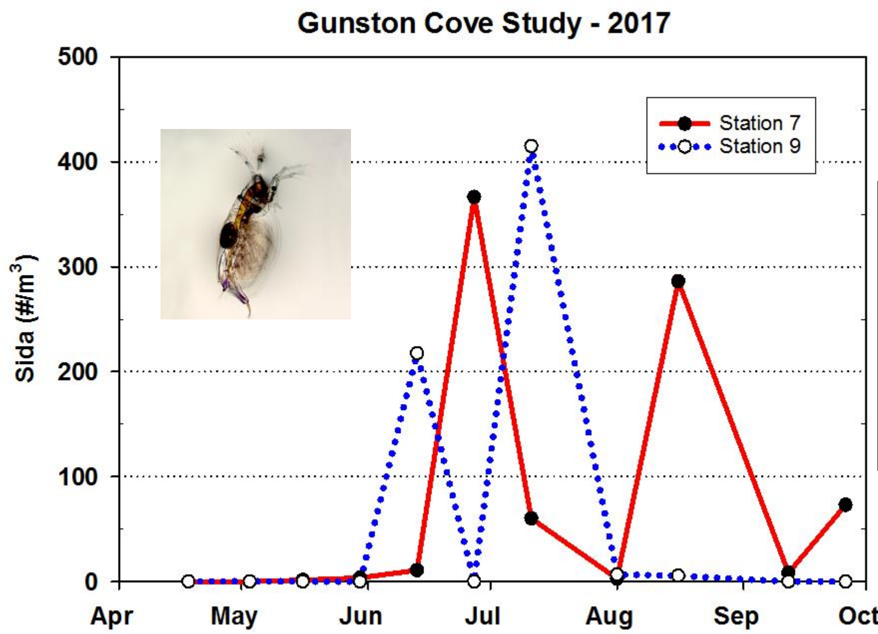


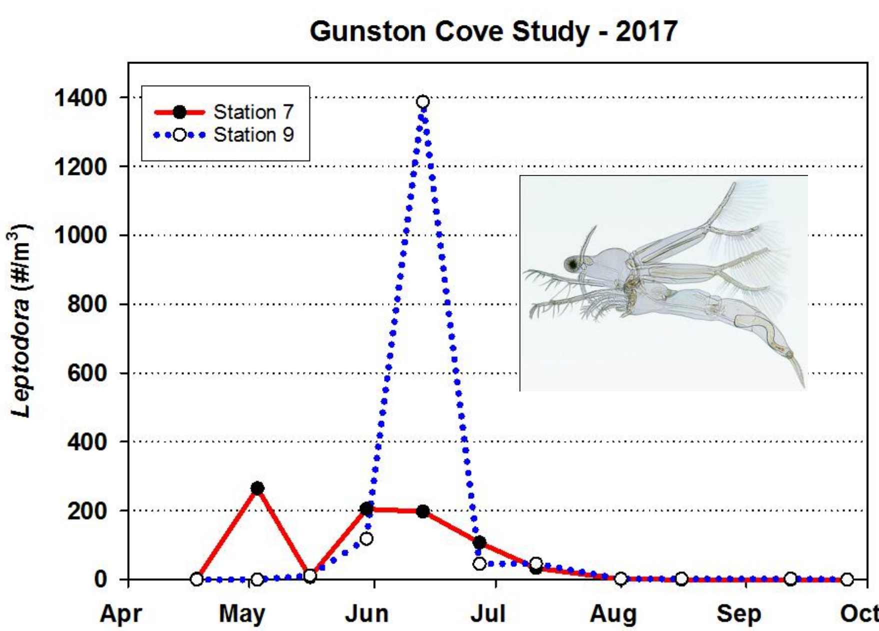
Figure 52. *Camptocercus* Density by Station (#/m^3).



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.

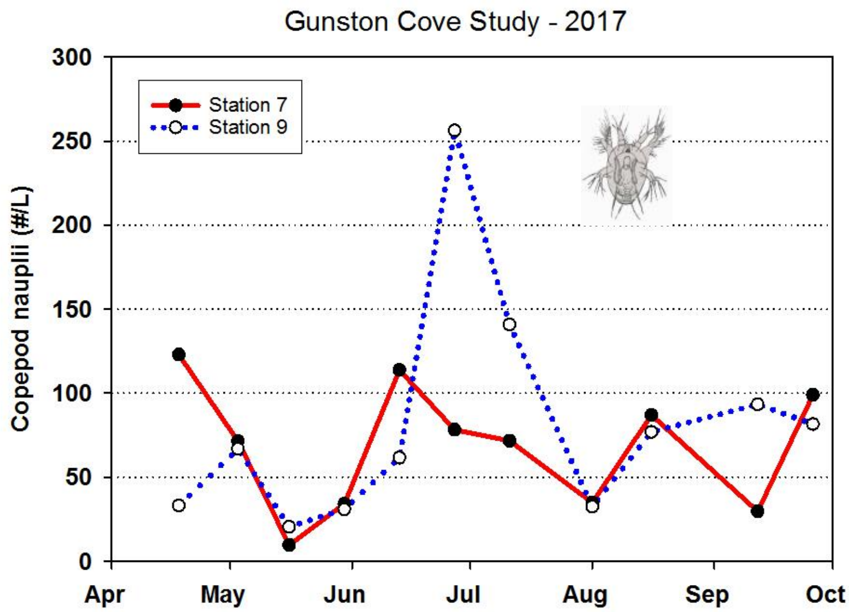
Figure 53. *Sida* Density by Station (#/m^3).

Sida, a smallish cladoceran related to *Diaphanosoma*, showed some marked, but short-lived peaks (Figure 53). Its peak was in the river was in early July with a slightly smaller peak in early June. In the river, the mean peak density of 400/m^3 was observed in early July. *Leptodora*, the large cladoceran predator, was present in many samples at both stations (Figure 54). Peak values of about 200/m^3 in June were observed in the cove in early May while in the river a much larger peak of nearly 1400/m3 . In addition, the cove station exhibited a peak in early May.



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.

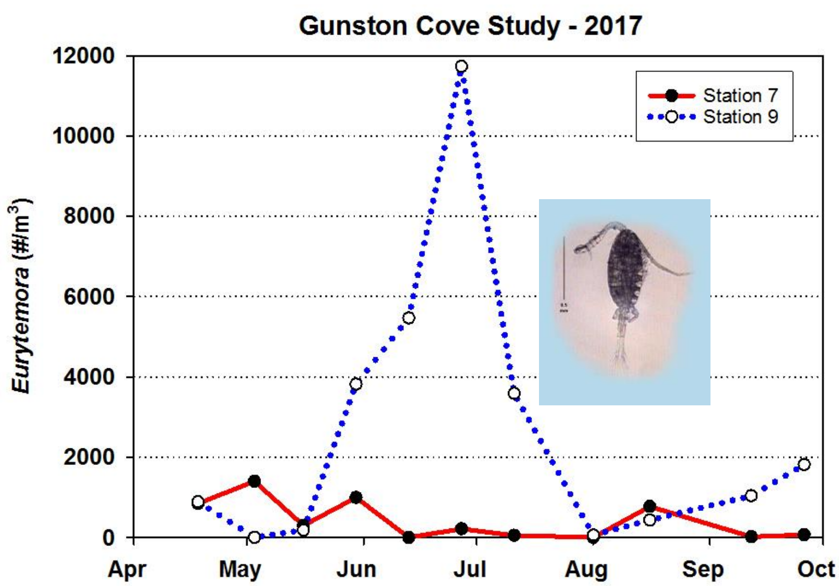
Figure 54. *Leptodora* Density by Station (#/m^3).



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-zooplankton samples.

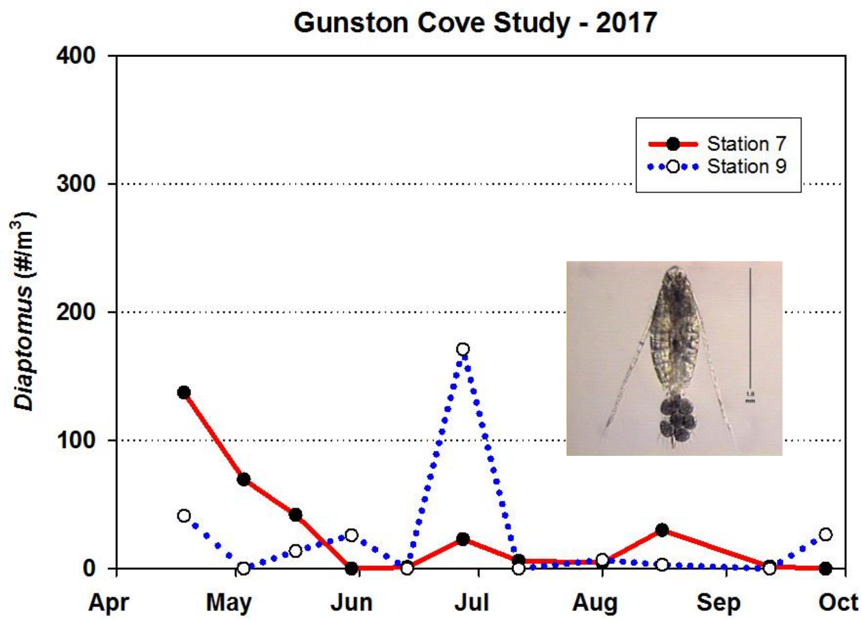
Figure 55. Copepod Nauplii Density by Station (#/L).

In the cove copepod nauplii peaked in April and again in late June at moderate levels of about 100/L (Figure 55). In the river a stronger peak of over 250/L was observed in late June. *Eurytemora* increased in the river in spring attaining high densities of nearly 12,000/m^3 in late June (Figure 56). In the cove *Eurytemora* was much lower with values generally below 1000/m^3.



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*.

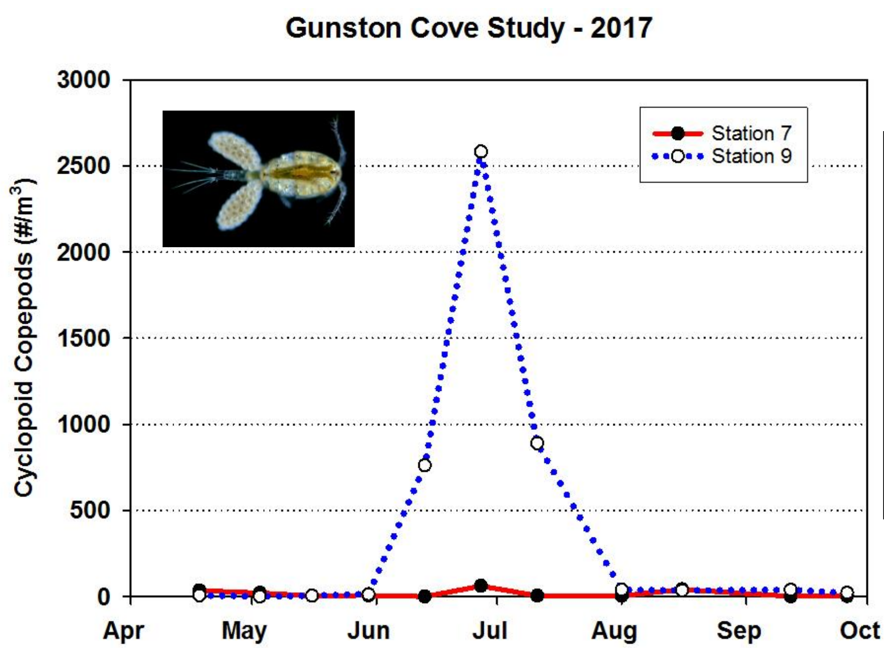
Figure 56. *Eurytemora* Density by Station (#/m^3).



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 57. *Diaptomus* Density by Station (#/m^3).

Diaptomus was was restricted to low values in 2017 (Figure 57). Peaks were in April in the cove and late June in the river. Cyclopoid copepods showed a strong peak in the river in late June at about 2500/m^3 (Figure 58).



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 58. Cyclopoid Copepods by Station (#/m^3).

E. Ichthyoplankton – 2017

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 2017, we collected 14 samples (7 at Station 7 and 7 at Station 9) during the months April through July and obtained a total of 1751 larvae (Table 4), which is more than last year (1317). The fish larvae are sometimes too damaged to distinguish at the species level, thus some of the counts are only to the genus level. While much progress has been made in the identification of clupeid larvae (herring and shad), a high proportion of specimens were too damaged by collection (stuck to the mesh of the net) to identify to the species level. The percent of the catch identified to the Family Clupeidae (but not further) was 36.66%. Of the Clupeidae that could be identified to the species level, Alewife was the most dominant species with 18.22% of the catch. All clupeids together constituted 82.64% of the catch. Other abundant clupeids were Gizzard Shad at 14.73%, Blueback Herring at 10.57%, Hickory Shad at 1.43% and American Shad at 1.03%. The most dominant non-clupeid species in the catch was White Perch with 7.48% of the catch. Striped bass (another *Morone sp.*) was present as well, and 0.46% of the catch was positively identified as Striped Bass. Another species somewhat abundant in the ichthyoplankton samples was Inland Silverside at 1.31%. A total of 16 species were identified.

Table 4. The number of larval fishes collected in Gunston Cove and the Potomac River in 2017.

Scientific Name	Common Name	7	9	Total	% of Total
Alosa aestivalis	Blueback Herring	51	134	185	10.57
Alosa mediocris	Hickory Shad	14	11	25	1.43
Alosa pseudoharengus	Alewife	143	176	319	18.22
Alosa sapidissima	American Shad	15	3	18	1.03
Clupeidae	Unk. clupeid species	453	189	642	36.66
Dorosoma cepedianum	Gizzard Shad	116	142	258	14.73
Eggs	Eggs	13	32	45	2.57
Fundulus heteroclitus	Mummichog	1	0	1	0.06
Lepomis cyanellus	Green Sunfish	2	3	5	0.29
Lepomis gibbosus	Pumpkinseed	1	0	1	0.06
Lepomis macrochirus	Bluegill	3	0	3	0.17
Lepomis species	Unidentified Sunfish	6	29	35	2.00
Menidia beryllina	Inland Silverside	17	6	23	1.31
Morone americana	White Perch	51	80	131	7.48
Morone saxatilis	Striped Bass	2	6	8	0.46
Morone species	Unk Perch/Bass Species	7	4	11	0.63
Perca flavescens	Yellow Perch	1	1	2	0.11
Unidentified	Unidentified	26	13	39	2.23
	TOTAL	**922**	**829**	**1751**	**100**

The mean density of larvae, which takes the volume of water sampled into account over the time sampled, is shown in Figure 59 and 60. Clupeid larvae in Figure 59 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. Interestingly we had two peaks in 2017, one in spring and one in summer (Figure 59). The two peaks were shared by the different species of Clupeids, so it is not a reflection of species-specific differences. The abundance of other larvae than Clupeids was lower, and had a distinct peak right at the start of sampling in April, and a smaller peak at the end of May (Figure 60). This is a similar pattern as previous years. The other larvae included all other taxa listed in Table 4.

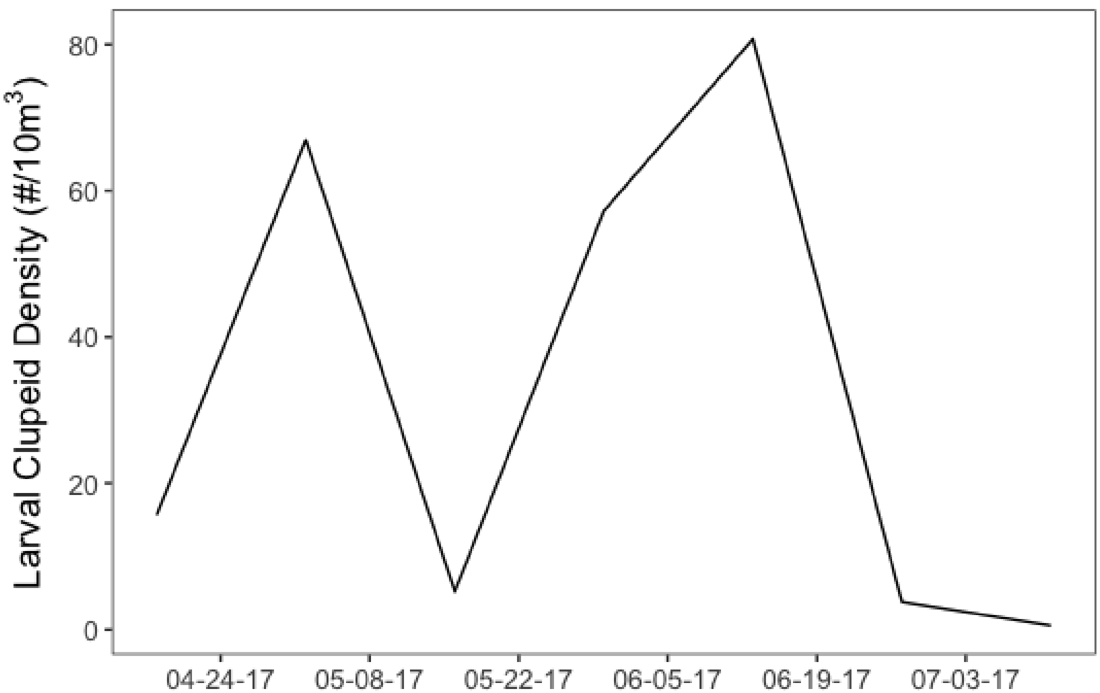


Figure 59. Clupeid larvae, mean density (abundance per 10m³).

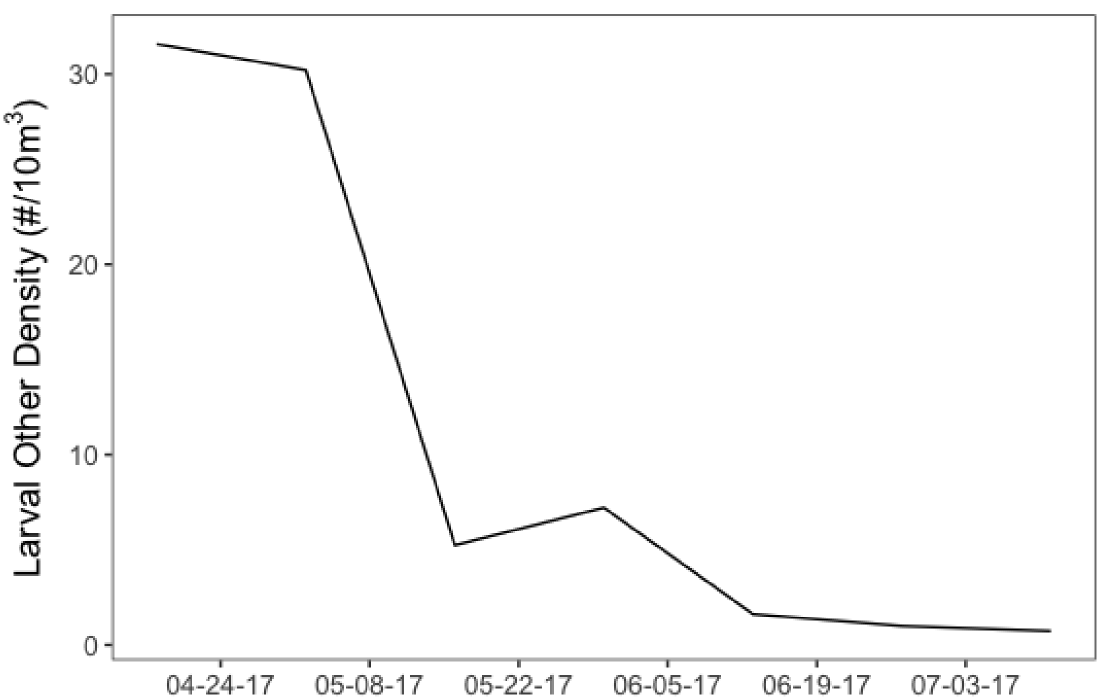


Figure 60. All other larvae, mean density (abundance per 10m³)

F. Adult and juvenile fishes – 2017

Trawls

Trawl sampling was conducted between April 21 and May 23 at station 10, and between April 21 and September 19 at station 7 and 9. These three fixed stations have been sampled continuously since the inception of the survey. Trawling at station 10 is obstructed by extensive submerged aquatic vegetation cover when we stop sampling. The site has been double sampled with a fyke net since 2012 which allows for comparison. The fyke net allows us to continue sampling that area when trawling at station 10 becomes impossible. A total of 2062 fishes comprising 24 species were collected in all trawl samples combined (Table 5). The most dominant species of the fish collected was White Perch (71.27%, numerically). Dominance of White Perch in the trawls is higher than last year, which indicates a decreased evenness (measure of diversity) of the fish community as sampled by the trawl. Gear selectivity plays a role here too, which is why we sample with multiple types of sampling gear. Other abundant taxa included Spottail Shiner (7.4%), different sunfishes (14.85% total, of which 5.3% unidentified, 5.04% Bluegill, 3.97% Pumpkinseed, 0.44% Redear Sunfish and 0.1% Bluespotted Sunfish), Tessellated Darter (1.54%), and Yellow Perch (1.25%). Other species were observed sporadically and at low abundances, and constituted less than 1% of the total catch (Tables 5 and 6).

The dominant migratory species, White Perch, was ubiquitous occurring at all stations on every sampling date (Tables 6 and 7). In the spring, adult White Perch were primarily caught in the nets while later in the summer juveniles dominated. A clear peak in abundance for White Perch was end of June to early July (Table 6).

Table 5. Adult and Juvenile Fish Collected by Trawling. Gunston Cove Study - 2017.

Scientific Name	**Common Name**	**Abundance**	**Percent**
Morone americana	White Perch	1469	71.27
Notropis hudsonius	Spottail Shiner	152	7.40
Lepomis species	Unidentified sunfish	109	5.30
Lepomis macrochirus	Bluegill	104	5.04
Lepomis gibbosus	Pumpkinseed	82	3.97
Etheostoma olmstedi	Tessellated Darter	32	1.54
Perca flavescens	Yellow Perch	26	1.25
Fundulus diaphanus	Banded Killifish	16	0.79
Carassius auratus	Goldfish	12	0.58
Hybognathus regius	Eastern Silvery Minnow	9	0.44

Lepomis microlophus	Redear Sunfish	9	0.44
Alosa species	Unk. *Alosa* species	9	0.43
Alosa pseudoharengus	Alewife	7	0.34
Morone saxatilis	Striped Bass	6	0.32
Ictalurus furcatus	Blue Catfish	4	0.19
Micropogonias undulatus	Atlantic Croaker	3	0.15
Enneacanthus gloriosus	Bluespotted Sunfish	2	0.10
Menidia beryllina	Inland Silverside	2	0.10
Pomoxis nigromaculatus	Black Crappie	2	0.10
Trinectes maculatus	Hogchoker	2	0.09
Alosa sapidissima	American Shad	1	0.05
Ameiurus nebulosus	Brown Bullhead	1	0.05
Micropterus salmoides	Largemouth Bass	1	0.05
Notemigonus crysoleucas	Golden Shiner	1	0.05
Total		**2062**	**100.00**

Table 6. Adult and Juvenile Fish Collected by Trawling. Gunston Cove Study - 2017.

Scientific Name	Common Name	4/21	5/12	5/23	6/20	6/6	7/18	7/7	8/1	8/15	9/19	Total
Alosa pseudoharengus	Alewife	0	0	2	0	0	0	0	5	0	0	**7**
Alosa sapidissima	American Shad	0	0	0	0	0	0	0	1	0	0	**1**
Alosa species	Unk Herring/Shad Species	3	0	0	0	0	1	1	4	0	0	**9**
Ameiurus nebulosus	Brown Bullhead	0	0	0	0	0	0	1	0	0	0	**1**
Carassius auratus	Goldfish	0	7	5	0	0	0	0	0	0	0	**12**
Enneacanthus gloriosus	Bluespotted Sunfish	0	0	2	0	0	0	0	0	0	0	**2**
Etheostoma olmstedi	Tessellated Darter	2	0	1	6	3	2	7	6	5	0	**32**
Fundulus diaphanus	Banded Killifish	4	0	1	0	0	3	3	1	4	0	**16**
Hybognathus regius	Eastern Silvery Minnow	2	0	0	0	0	0	4	3	0	0	**9**
Ictalurus furcatus	Blue Catfish	0	1	1	0	0	0	1	0	1	0	**4**
Lepomis gibbosus	Pumpkinseed	5	14	5	29	13	1	1	2	10	2	**82**
Lepomis macrochirus	Bluegill	28	32	11	5	7	1	2	11	6	1	**104**
Lepomis microlophus	Redear Sunfish	2	7	0	0	0	0	0	0	0	0	**9**
Lepomis species	Unidentified Sunfish	0	0	0	0	0	23	12	15	57	2	**109**
Menidia beryllina	Inland Silverside	0	0	1	1	0	0	0	0	0	0	**2**
Micropogonias undulatus	Atlantic Croaker	0	0	0	1	2	0	0	0	0	0	**3**
Micropterus salmoides	Large-mouth Bass	1	0	0	0	0	0	0	0	0	0	**1**
Morone americana	White Perch	15	8	7	82	33	319	777	130	74	24	**1469**
Morone saxatilis	Striped Bass	0	0	0	0	0	2	2	2	0	0	**6**
Notemigonus crysoleucas	Golden Shiner	0	0	1	0	0	0	0	0	0	0	**1**
Notropis hudsonius	Spottail Shiner	1	2	20	47	4	47	20	7	4	0	**152**
Perca flavescens	Yellow Perch	0	2	0	18	3	2	0	1	0	0	**26**
Pomoxis nigromaculatus	Black Crappie	0	1	0	0	1	0	0	0	0	0	**2**
Trinectes maculatus	Hogchoker	0	0	0	0	0	1	0	0	0	1	**2**
Total		**63**	**74**	**57**	**189**	**66**	**403**	**831**	**188**	**161**	**30**	**2062**

In total numbers and species richness of fish, station 7 dominated the other stations by far with 1880 individuals from 23 species (Table 7, Figure 61a,b). Stations 9 and 10 had 90 individuals from 5 species and 92 individuals from 12 species, respectively (Table 7). Station 9 samples the open water of the mainstem Potomac and thereby doesn't sample preferred habitat such as the littoral zone or the bottom. A notable other species collected in station 9 is Blue Catfish, which is an invasive piscivorous species. The total abundance and number of species in station 9 have been declining over time. Whether this is related to the introduced catfish is yet unknown. Two Blue Catfish were collected in station 7 this year as well. This is a very small portion of the total catch in station 7, but an indication that they don't stick to the mainstem as seemed to have been the case in previous years. A high number of White Perch were collected in the Cove (station 7) in mid-summer (Table 6, Figure 62a), which constitutes the bulk of the total sample. Other taxa collected in high abundance in station 7 were sunfishes (234 specimens) and Spottail Shiner (151 specimens). Because of the big difference in abundance between months and sites, the relative contribution of species in low abundance collections is hard to see. Therefore, figures have been included that visualize the relative proportion of species per month (Figure 61b) and location (Figure 62b).

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 – 2017.

Scientific Name	**Common Name**	**7**	**9**	**10**
Alosa pseudoharengus	Alewife	7	0	0
Alosa sapidissima	American Shad	0	1	0
Alosa species	Unk. *Alosa* species	9	0	0
Ameiurus nebulosus	Brown Bullhead	1	0	0
Carassius auratus	Goldfish	9	0	3
Enneacanthus gloriosus	Bluespotted Sunfish	1	0	1
Etheostoma olmstedi	Tessellated Darter	30	0	2
Fundulus diaphanus	Banded Killifish	10	1	5
Hybognathus regius	Eastern Silvery Minnow	8	0	1
Ictalurus furcatus	Blue Catfish	2	2	0
Lepomis gibbosus	Pumpkinseed	68	1	13
Lepomis macrochirus	Bluegill	52	0	52
Lepomis microlophus	Redear Sunfish	4	0	5
Lepomis species	Unidentified Sunfish	109	0	0
Menidia beryllina	Inland Silverside	2	0	0
Micropogonias undulatus	Atlantic Croaker	3	0	0
Micropterus salmoides	Largemouth Bass	1	0	0
Morone americana	White Perch	1378	85	6
Morone saxatilis	Striped Bass	6	0	0
Notemigonus crysoleucas	Golden Shiner	1	0	0
Notropis hudsonius	Spottail Shiner	151	0	1
Perca flavescens	Yellow Perch	24	0	2
Pomoxis nigromaculatus	Black Crappie	1	0	1
Trinectes maculatus	Hogchoker	2	0	0
Total		**1880**	**90**	**92**

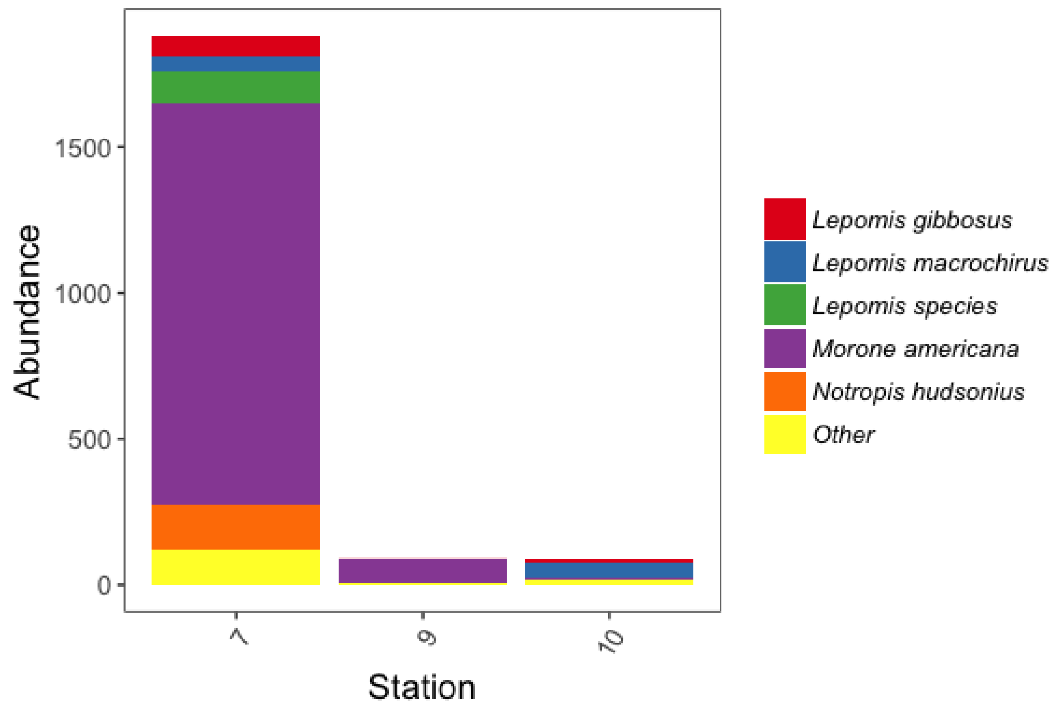


Figure 61a. Adult and Juvenile Fishes Collected by Trawling in 2017. Dominant Species by Station.

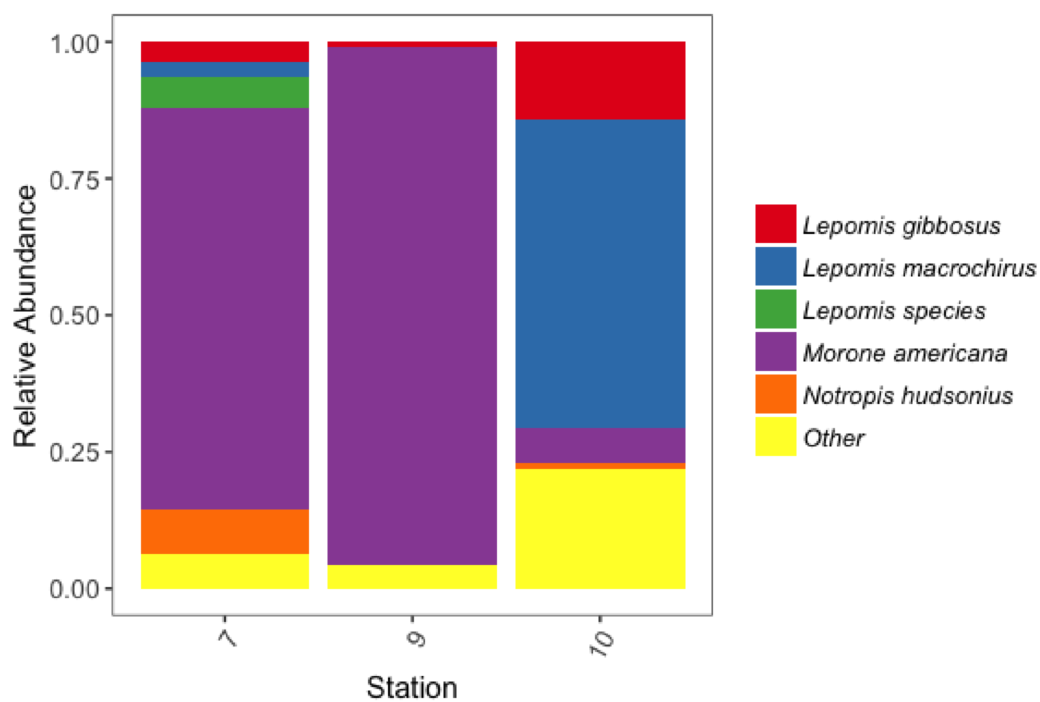


Figure 61b. Relative abundance of Adult and Juvenile Fishes Collected by Trawling in 2017.

The six most abundant species varied in representation across stations (Figure 61b). At all stations, White Perch made up a significant proportion of the total catch. Total catch of White Perch was significantly higher in Station 7 than Station 9 and 10, and is the main reason for the high total catch of station 7 (Figure 61a). We were able to identify a few (6) juvenile Striped Bass among the representatives of the *Morone* genus (the rest were White Perch); which shows that the juveniles of Striped Bass can be found in the fresh upper reaches of the Potomac River. Another group that is usually found in higher salinities, but can sometimes show up in high numbers in our collections is Bay Anchovy, but we did not collect any this year. Station 10 showed a high proportion of Bluegill, which was caught in the same abundance (but not proportion) at station 7 as well. Alosines (herring or shad) were not a dominant group in the trawls this year, though we did see high representation among the larval collections. Another group that can sometimes show up in high numbers is bay Anchovy, which we did not see in our collections this year. Blue Catfish (not shown in figure) are primarily a mainstem species and have not been featured prominently at stations within the cove, but we did collect two specimens at station 7 this year. All species were present in their highest abundance at Station 7, except for American Shad (just 1 at Station 9) and Redear Sunfish (5 at Station 10 while 4 at Station 7). Station 7 was overall the most productive site, with a total abundance an order of magnitude higher than the other two stations. Because of extensive SAV cover, Station 10 was only sampled in April and May, which should be kept in mind when comparing stations. During April and May, 47% of the total catch was collected at Station 10, after which collections at Station 10 stopped. The results of the fyke net collections provide insight in the relative abundance of fish species in the deeper cover throughout the rest of the season.

When looking at the seasonal trend it is clear that White Perch was the most common species, with a distinct peak in abundance in mid-summer (Figure 62a and b). The relative abundance of sunfishes was highest early in the season, but were collected throughout the season as well. Spottail Shiner were most abundant in July, while relative abundance (proportional to the rest of the catch; Figure 62b) was highest in June. The most productive month was July, which was dominated by a large cohort of juvenile White Perch.

Blueback Herring (*Alosa aestivalis*) and Alewife (*Alosa pseudoharengus*) were formerly major commercial species, but are now collapsed 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.

Bay Anchovy (*Anchoa mitchilli)* is commonly found in shallow tidal areas but usually in higher salinities. Due to its euryhaline nature, it can occur in freshwater. Feeds mostly on zooplankton, but also on small fishes, gastropods and isopods. They are an important forage fish.

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.

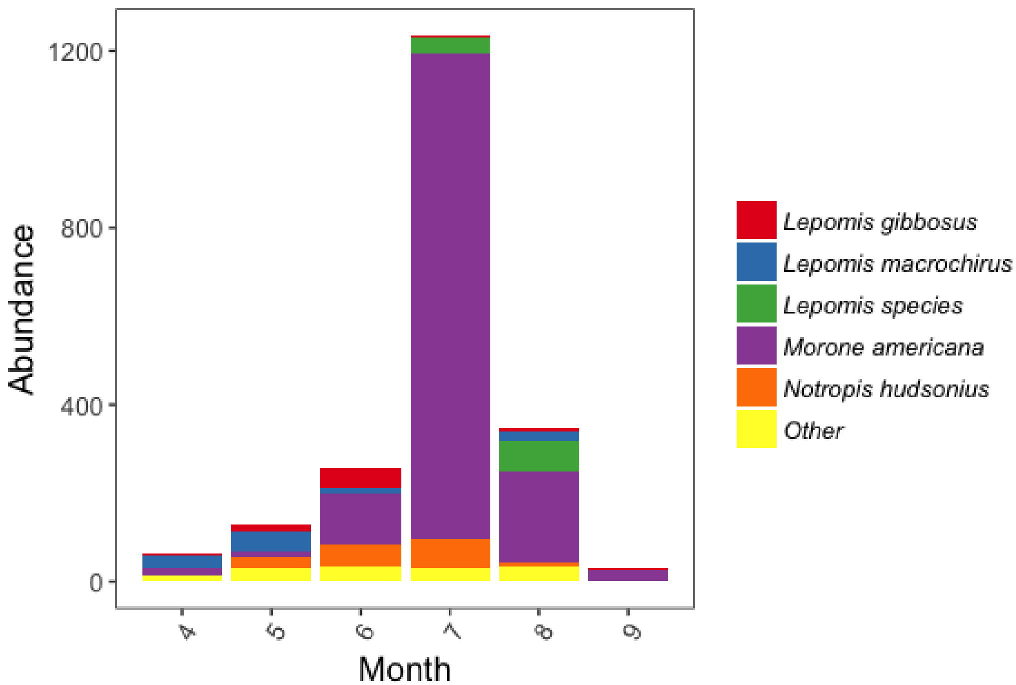


Figure 62a. Adult and Juvenile Fishes Collected by Trawling in 2017. Dominant Species by Month.

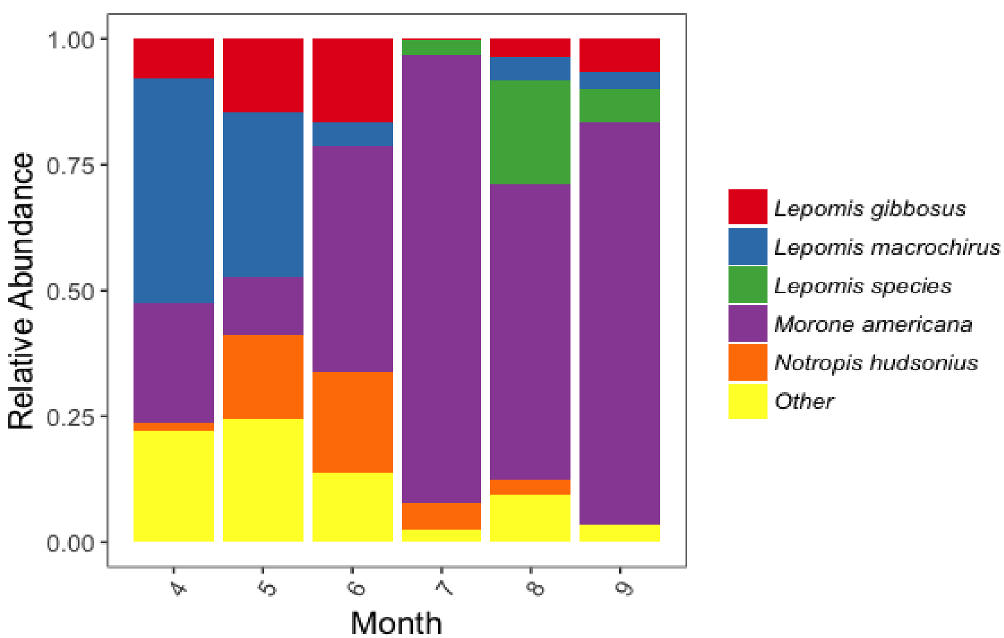


Figure 62b. Relative Abundance for Adult and Juvenile Fishes Collected by Trawling in 2017.

Seines

Seine sampling was conducted approximately semi-monthly at 4 stations between April 21 and September 19. As planned, only one sampling trip per month was performed in April and September. We stopped seining at station 4 on June 20 (last seine sample was on June 20) due to dense SAV growth.

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.

A total of 35 seine samples were conducted, comprising 3530 fishes of 24 species (Table 8). This is similar but a little lower than the number of individuals and species collected last year. Similar to last year, the most dominant species in seine catches was Banded Killifish, with a relative contribution to the catch of 57.42%. Other dominant species (with >5% of relative abundance) were Inland Silverside (14.79%) followed by White Perch (9.15%). Other taxa that contributed at least 1% to total abundance include Bluegill (3.03%), Mosquitofish (2.72%), Eastern Silvery Minnow (2.18%), Spottail Shiner (1.98%), Pumpkinseed (1.67%), and Mummichog (1.59%). Other species occurred at low abundances (Table 8). The extensive SAV cover, which now is an established presence in the cove, is responsible for the high abundance of Banded Killifish in the seine catches.

Banded Killifish was abundant and present at all sampling dates, with higher abundances in spring and early summer than late summer (Table 9, Figure 63). The highest abundance of Banded Killifish occurred in June, which was the month of the highest total abundance because of it. Inland Silverside had highest abundance at the end of Spring, with most specimens collected in May. White Perch was mostly collected later in the season with highest numbers in August (Table 9, Figure 63)

The highest abundance of Banded Killifish was found in station 6, but was pretty evenly spread across all stations (Table 10, Figure 64). Banded Killifish was most dominant at all stations. The highest abundances of Inland Silverside and White Perch where at Station 11. These are pelagic species, and Station 11 is a beach closest to the mainstem. Abundance varied from 1216 fish at station 11 to 702 fish at station 4B (Table 10). Station 11 had the highest abundance because of the combination of all three most abundant species collected with a seine net. Species richness varied from 10 species at station 4, to 19 species at station 4B. It should be noted that sampling was halted at station 4 in mid-summer, which can have an effect on the total number of species collected.

Table 8. Adult and Juvenile Fish Collected by Seining. Gunston Cove Study - 2017.

Scientific Name	**Common Name**	**Abundance**	**Percent**
Fundulus diaphanus	Banded Killifish	2027	57.42
Menidia beryllina	Inland Silverside	522	14.79
Morone americana	White Perch	323	9.15
Lepomis macrochirus	Bluegill	107	3.03
Gambusia holbrooki	Mosquitofish	96	2.72
Hybognathus regius	Eastern Silvery Minnow	77	2.18
Notropis hudsonius	Spottail Shiner	70	1.98
Lepomis gibbosus	Pumpkinseed	59	1.67
Fundulus heteroclitus	Mummichog	56	1.59
Etheostoma olmstedi	Tessellated Darter	35	0.99
Morone saxatilis	Striped Bass	29	0.82
Micropterus salmoides	Largemouth Bass	23	0.65
Lepomis species	Unidentified Sunfish	22	0.62
Alosa species	Unk. *Alosa* Species	21	0.59
Notemigonus crysoleucas	Golden Shiner	19	0.54
Carassius auratus	Goldfish	14	0.40
Alosa pseudoharengus	Alewife	10	0.28
Strongylura marina	Atlantic Needlefish	8	0.23
Enneacanthus gloriosus	Bluespotted Sunfish	5	0.14
Alosa sapidissima	American Shad	2	0.06
Ameiurus nebulosus	Brown Bullhead	2	0.06
Carpiodes cyprinus	Quillback	1	0.03
Dorosoma cepedianum	Gizzard Shad	1	0.03
Pimephales promelas	Fathead Minnow	1	0.03
Total		**3530**	**100.00**

Table 9. Adult and Juvenile Fish Collected by Seining. Gunston Cove Study - 2017.

Scientific Name	Common Name	4/21	5/12	5/23	6/6	6/20	7/7	7/18	8/1	8/15	9/19	**Total**
Alosa pseudoharengus	Alewife	0	2	8	0	0	0	0	0	0	0	**10**
Alosa sapidissima	American Shad	0	1	1	0	0	0	0	0	0	0	**2**
Alosa sp.	Unk. *Alosa* species	0	0	0	6	0	4	0	0	5	6	**21**
Ameiurus nebulosus	Brown Bullhead	0	0	0	0	0	1	1	0	0	0	**2**
Carassius auratus	Goldfish	0	0	0	1	1	6	0	3	1	2	**14**
Carpiodes cyprinus	Quillback	0	0	0	0	0	0	1	0	0	0	**1**
Dorosoma cepedianum	Gizzard 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	5	**5**
Etheostoma olmstedi	Tessellated Darter	7	2	3	13	1	3	0	5	1	0	**35**
Fundulus diaphanus	Banded Killifish	418	152	315	593	107	92	85	21	59	185	**2027**
Fundulus heteroclitus	Mummichog	35	1	0	5	1	3	6	3	1	1	**56**
Gambusia holbrooki	Mosquitofish	8	5	11	37	0	28	2	1	0	4	**96**
Hybognathus regius	Eastern Silvery Minnow	2	0	1	0	0	4	0	67	3	0	**77**
Lepomis gibbosus	Pumpkinseed	16	1	4	7	0	0	0	8	0	23	**59**
Lepomis macrochirus	Bluegill	49	4	11	10	0	8	0	8	3	14	**107**
Lepomis sp.	Unk. sunfish	0	0	0	0	0	0	0	5	3	14	**22**
Menidia beryllina	Inland Silverside	49	180	133	55	73	3	5	7	3	14	**522**
Micropterus salmoides	Largemouth Bass	0	0	1	1	1	18	0	1	0	1	**23**
Morone americana	White Perch	50	1	6	3	2	39	64	110	24	24	**323**
Morone saxatilis	Striped Bass	0	0	0	0	1	16	0	9	0	3	**29**
Notemigonus crysoleucas	Golden Shiner	0	2	1	11	0	1	0	4	0	0	**19**
Notropis hudsonius	Spottail Shiner	40	0	0	8	2	9	1	7	2	1	**70**
Pimephales promelas	Fathead Minnow	0	0	0	0	0	0	0	1	0	0	**1**
Strongylura marina	Atlantic Needlefish	0	0	0	4	3	1	0	0	0	0	**8**
Total		**674**	**351**	**495**	**754**	**192**	**237**	**165**	**260**	**105**	**297**	**3530**

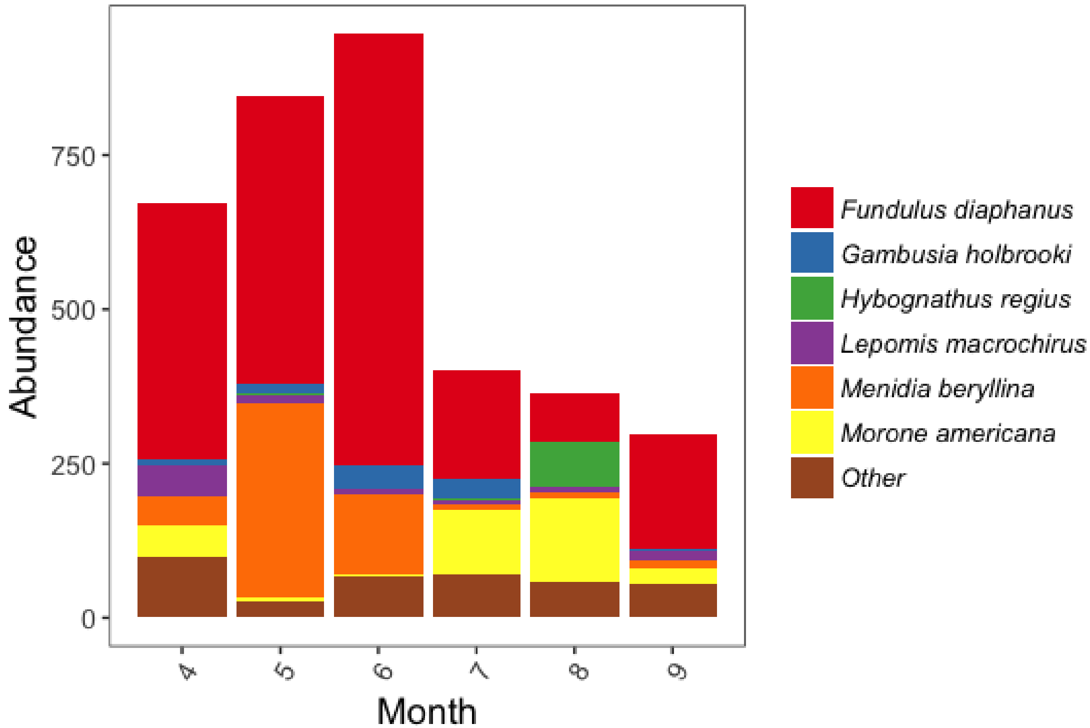


Figure 63. Adult and Juvenile Fish Collected by Seining in 2017. Dominant Species by Month.

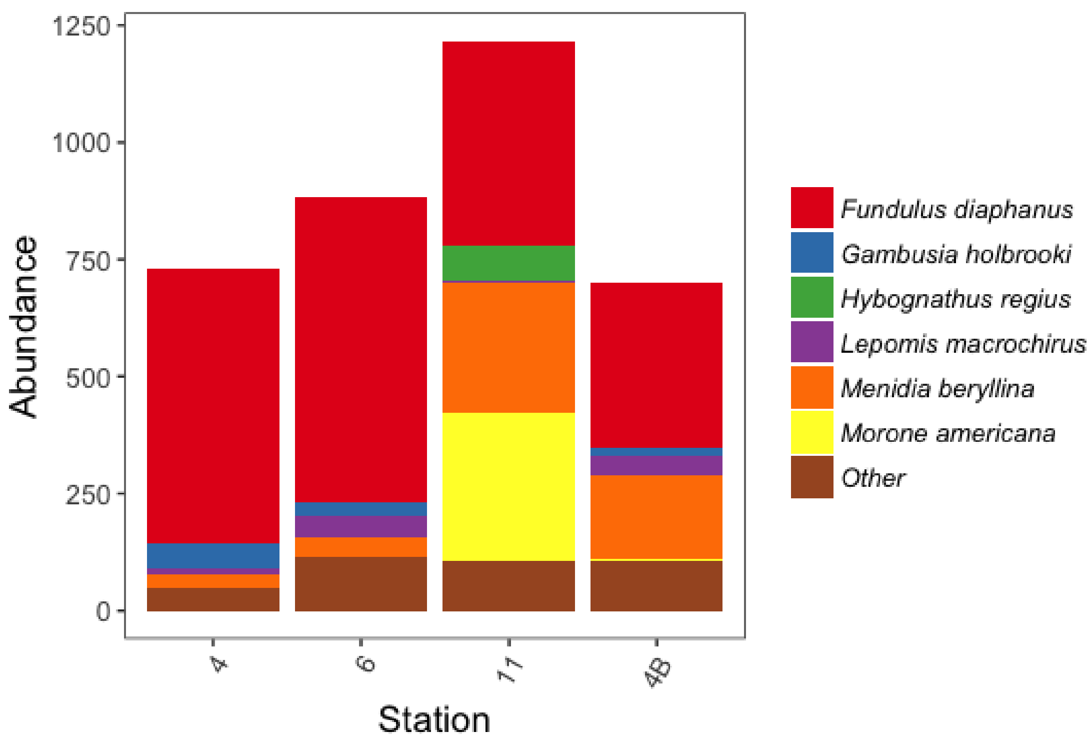


Figure 64. Adult and Juvenile Fishes Collected by Seining in 2017. Dominant Species by Station.

Table 10. Adult and Juvenile Fish Collected by Seining in 2017 per station in Gunston Cove.

Scientific Name	Common Name	4	6	11	4B
Alosa pseudoharengus	Alewife	2	8	0	0
Alosa sapidissima	American Shad	0	0	0	2
Alosa species	Unk Herring/Shad Species	0	0	20	1
Ameiurus nebulosus	Brown Bullhead	0	1	1	0
Carassius auratus	Goldfish	0	3	1	10
Carpiodes cyprinus	Quillback	0	0	0	1
Dorosoma cepedianum	Gizzard Shad	0	0	1	0
Enneacanthus gloriosus	Bluespotted Sunfish	0	5	0	0
Etheostoma olmstedi	Tessellated Darter	7	6	0	22
Fundulus diaphanus	Banded Killifish	582	654	436	355
Fundulus heteroclitus	Mummichog	27	27	1	1
Gambusia holbrooki	Mosquitofish	54	26	0	16
Hybognathus regius	Eastern Silvery Minnow	0	1	76	0
Lepomis gibbosus	Pumpkinseed	7	24	3	25
Lepomis macrochirus	Bluegill	14	48	2	43
Lepomis species	Unidentified Sunfish	0	16	0	6
Menidia beryllina	Inland Silverside	28	39	279	176
Micropterus salmoides	Large-mouth Bass	0	13	0	10
Morone americana	White Perch	0	3	315	5
Morone saxatilis	Striped Bass	0	1	18	10
Notemigonus crysoleucas	Golden Shiner	5	8	0	6
Notropis hudsonius	Spottail Shiner	0	1	59	10
Pimephales promelas	Fathead Minnow	0	0	0	1
Strongylura marina	Atlantic Needlefish	2	0	4	2
Total		**728**	**884**	**1216**	**702**

Fyke nets

We added fyke nets to the sampling regime in 2012 to better represent the fish community present within SAV beds. This year we collected a total number of 1196 specimens of 16 species in the two fyke nets (Station Fyke 1 and Station Fyke 2; Figure 1b; Table 11); the abundance is more than twice as much as last year. While Banded Killifish is abundant here as well (16.76% of the catch), which is not surprising seen as this gear specifically samples SAV habitat, the fyke nets show a high contribution of sunfishes relative to the other gear types (57.69% of the catch). Other taxa contributing more than 1% of the catch include Inland Silverside at 16.24%, White Perch at 5.62%, and Goldfish at 2.26%. We collected one Brown Bullhead, which is a native catfish, in the fyke nets this year. Relative high catches in the fyke nets of native catfishes in previous years may be an indication of a spatial shift of native bullheads and catfishes to shallow vegetated habitat, now that Blue Catfish is caught in higher numbers in the open water trawls (in the Potomac mainstem).

Table 11. Adult and Juvenile Fish Collected by Fyke Nets. Gunston Cove Study - 2017.

Scientific Name	**Common Name**	**Abundance**	**Percent**
Lepomis sp.	Unk. sunfish	431	36.02
Fundulus diaphanus	Banded Killifish	200	16.76
Menidia beryllina	Inland Silverside	194	16.24
Lepomis gibbosus	Pumpkinseed	155	12.93
Lepomis macrochirus	Bluegill	97	8.07
Morone americana	White Perch	67	5.62
Carassius auratus	Goldfish	27	2.26
Notropis hudsonius	Spottail Shiner	5	0.42
Lepomis microlophus	Redear Sunfish	5	0.42
Micropterus salmoides	Largemouth Bass	4	0.33
Morone saxatilis	Striped Bass	4	0.33
Enneacanthus gloriosus	Bluespotted Sunfish	3	0.25
Perca flavescens	Yellow Perch	1	0.08
Ameiurus nebulosus	Brown Bullhead	1	0.08
Etheostoma olmstedi	Tessellated Darter	1	0.08
Strongylura marina	Atlantic Needlefish	1	0.08
Total		**1196**	**100.00**

Table 12. Adult and Juvenile Fish Collected by Fyke Nets. Gunston Cove Study - 2017.

Scientific Name	Common Name	5/12	5/23	6/20	6/6	7/18	7/7	8/1	8/15	9/19	Total
Ameiurus nebulosus	Brown Bullhead	0	0	0	0	0	0	0	1	0	**1**
Carassius auratus	Goldfish	0	0	0	0	0	24	1	2	0	**27**
Enneacanthus gloriosus	Bluespotted Sunfish	0	0	1	0	0	0	0	0	2	**3**
Etheostoma olmstedi	Tessellated Darter	0	0	0	0	0	1	0	0	0	**1**
Fundulus diaphanus	Banded Killifish	0	7	86	44	3	40	14	1	5	**200**
Lepomis gibbosus	Pumpkinseed	0	3	49	1	22	9	19	25	27	**155**
Lepomis macrochirus	Bluegill	0	1	13	0	6	4	24	16	33	**97**
Lepomis microlophus	Redear Sunfish	0	0	0	0	0	5	0	0	0	**5**
Lepomis species	Unidentified Sunfish	0	0	0	0	5	283	67	27	49	**431**
Menidia beryllina	Inland Silverside	5	29	5	150	1	4	0	0	0	**194**
Micropterus salmoides	Large-mouth Bass	0	0	0	0	1	3	0	0	0	**4**
Morone americana	White Perch	1	1	0	0	1	60	4	0	0	**67**
Morone saxatilis	Striped Bass	0	0	0	0	0	4	0	0	0	**4**
Notropis hudsonius	Spottail Shiner	0	0	0	0	0	2	2	1	0	**5**
Perca flavescens	Yellow Perch	0	0	0	0	0	0	1	0	0	**1**
Strongylura marina	Atlantic Needlefish	0	0	0	0	1	0	0	0	0	**1**
Total		**6**	**41**	**154**	**195**	**40**	**439**	**131**	**73**	**116**	**1196**

Highest abundances were collected in July this year, because of a high abundance of sunfishes that month (Table 12, Figure 65). Other species, namely White Perch and Goldfish, were present at their highest abundance that month as well.

Fyke 1 had a higher total catch (746 specimens; Table 13) than Fyke 2. The community structure collected with the two fyke nets is very similar; similar community composition with a similar relative contribution to the catch (Table 13, Figure 66). Abundance in Fyke 1 was higher than Fyke 2 just like last year, due to the higher abundance of sunfishes collected in Fyke 1 (Figure 66).

Table 13. Adult and Juvenile Fish Collected by Fyke Nets. Gunston Cove Study - 2017.

Scientific Name	**Common Name**	**Fyke 1**	**Fyke 2**
Ameiurus nebulosus	Brown Bullhead	1	0
Carassius auratus	Goldfish	9	18
Enneacanthus gloriosus	Bluespotted Sunfish	1	2
Etheostoma olmstedi	Tessellated Darter	1	0
Fundulus diaphanus	Banded Killifish	106	94
Lepomis gibbosus	Pumpkinseed	81	74
Lepomis macrochirus	Bluegill	59	37
Lepomis microlophus	Redear Sunfish	1	4
Lepomis species	Unk. Sunfish	347	83
Menidia beryllina	Inland Silverside	71	123
Micropterus salmoides	Largemouth Bass	4	0
Morone americana	White Perch	58	9
Morone saxatilis	Striped Bass	2	2
Notropis hudsonius	Spottail Shiner	3	2
Perca flavescens	Yellow Perch	0	1
Strongylura marina	Atlantic Needlefish	1	0
Total		**746**	**450**

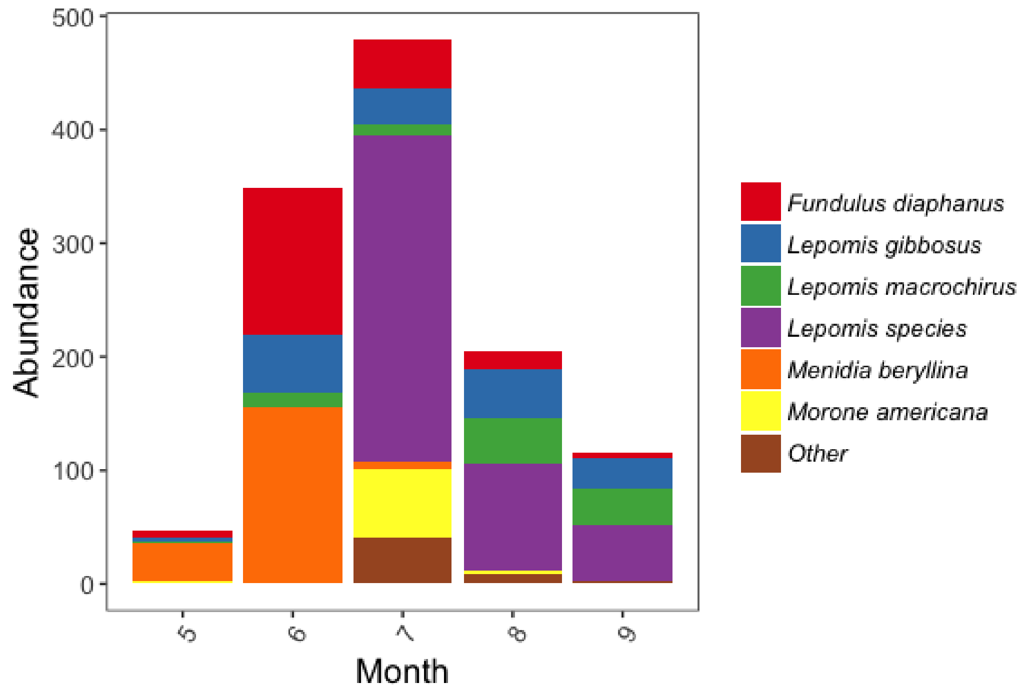


Figure 65. Adult and Juvenile Fish Collected by Fyke Nets. Dominant Species by Month. 2017.

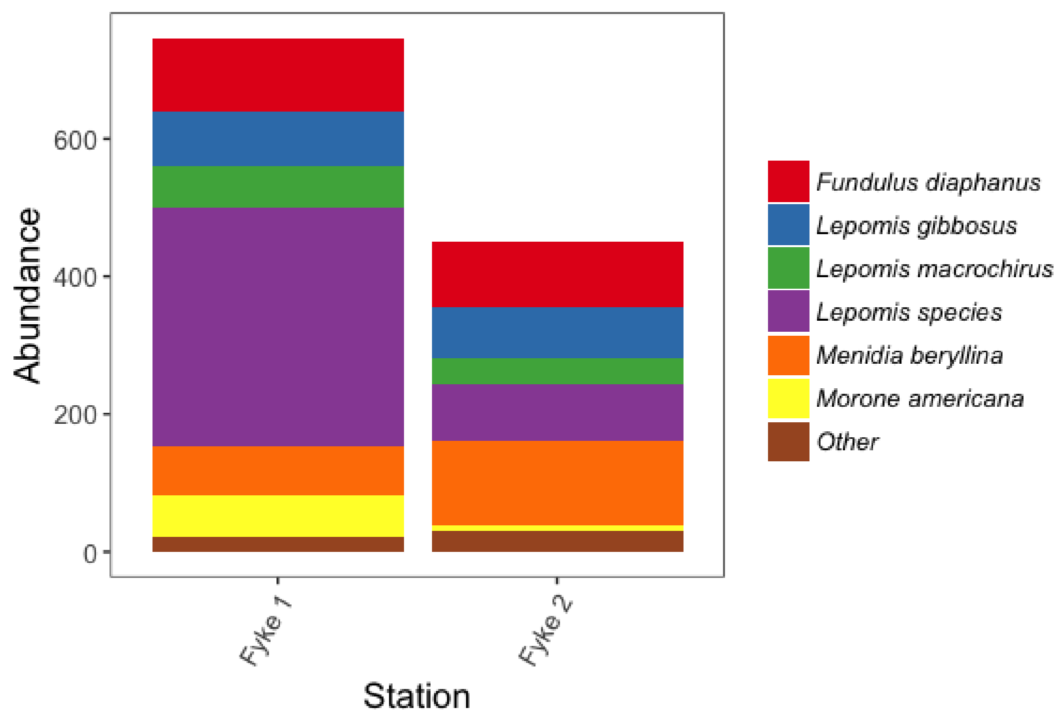


Figure 66. Adult and Juvenile Fishes Collected by Fyke Nets. Dominant Species by Station. 2017.

G. Submersed Aquatic Vegetation – 2017

The map below (Figure 67) depicts the area covered by SAV as determined by the Virginia Institute of Marine Science utilizing aerial imagery for 2017. This map indicates that SAV coverage in 2017 was similar to 2015 and 2016 and was more extensive than in 2013 and 2014. Again, covering almost all of the inner cove up to about Station 7 which was just outside the SAV area.

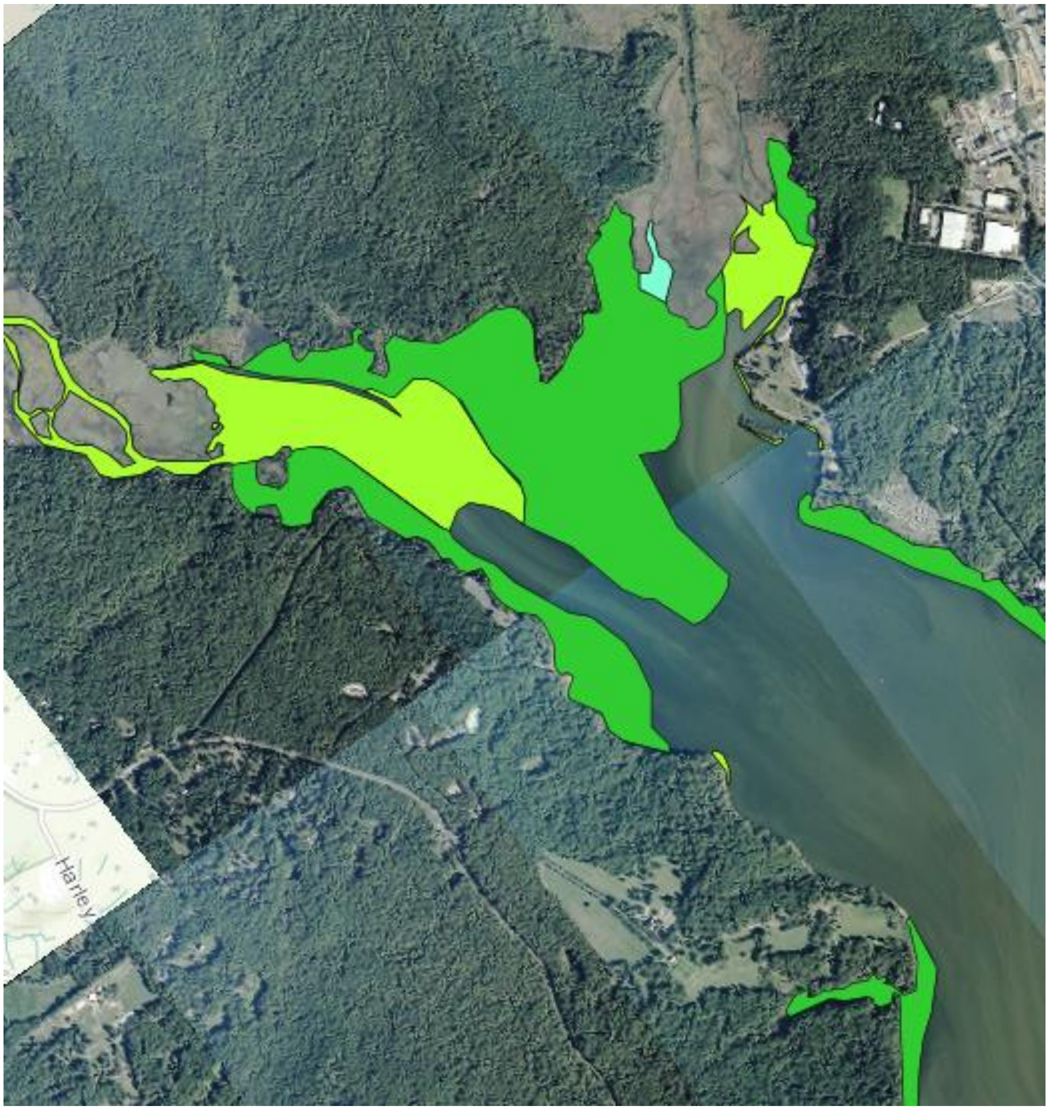


Figure 67. Distribution and density of Submersed Aquatic Vegetation (SAV) in the Gunston Cove area in 2017. VIMS (http://www.vims.edu/bio/sav/index.html).

The distribution of dominant SAV taxa was determined at 31 points in the inner portions of Gunston Cove during data mapping cruises by inserting a garden rake to the bottom, twisting it to collect plants and pulling it on board. The results are summarized in Table 14. *Hydrilla* was found at many sites, but its coverage intensity was generally only moderate. *Najas guadalupensis* (common water-nymph) was present in even more plots and was quite dense in some areas. This is significant because *N. guadalupensis* is native to the Chesapeake Bay region. *Ceratophyllum* and *Najas minor* were present at many points, but had a low density. *Vallisneria* and Zosterella (formerly called *Heteranthera)* were more restricted in their occurance.

Table 14. Relative abundance of dominant SAV species determined during data mapping cruises.

Scientific Name	**Common Name**	**Freq (#)**	**Freq (%)**	**Avg. Density**
Hydrilla verticillata	hydrilla	14	45.2	0.96
Ceratophyllum demersum	coontail	11	35.5	0.77
Najas minor	minor naiad	13	41.9	0.77
Zosterella dubia	water star-grass	1	3.2	1.00
Najas guadalupensis	common water-nymph	17	54.8	2.09
Vallisneria americana	wild celery	2	6.5	1.25

A total of 31 points were sampled. 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.

H. Benthic Macroinvertebrates - 2017

Triplicate petite ponar samples were collected in Gunston Cove proper (Station 7) and in the Potomac River (Station 9) monthly from May through September.

Taxonomic Groups: Annelid worms (including Oligochaetes and Polychaetes) were found in high numbers (total N = 815) at each site over all dates. Overall, they accounted for 69% of all benthic organisms found. Oligochaetes were the dominant taxonomic group, accounting for 99% of individuals.

Crustaceans (including Gammarid amphipods and isopods) were the second highest in abundance across sites and dates, accounting for 23% of all individuals (N = 274). Gammarid amphiods (scuds) dominated this group, accounting for 86% of all crustaceans observed.

The remainder of the taxonomic groups accounted for minor components of the overall diversity. These included Bivalvia (N = 33; 2.8% of total abundance), Gastropods (N = 8; 0.7%), and Insecta (N = 50; 4.2%). The bivalve group was composed of only two taxonomic groups, namely the fingernail clams from the family Sphaeriidae (66.7%) and by the invasive Asian clam, *Corbicula fluminea* (33.3%). The gastropod (i.e., snails) group was composed of taxa from Viviparidae, Valvatidae, and Pleuroceridae. The most dominant family was Viviparidae, accounting for 57% of all gastropods found. Insects were dominated by Chironomids (midges), which accounted for 96% of all insects, but single representatives of the Chaoboridae and Hydroptilidae were also found.

Table 15. Gunston Cove Benthos. 2017. Average total individuals per petite ponar.

Month and Day	Site	Total	Average	Range	SE ±
May 2	GC 7	27	9	2-18	4.7
	GC 9	166	55	50-63	3.9
June 27	GC 7	76	25	23-28	1.5
	GC 9	85	28	8-60	16
July 11	GC 7	131	44	11-81	20
	GC 9	184	61	17-146	42
August 1	GC 7	28	9	5-15	3.0
	GC 9	81	27	19-43	8.0
September 12	GC 7	68	23	14-36	6.7
	GC 9	334	111	45-172	37

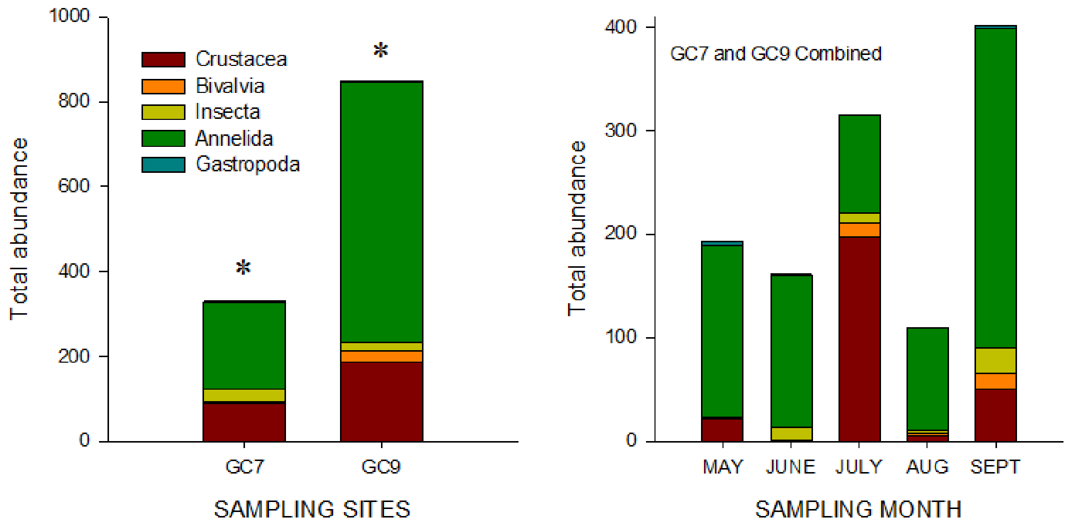


Figure 68. Taxa total abundance by Station (left) and Month (right).

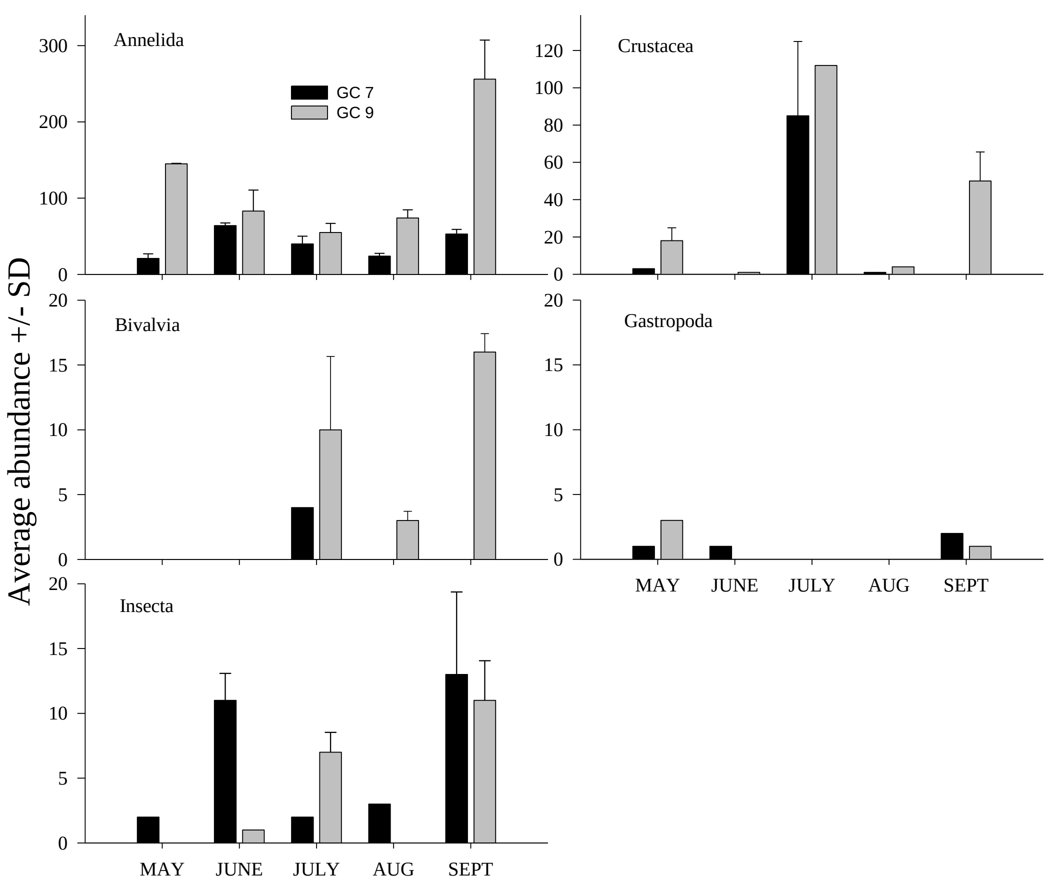


Figure 69. Taxa total abundance by Month. Each Taxon a separate graph.

Spatial and temporal trends: There was no significant interaction between site and month in terms of total benthic macroinvertebrate abundance (GLM; Wald Chi-square= 58.39, 1 df, p=0.68). However, both site and month individually contributed to significant differences in benthic macroinvertebrate abundance (GLM; site: Wald Chi-square= 11.34, 1 df, p=0.001; month: Wald Chi-square= 12.03, 4 df, p=0.017). This indicates that, across all month, the sites were significantly different from one another in terms of total benthic macroinvertebrate abundance, and that months were significantly different from one another, after combining the sites together.

Spatial trends: The total and average abundance of organisms was significantly higher at GC9 over time, which is the closest location to the Potomac River, as compared to the site within Gunston Cove (GC7). In general, both sites were dominated by Annelida, driven by high abundances of Oligochaete, and Crustaceans (mostly Gammarid amphipods). Site CG9 had a higher diversity of taxa than GC7, likely due to differences in sediment and flow characteristics. Other dominant taxa at GC9 included Insecta (mostly Chironomids) and Gastropoda (i.e., snails). The only taxa to increase in abundance from the bay to the river site were Bivalva (mostly the invasive Asian clam *Corbicula fluminea*).

Temporal trends: There was a significant difference in total benthic macroinvertebrate abundance between months when GC7 and GC9 were combined. Across the months, Annelids (mostly Oligochaetes) were the dominant taxa except for July when Crustaceans (mostly Gammarid amphipods) dominated. Insecta (mostly Chironomids) also contributed sporadically, with highest abundances during June and September. There was a seasonal increase in Crustaceans driven by Gammarid amphipods, which peaked during July most likely due to recruitment. Bivalves increased in abundance during the latter part of the sampling season (July to September), but never increased above a maximum of nine individuals per replicate sample. The lowest abundances of insect larvae across all sites occurred during May and August, but abundances were relatively inconsistent. Annelids, composed of Oligochaetes and Polychaetes, were dominant taxa recorded during all months but had highest abundances during September. There was no obvious temporal trend in gastropod abundances. Overall, larger increases in abundances over the sampling period for many of the taxa described above are in direct relation to seasonal changes and recruitment.

Community comparisons: To investigate differences in benthic macroinvertebrate community composition, abundance of broader taxonomic groupings was fourth-root-transformed to decrease the importance of very abundant taxa. Transformed values were used to create a resemblance matrix using S17 Bray–Curtis similarity index (Bray & Curtis, 1957). These data were compared using site identification and overall location (M= mainstem, E= embayment) as factors, and non-metric multidimensional scaling plots (MDS) were generated to visualize differences. A permutational multivariate analysis of variance (PERMANOVA) was used to determine whether significant differences in taxa assemblages existed between sites, months, and the interaction between sites and months. SIMPER analysis was conducted on the fourth-root-transformed data to determine which taxa were driving the differences observed. PERMANOVA, MDS and SIMPER analyses were performed using PRIMER 6 (Clarke & Gorley, 2006).

PERMANOVA portioning shows that small-scale spatiotemporal variation, identifiable from a statistically significant interaction between site and month (Psuedo-F=2.41, p= 0.032), influenced the benthic macroinvertebrate communities in 2017. Both site and month, individually, also significantly contributed to differences in benthic macroinvertebrate communities (site: Psuedo-F=3.95, p= 0.018; month: Psuedo-F=2.27, p= 0.027). The two taxa groups contributing most to the dissimilarity between sites were the Crustaceans (isopods and amphipods) and Insecta, which were the most variable in abundance of all the taxonomic groups.

On the ordination plot (Figure 70) there is a fairly consistent separation between samples collected at Station 7 (cove) as compared to Station 9 (river channel). In particular cove samples were found on the right side of the ordination plot and river stations on the left side. The most apparent outlier from this trend was the July sample at Station 7 which plotted on the left side of the graph. The July samples from Station 7 had generally higher total densities and even more importantly contained significant numbers of bivalves and crustaceans more typical of Station 9 samples.

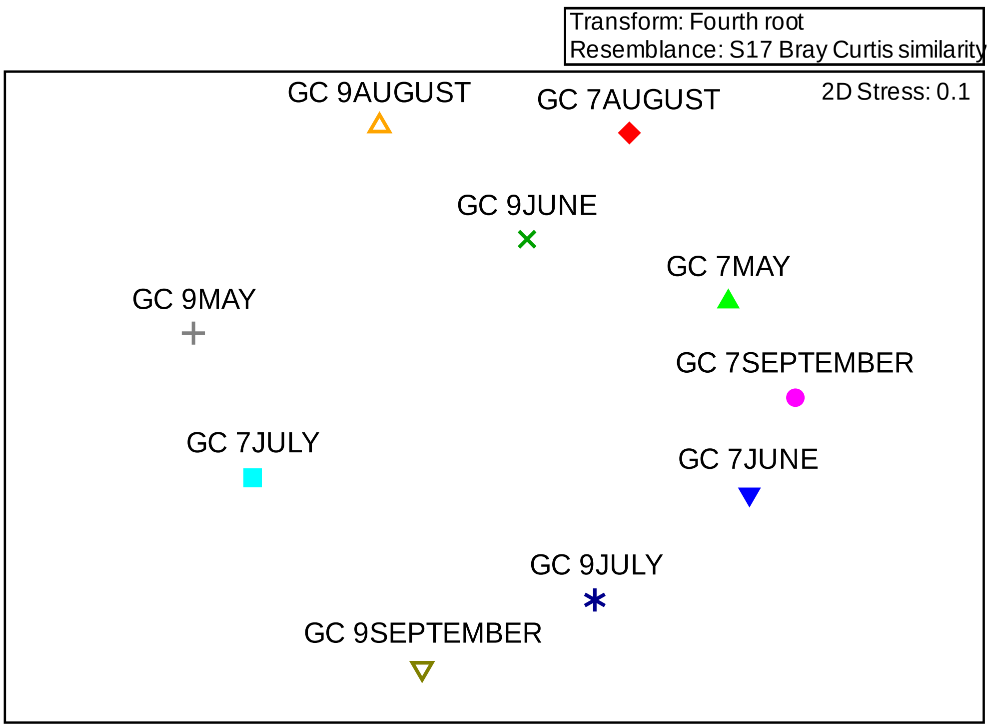


Figure 70. NMDS results by Station and by Month.

DISCUSSION

A. 2017 Data

In 2017 air temperature was substantially above average in April and June, but near normal for the rest of the year. The later part of May was a period of cooling temperatures. Precipitation was well above normal during May and July. The largest daily rainfall total was 8.41 cm on July 28. Over two days on July 22-23, 6.02 cm were observed. As a result of these two rainfall periods, July had with flows that were considerably above normal in both the river and the Gunston Cove tributaries. The same was true of May which showed much higher flows than April in contrast to long term average patterns. Rainfall and runoff patterns relative to sampling dataes are shown in Figure 71.

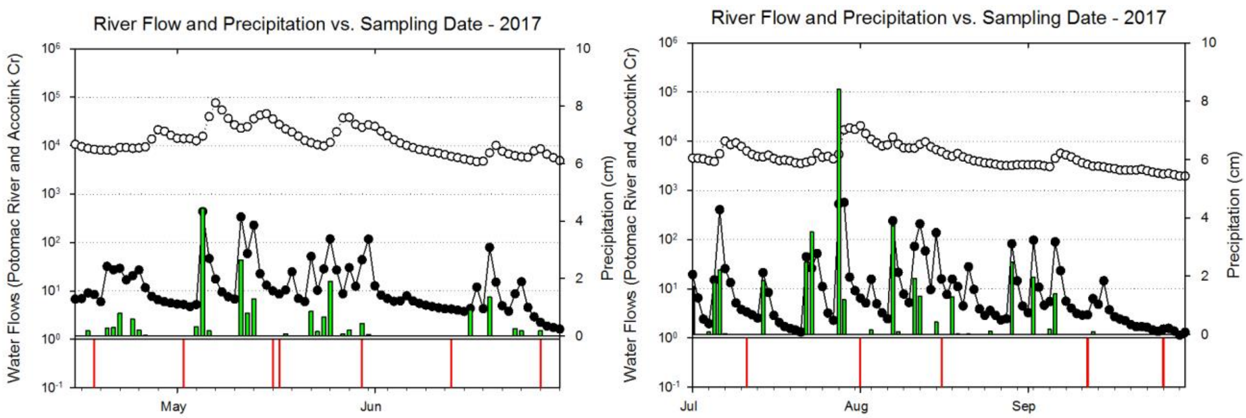


Figure 71. Precipitation (green bars), Accotink Creek flows (solid circles), Potomac River flows (open circles) and water quality/plankton sampling events (red lines at bottom).

Mean water temperature was similar at the two stations with a pronounced dip in late May and a peak of nearly 30° in early July. Specific conductance declined substantially at both stations in the wake of the late May flow events. The declines in late July and early August also appeared to be related to increased flow. Chloride showed only a slight decline in May and little response to the flow events in July. Dissolved oxygen saturation and concentration (DO) were normally substantially higher in the cove than in the river due to photosynthetic activity of phytoplankton and SAV. Field pH patterns mirrored those in DO: higher values in the cove than the river and an even larger drop in August. Total alkalinity was generally higher in the river than in the cove and was fairly constant except for the August decline. Secchi disk transparency was quite constant over the year and did not attain values above 1 m, in contrast to recent years. Light attenuation coefficient and turbidity followed a similar pattern.

Ammonia nitrogen was consistently low in the study area during 2017, but all values were below the limits of detection making analysis of any temporal or spatial trends impossible. Un-ionized ammonia remained below values that would cause toxicity issues, but exact values were not possible due to the high incidence of non-detects for total ammonia. Nitrate values declined seasonally at both sites due to algal and plant uptake and possibly denitrification. By late June nitrate nitrogen in the cove was below detection limits where it remained through the remainder of the year. River nitrate nitrogen levels reached a low of about 0.5 mg/L. Nitrite was higher in the river and peaked in September. Organic nitrogen exhibited substantial variability averaging somewhat higher in the cove over the year. Total phosphorus was similar at both sites and showed little seasonal change. Soluble reactive phosphorus was very low and consistently below detection limits in the cove and higher in the river. N to P ratio did not show a consistent seasonal pattern, but was lowest in the cove in late June at about 10 which is still indicative of P limitation of phytoplankton and SAV. BOD was generally higher in the cove than in the river. TSS and 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, but showed a similar seasonal pattern. Chlorophyll was unusually high in the cove in late April and early May. A decline was observed in late May followed by a resurgence in June and July at both stations with a maximum in mid-July at both stations. A decline was observed at both stations in late July and early August. Cell density tracked chlorophyll fairly well in the cove with maxima in May and July. Little seasonal change was observed in cell density in the river. Cell density in the cove was dominated by cyanobacteria, with *Oscillatoria, Merismopedia,* and *Anabaena* being the dominants. In the river, cyanobacteria dominanted in most months with diatoms being important in spring and early summer. Pennate diatoms and *Oscillatoria* were dominant. Phytoplankton biovolume was strongly weighted towards diatoms with *Melosira* and discoid centrics making the greatest contributions.

Rotifers continued to be the most numerous zooplankton in 2017. Rotifer densities were unusually high in early May in the cove, but were low in the river until later in the year. Another peak was observed in late June. *Brachionus* and *Keratella* shared dominance in both areas. *Bosmina*, a small cladoceran that was often common was present at low densities in 2017 except for the early May sample in the river where it was very abundant. *Diaphanosoma*, a larger cladoceran was found in both area at moderate densities peaking in the summer. Surprisingly, *Daphnia* was present at very low levels in 2017. *Leptodora* was moderately abundant in the cove and showed high abundance in mid June in the river. Copepod nauplii densities reached a distinct peak in the river in late June, but were variable in the cove. The calanoid copepod *Eurytemora* was very abundant in the river in June and July, but relatively rare in the cove. A second calanoid *Diaptomus* was found at much lower levels. Cyclopoid copepods had a strong maximum in the river in late June, but were rare in the cove.

In 2017 ichthyoplankton was dominated by clupeids, most of which were Alewife, Gizzard Shad, and Blueback Herring, and to a lesser extent Hickory Shad, and American Shad. White Perch was found in relatively high densities as well. *Morone* species (White Perch and Striped Bass) were mostly found in the Potomac mainstem, confirming their affinity for open water. Other taxa were found in very low densities similar to the previous year. The highest density of fish larvae occurred at the start of May, which was driven by a high density of Clupeid larvae in combination with relative density of other larvae. The non-clupeid larval density was highest in spring and declines from there, while clupeid density saw two distinct peaks (at the beginning of May and June).

In trawls, White Perch (*Morone americana*) dominated with 71.27% of the catch, distantly followed by the still abundant taxa Spottail Shiner (*Notropis hudsonius*) and several species of sunfish. White Perch was by far the most abundant species and was found in all months at all stations, with peak abundance in July. Sunfishes were found throughout the year as well. Other numerically abundant taxa included Tessellated Darter, Yellow Perch, Banded Killifish, and Goldfish. Blue Catfish was collected with the trawl again this year, this time two in the mainstem, and two in the cove. We collected one native catfish (Brown Bullhead) within Gunston Cove. Almost all specimens of White Perch, sunfish, and Spottail Shiner were collected at station 7, which is our trawl station most representative of Gunston Cove. Station 10 (further into the Cove) was now only sampled until the last sampling date in May, as heavy SAV growth obstructed the trawling activity as soon as the summer started this season.

In seines, the most abundant species was Banded Killifish (*Fundulus diaphanus*). 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). The abundance peak of Banded Killifish was in early June. Other taxa with high abundances were Inland Silverside and White Perch.

Fyke nets were part of the sampling regime again in 2017. The total catch of the fyke nets is smaller than the other gears, but still represents an interesting contribution to the total catch because the composition of the catch is different than the trawls and seines. Sunfishes were the most dominant taxa, with Banded Killifish as the second most abundant species. Sunfishes that could be identified to the species level were represented in order of abundance by Pumpkinseed, Bluegill, Redear Sunfish, and Bluespotted Sunfish. Fish abundance was highest in July. Overall catches were lowest in May, when SAV was still absent or sparse. Like last year, we found very few native catfishes in the fyke nets this year (one Brown Bullhead).

The coverage of submersed aquatic vegetation (SAV) in 2017 was similar to recent years. Mapping of the SAV coverage by species revealed that a native aquatic plant, *Najas guadalupensis* (common water-nymph), was the most frequently encountered plant and had the highest density. The exotic plant *Hydrilla* also widespread, but less dense. *Najas minor* (minor naiad, non native) and *Certophyllum demersum* (coontail, native) were also frequently encountered. As in most previous years, oligochaetes were the most common invertebrates collected in ponar samples in 2017. Encouragingly, the second most abundant taxon at both stations was Crustacea, represented by amphipods. While these often had been abundant in the river, their significant levels in the cove was new in 2017. Chironomids in the cove and bivalves in the river were next in abundance. There were significantly more individuals at the river station.

B. Water Quality Trends: 1983-2017

To assess long-term trends in water quality, data from 1983 to 2017 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 16
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1984-2017
GMU Water Quality Data
June-September

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Temperature	0.196	0.055	0.001	0.115	0.029	NS
Conductivity, standardized to 25°C	0.164	1.99	0.004	0.033	-----	NS
Dissolved oxygen, mg/L	0.036	-----	NS	0.205	0.025	0.001
Dissolved oxygen, percent saturation	0.043	-----	NS	0.233	0.367	<0.001
Secchi disk depth	0.725	1.84	<0.001	0.378	0.600	<0.001
Light attenuation coefficient	0.688	0.093	<0.001	0.204	0.020	0.003
pH, Field	0.185	-0.012	0.003	0.194	0.009	0.004
Chlorophyll, depth-integrated	0.608	-3.81	<0.001	0.275	-0.727	<0.001
Chlorophyll, surface	0.598	-3.88	<0,001	0.260	-0.805	<0.001

For Station 7, n=296-315 except pH, Field where n=249 and Light attenuation coefficient where n=233
For Station 9, n=254-268 except pH, Field where n=216 and Light attenuation coefficient where n=203.

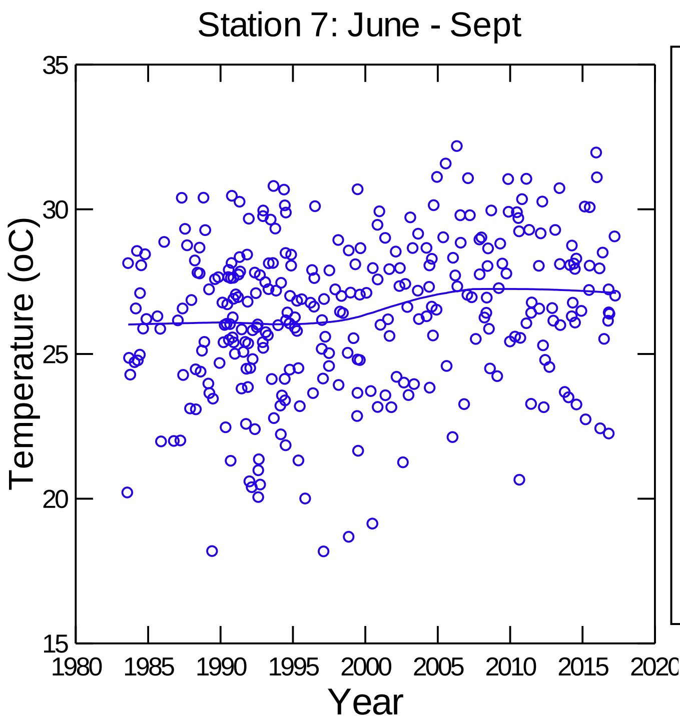
Significance column indicates the probability that a correlation coefficient this large could be due to chance alone. If this probability is greater than 0.05, then NS (not significant) is indicated. Both near surface and near bottom samples included.

Table 17
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1983-2017
Fairfax County Environmental Laboratory Data
June-September

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Chloride	0.022	-----	NS	0.022	-----	NS
Lab pH	0.492	-0.033	<0.001	0.276	-0.013	<0.001
Alkalinity	0.087	0.106	0.056	0.322	0.415	<0.001
BOD	0.644	-0.162	<0.001	0.396	-0.042	<0.001
Total Suspended Solids	0.360	-0.924	<0.001	0.185	-0.192	<0.001
Volatile Suspended Solids	0.406	-0.601	<0.001	0.375	-0.130	<0.001
Total Phosphorus	0.566	-0.004	<0.001	0.311	-0.001	<0.001
Soluble Reactive Phosphorus	0.135	-0.0001	0.003	0.035	-----	NS
Ammonia Nitrogen	0.311	-0.017	<0.001	0.310	-0.0029	<0.001
Un-ionized Ammonia Nitrogen	0.337	-0.004	<0.001	0.325	-0.0003	<0.001
Nitrite Nitrogen	0.433	-0.003	<0.001	0.170	-0.001	<0.001
Nitrate Nitrogen	0.596	-0.035	<0.001	0.675	-0.038	<0.001
Organic Nitrogen	0.578	-0.047	<0.001	0.355	-0.012	<0.001
N to P Ratio	0.327	-0.356	<0.001	0.539	-0.558	<0.001

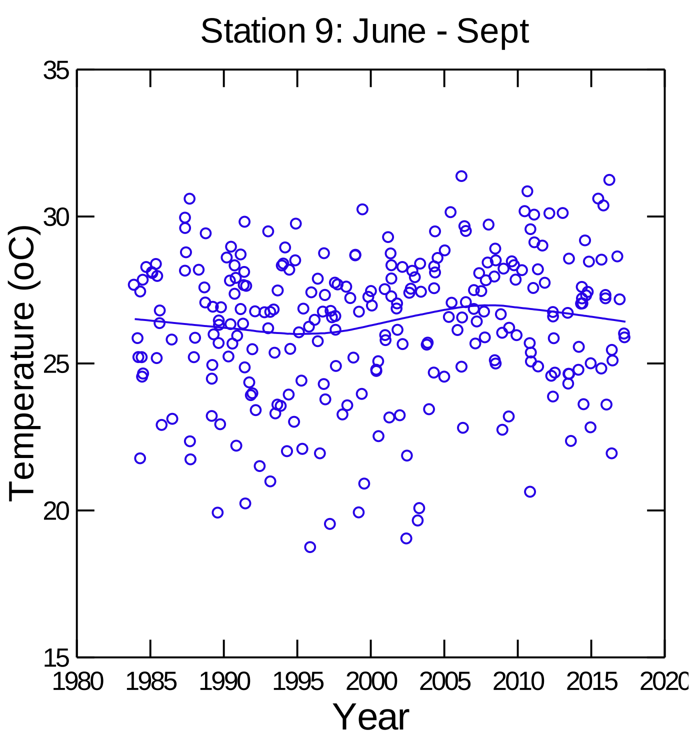
For Station 7, n=447-490 except Nitrite Nitrogen where n=412
For Station 9, n=448-497 except Nitrite Nitrogen where n =412.

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.



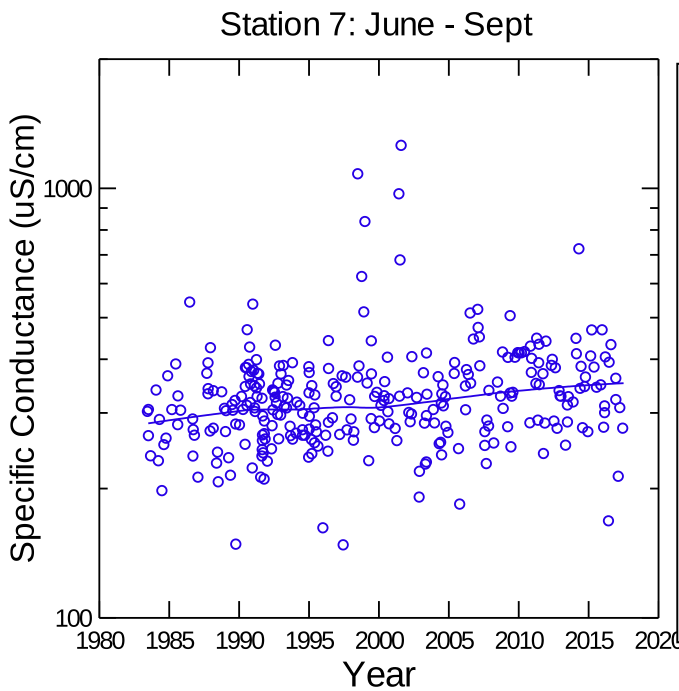
Water temperatures during the summer months generally varied between 20ºC and 30ºC over the study period (Figure 72). The LOWESS curve indicated an average of about 26°C during the period 1984-2000 with a slight upward trend in the last few years to about 27ºC. Linear regression analysis indicated a significant linear trend in water temperature in the cove when the entire period of record is considered (Table 16). The slope of this relationship is 0.06°C/year.

Figure 72. Long term trend in Water Temperature (GMU Field Data). Station 7. Gunston Cove.



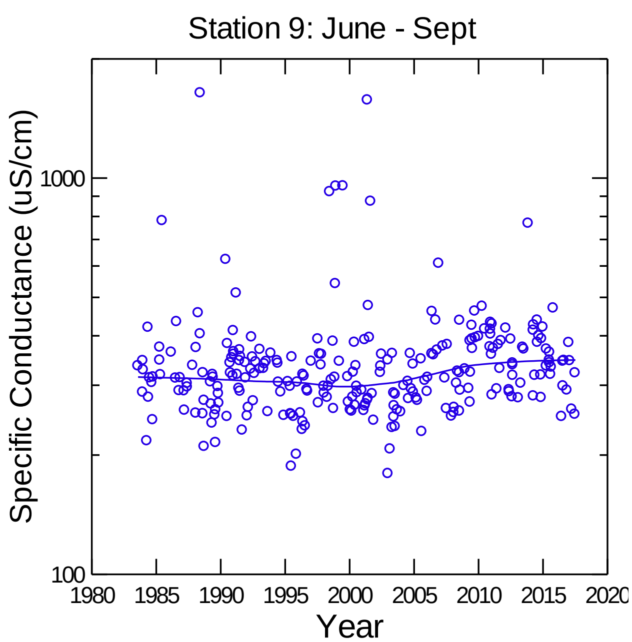
In the river summer temperatures have been similar to those in the cove with fewer readings above 30°C in the river (Figure 73). The long term trend exhibited a near significant increase, but at a lower rate (0.03°C/year) (Table 16).

Figure 73. Long term trend in Water Temperature (GMU Field Data). Station 9. Gunston Cove.



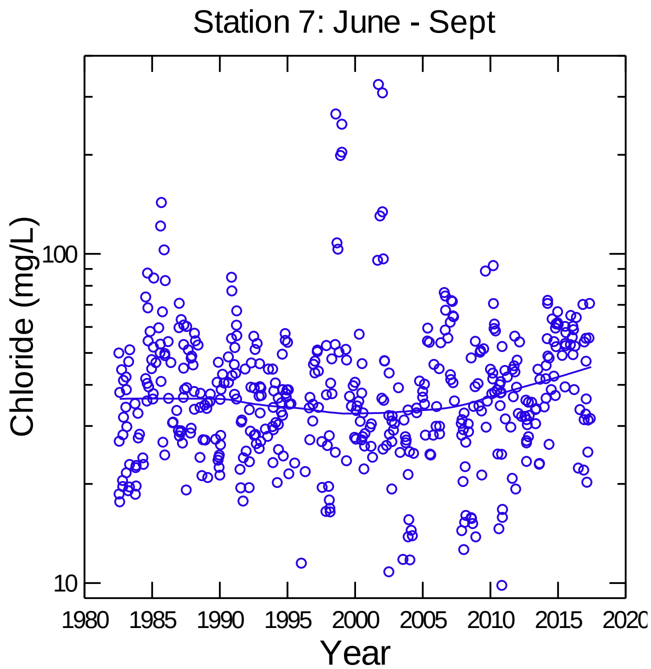
Specific conductance was generally in the range 200-500 µS/cm over the study period (Figure 74). Some significantly higher readings have been observed sporadically. A slight increase in specific conductance was suggested by the LOWESS line over the study period. This was confirmed by linear regression analysis which found a significant linear increase of 2.0 µS/cm per year over the long term study period (Table 16). This would yield a total increase of 70 uS/cm over the entire study period.

Figure 74. Long term trend in Specific Conductance (GMU Field Data). Station 7. Gunston Cove.



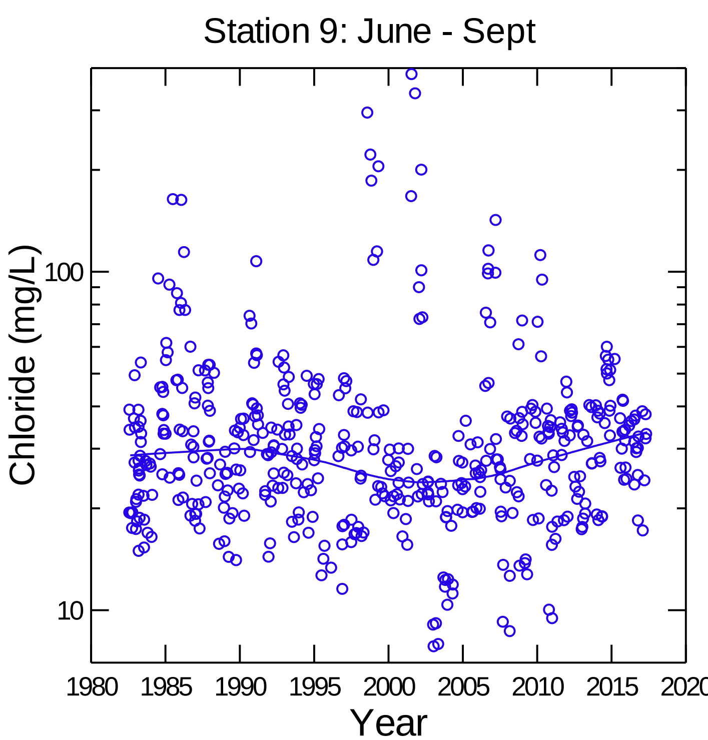
Conductivity values in the river were in the same general range as in the cove (Figure 75). Most values were between 200 and 500 µS/cm with a few much higher values. These higher values are probably attributable to intrusions of brackish water from downstream during years of low river flow. Linear regression did not reveal a significant trend in river conductivity (Table 16). However, the trend line has moved up in recent years from about 300 µS/cm to about 350 µS/cm.

Figure 75. Long term trend in Specific Conductance (GMU Field Data). Station 9. River mainstem.



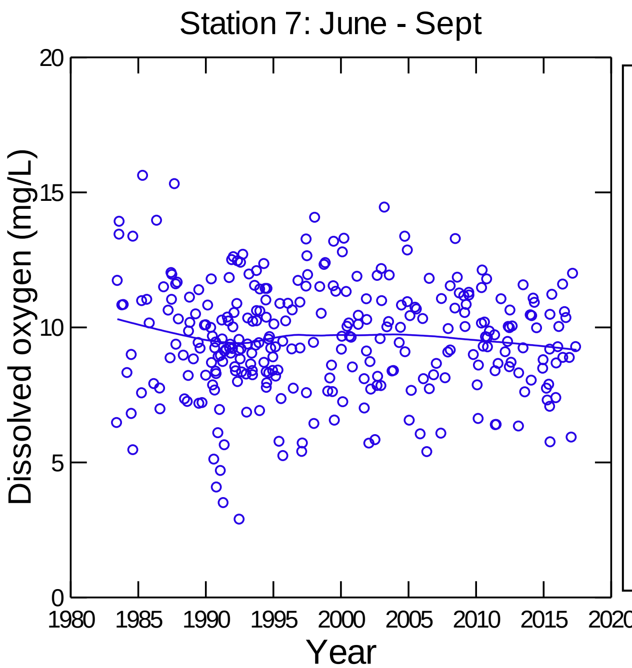
Chloride levels were clustered in a relatively narrow range of 20-60 mg/L for the entire study period (Figure 76). Higher values observed in some years were probably due to the estuarine water intrusions that occur in dry years. The trend line is nearly flat and a linear regression was not statistically significant (Table 17).

Figure 76. Long term trend in Chloride (Fairfax County Lab Data). Station 7. Gunston Cove.



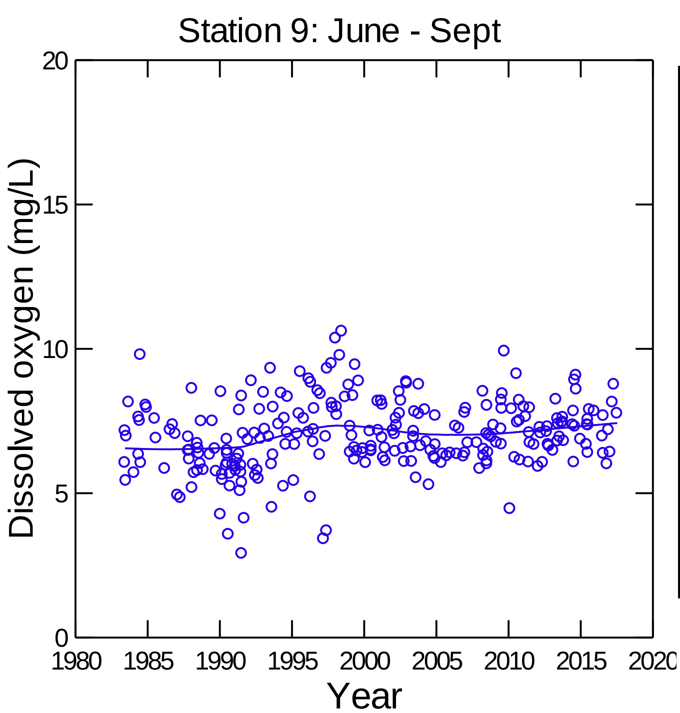
Chloride in the river has been slightly more variable than that in the cove, but in the same general range (Figure 77). The higher readings are again due to brackish water intrusions in dry years. A slight trend of increasing values in the 1980’s followed by decreases in the 1990’s and increases since 2005 was suggested by the LOWESS trend line. However, temporal linear regression analysis was not statistically significant (Table 17).

Figure 77. Long term trend in Chloride (Fairfax County Lab Data). Station 9. River mainstem.



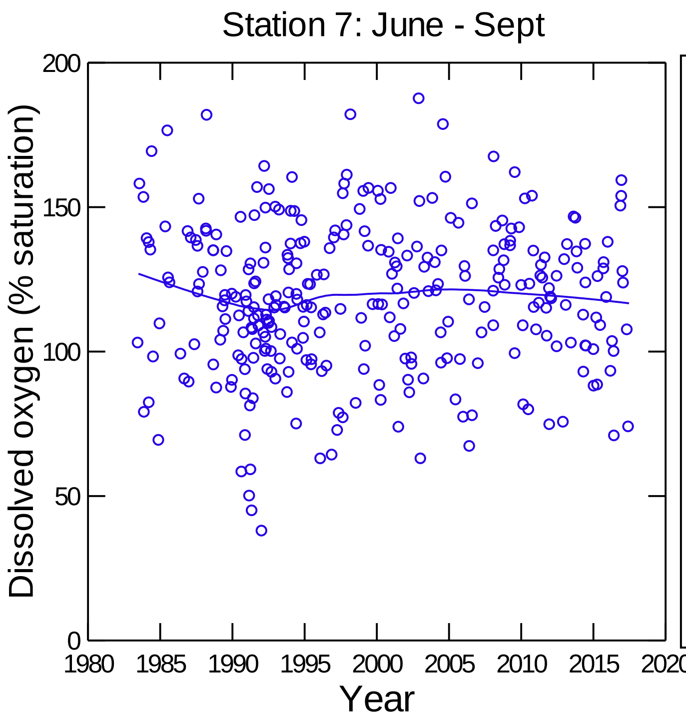
Dissolved oxygen in the cove has generally been in the range 7-13 mg/L during the summer months (Figure 78). A slight downward trend was observed through 1990, but since then the trend line has flattened, suggesting little consistent change and a mean of about 10 mg/L. In the cove dissolved oxygen (mg/L) did not exhibit a significant linear trend over the long term study period (Table 16).

Figure 78. Long term trend in Dissolved Oxygen, mg/L (GMU Data). Station 7. Gunston Cove.



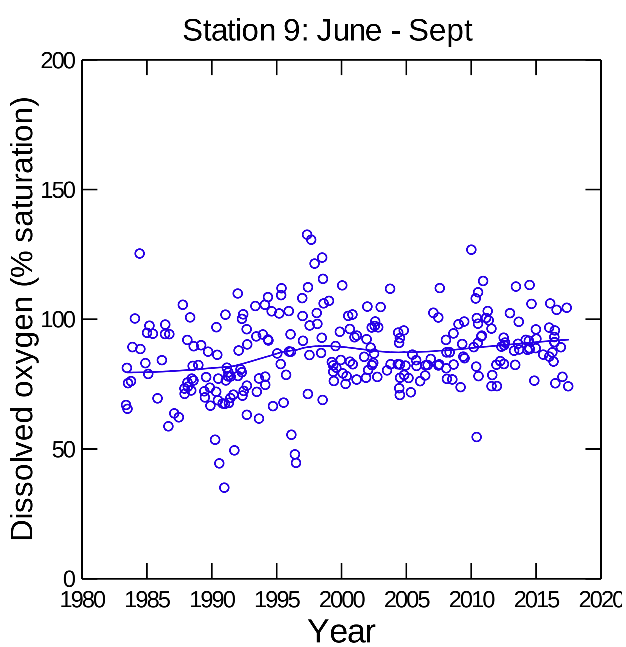
In the river dissolved oxygen values generally were in the range 5-9 mg/L over the long term study period (Figure 79). The LOWESS trend line some subtle changes from year to year, but little consistent pattern. The linear regression analysis over the entire period indicated a significant positive trend with slope of 0.02 mg/L per year or 0.6 mg/L over the period of record (Table 16).

Figure 79. Long term trend in Dissolved Oxygen, mg/L (GMU Data). Station 9. River mainstem.



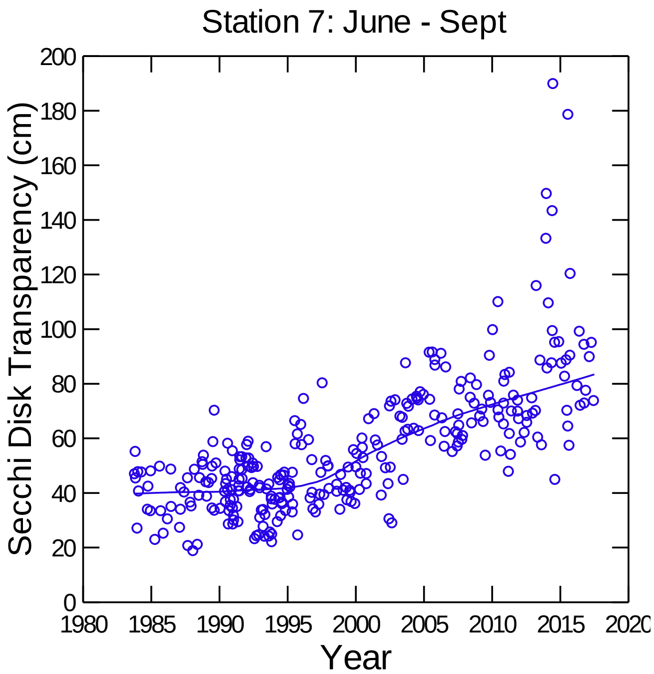
Dissolved oxygen was generally in the range 100-150% saturation in the cove over the long term study period indicating the importance of photosynthesis in the cove (Figure 80). A decline was indicated by the trend line through 1990 followed by a slight recovery in subsequent years. Percent saturation DO did not exhibit a significant linear trend over the long term study period (Table 16). 2016 values fell around the trend line.

Figure 80. Long term trend in Dissolved Oxygen, % saturation (GMU Data). Station 7. Gunston Cove.



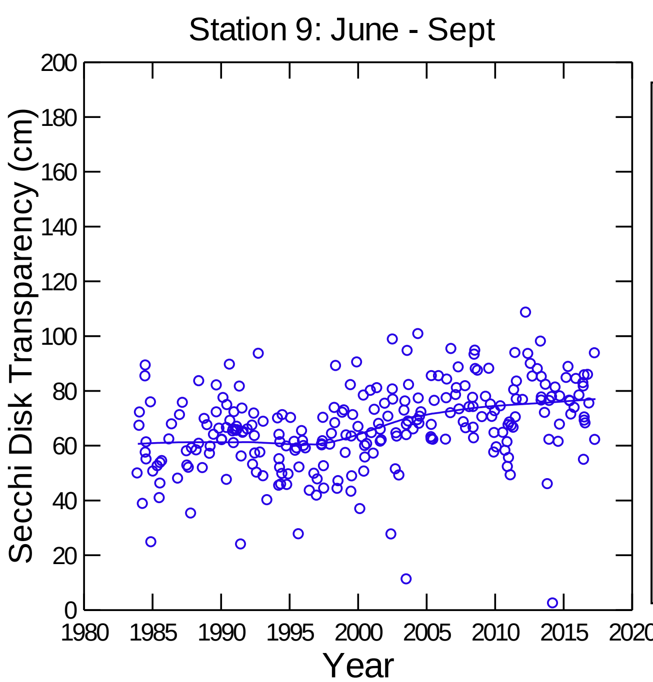
In the river dissolved oxygen was generally less than 100% indicating that photosynthesis was much less important in the river than in the cove and that respiration dominated (Figure 81). The trend line showed a very gradual increase which was statistically significant as indicated by regression analysis with a slope of 0.2% per year or about 6% over the course of the study (Table 16). 2016 readings were near the long term trend line. Despite this increase river DO was still below cove DO in general.

Figure 81. Long term trend in Dissolved Oxygen, % saturation (GMU Data). Station 9. Gunston Cove.



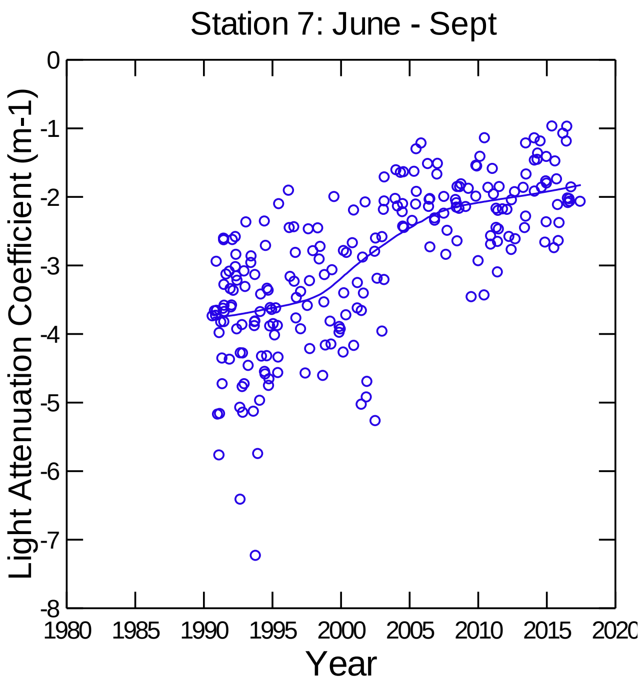
Secchi disk transparency is a measure of water clarity. Secchi disk was fairly constant from 1984 through 1995 with the trend line at about 40 cm (Figure 82). Since 1995 there has been a steady increase in the trend line from 40 cm to 85 cm in 2016. Linear regression was highly significant with a predicted increase of 1.8 cm per year or a total of nearly 60 cm over the study period (Table 16). In 2016 and 2017 most readings were above the trend line as in 2014 and 2015 which is forcing the trend line up.

Figure 82. Long term trend in Secchi Disk Transparency (GMU Data). Station 7. Gunston Cove.



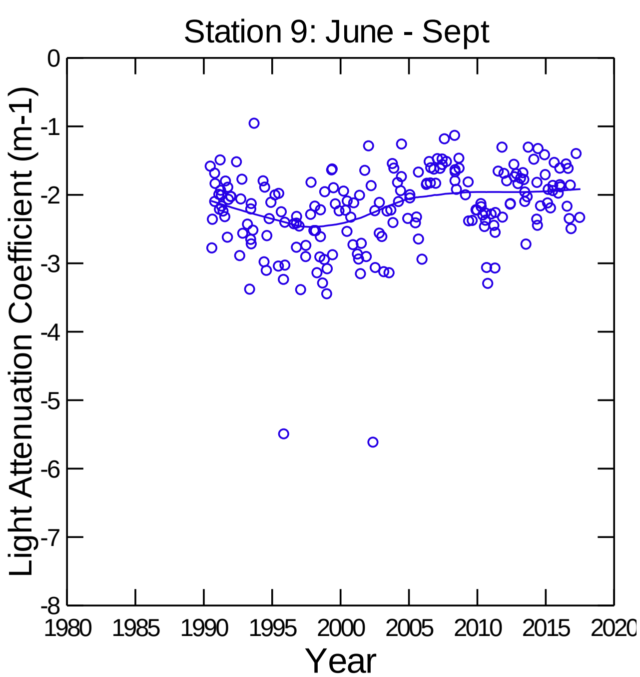
In the river Secchi depth was somewhat greater than in the cove in the 1980’s (Figure 83). The trend line was fairly constant at about 60 cm until about 2000. A rise to about 75 cm was observed by 2005 where it has remained. Linear regression revealed a significant increase of 0.6 cm per year with total increase of 20 cm predicted over of the study period (Table 16).

Figure 83. Long term trend in Secchi Disk Transparency (GMU Data). Station 9. River mainstem.



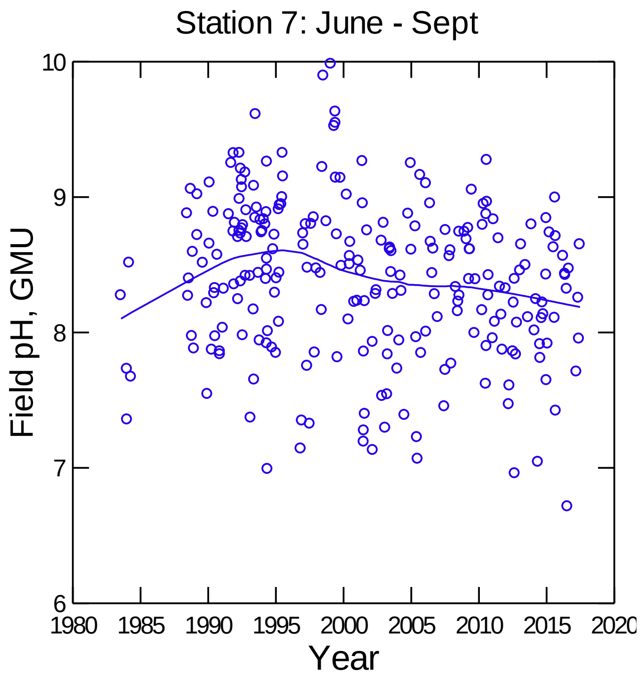
Light attenuation coefficient, another measure of water clarity, reinforces the conclusion that water clarity has been improving in the cove since 1995 (Figure 84). Trend line for the coefficient rose from about -4 to -2 m^{-1} during this time. And values for 2015 and 2016 were generally above -2. Consistent with this was the regression analysis which revealed a significant linear increase in light attenuation coefficient over the period 1991-2016 with a slope of 0.1 per year yielding a prediction that light attenuation improved by about 2.3 units over this period (Table 16).

Figure 84. Long term trend in Light Attenuation Coefficient (GMU Data). Station 7. Gunston Cove.



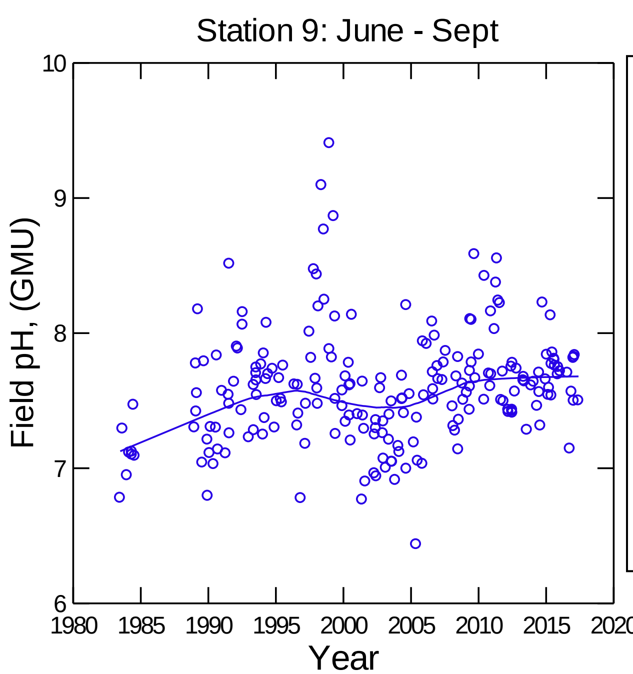
In the river light attenuation coefficient suggested a decline in light transparency between 1991 and 1997 followed by an increase through about 2008 (Figure 85). Between 2008 and 2016 the trend line indicates that light transparency has held fairly constant. Regression indicated a weak, but significant linear trend over the entire period (Table 16). The regression coefficient was 0.02 yielding a change of 0.6 units over the period, much less than found at Station 7.

Figure 85. Long term trend in Light Attenuation Coefficient (GMU Data). Station 9. River mainstem.



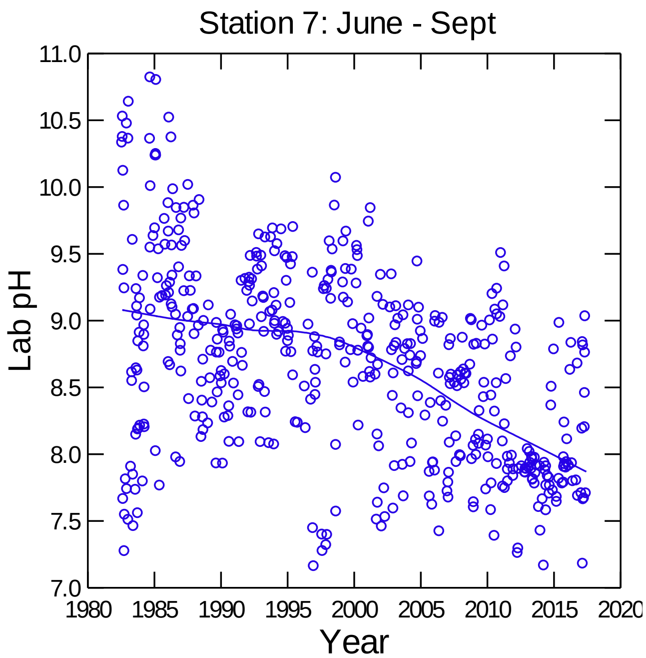
Field pH has not been measured as consistently over the entire study period as other parameters. Cove values have generally been in the 8-9 range. There is a clear trend of decreasing values since 1995 (Figure 86). Linear regression analysis now gives some evidence of a declining linear trend with a slope of -0.012 units per year when the entire study period was considered (Table 16).

Figure 86. Long term trend in Field pH (GMU Data). Station 7. Gunston Cove.



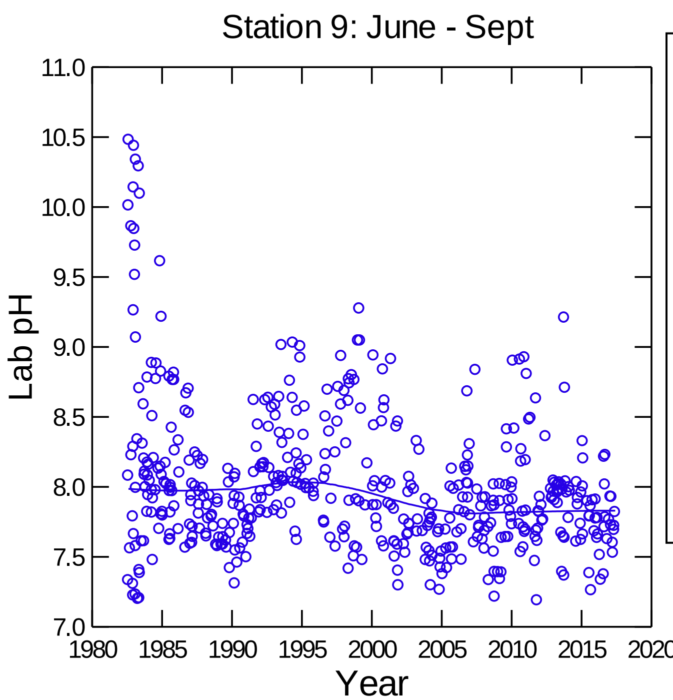
In the river a different pattern has been observed over this period (Figure 87). pH in the river has been consistently lower by about 1 pH unit than in the cove. If anything the trend line has shown a tendency to increase. When all years were considered, field pH in the river shows a significant increase at a rate of 0.01 units per year (Table 16).

Figure 87. Long term trend in Field pH (GMU Data). Station 9. River mainstem.



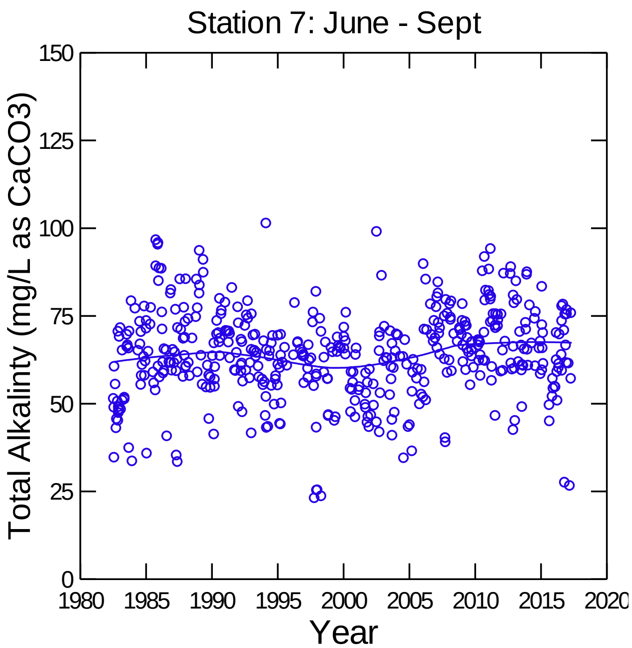
Lab pH as measured by Fairfax County personnel was generally in the range 8 to 10 over most of the long term study period (Figure 88). Since about 1997 a decline is very evident with the trend line decreasing from about 9.1 to about 7.8. Linear regression indicates a significant decline in lab pH over the study period at a rate of about 0.03 pH units per year or a total of 1.0 units over the study period (Table 17). 2017 data were above the trend line.

Figure 88. Long term trend in Lab pH (Fairfax County Lab Data). Station 7. Gunston Cove.



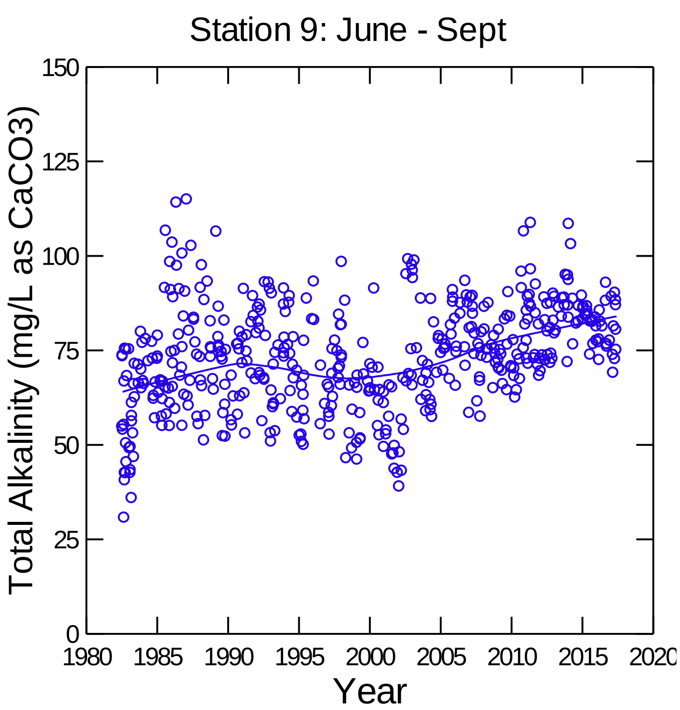
In the river, long term pH trends as measured by Fairfax County lab personnel indicate that most values fell between 7 and 8.5 (Figure 89). The trend line has increased and decreased slightly over the years. pH in the river showed a significant linear decline with a rate of 0.013 per year yielding a total decline of 0.43 units over the long term study period (Table 17).

Figure 89. Long term trend in Lab pH (Fairfax County Lab Data). Station 9. Potomac mainstem.



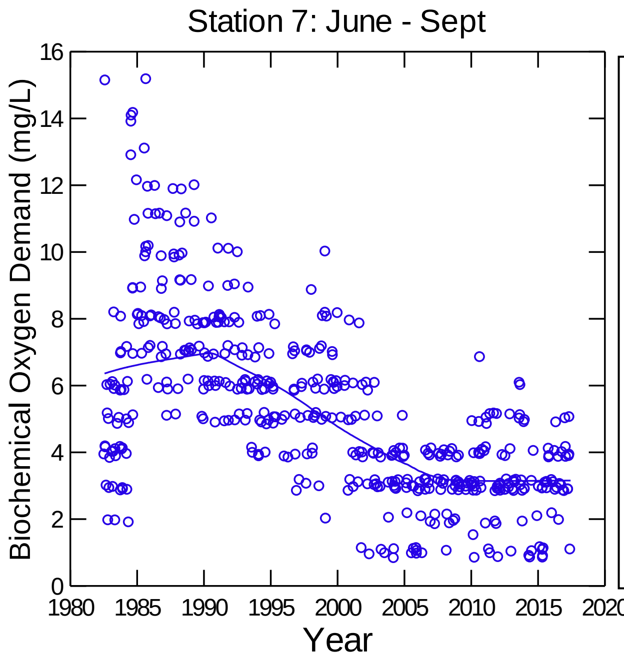
Total alkalinity as measured by Fairfax County personnel exhibited little variation early on and a slow increase since 2000 (Figure 90). The trend line at 2017 was slightly higher than it was in 1983. Overall, a very weak statistically significant linear trend has developed in total alkalinity in the cove over this period with a slope of 0.11 mg/L per year yielding a projected increase of about 3.5 mg/L over the entire study period (Table 17).

Figure 90. Long term trend in Total Alkalinity (Fairfax County Lab Data). Station 7. Gunston Cove.



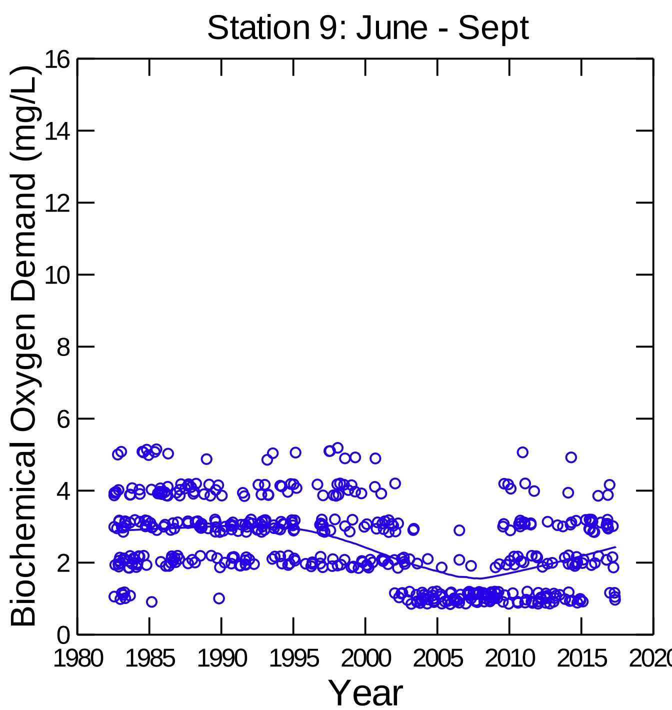
In the river a similar pattern has been observed over the three decades with an even clearer recent increase (Figure 91). There is a significant linear trend over the period with a slope of 0.41 mg/L suggesting a modest increase of about 13 mg/L over the entire study period (Table 17).

Figure 91. Long term trend in Total Alkalinity (Fairfax County Lab Data). Station 9. Potomac mainstem.



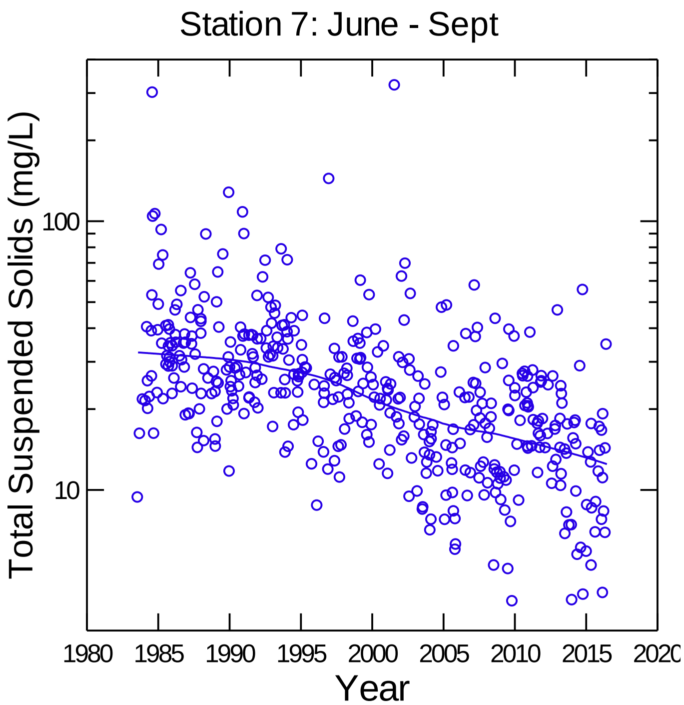
Biochemical oxygen demand has shown a distinct pattern over the long term study period in Gunston Cove (Figure 92). In the 1980's the trend line rose from about 6 mg/L to 7 mg/L by 1989. Since then there has been a steady decline such that the trend line has dropped back to about 3 mg/L. BOD has shown a significant linear decline over the entire study period at a rate of 0.16 mg/L per year yielding a net decline of about 5.4 mg/L over the entire period of record (Table 17).

Figure 92. Long term trend in Biochemical Oxygen Demand (Fairfax County Lab Data). Station 7. Gunston Cove.



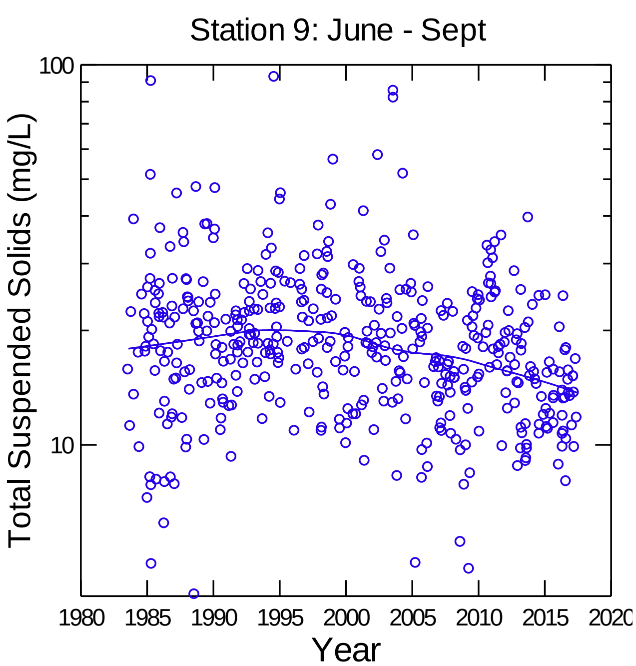
In the river biochemical oxygen demand exhibited a less distinct pattern through the mid 1990's (Figure 93). However, since that time it has decreased somewhat to a trend line value of about 1.0 mg/L. BOD in the river has exhibited a significant linear decrease at a rate of 0.046 units when the entire period of record was considered (Table 17). This would project to an overall decrease of 1.5 units. Many values are not detects of less than 2 mg/L.

Figure 93. Long term trend in Biochemical Oxygen Demand (Fairfax County Lab Data). Station 9. Potomac mainstem.



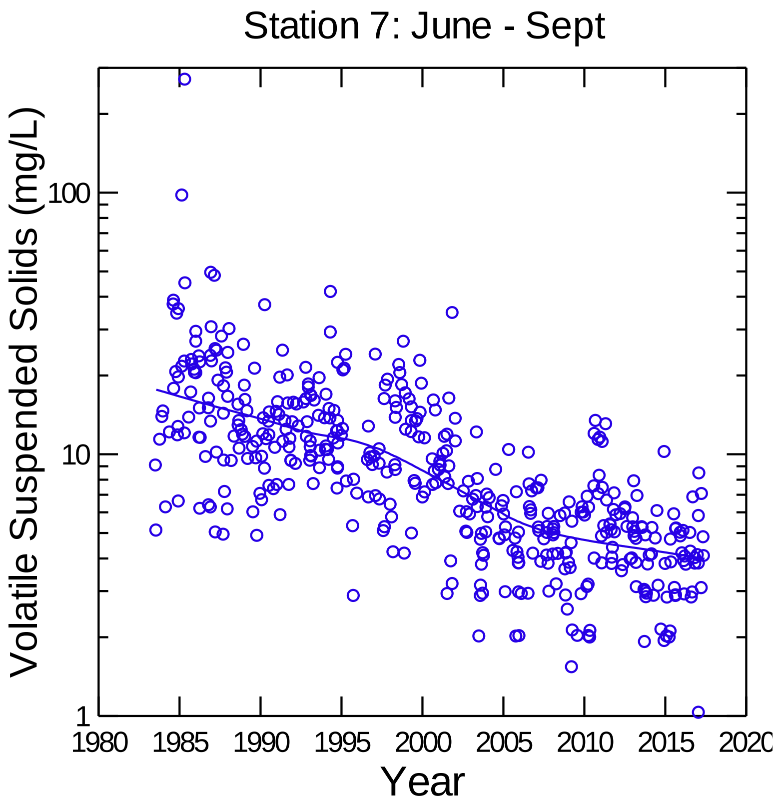
Total suspended solids (TSS) has shown a great deal of variability over the long term study period. Nonetheless, a decreasing trend in TSS is clear in the cove with the trend line decreasing from about 32 mg/L in 1983 to about 12 mg/L in 2017 (Figure 94). Linear regression was significant indicating a decline of 0.92 mg/L per year yielding a total decline of 29.5 mg/L since 1984 (Table 17).

Figure 94. Long term trend in Total Suspended Solids (Fairfax County Lab Data). Station 7. Gunston Cove.



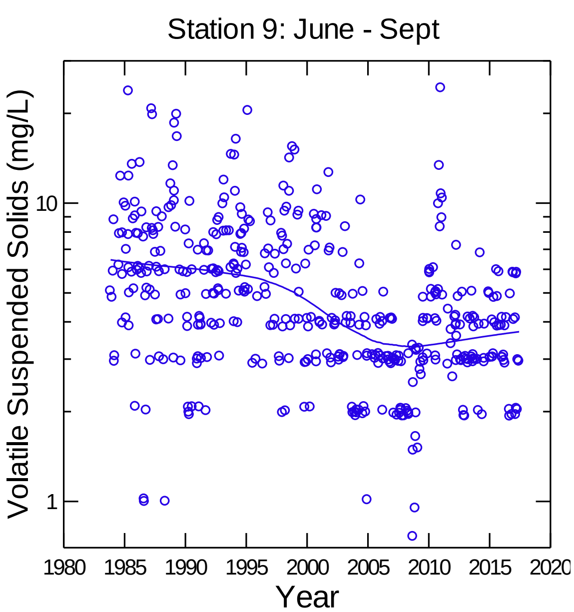
In the river TSS trends have not been as apparent (Figure 95). While much higher values have been observed sporadically, the LOWESS line remained steady at about 18-20 mg/L through most of the period with a slight decrease to about 15 mg/L suggested recently. In the river TSS exhibited a significant linear decline over the period of record at a rate of about 0.19 units per year yielding a total decline of about 5.4 mg/L over the entire study period (Table 17).

Figure 95. Long term trend in Total Suspended Solids (Fairfax County Lab Data). Station 9. Potomac mainstem.



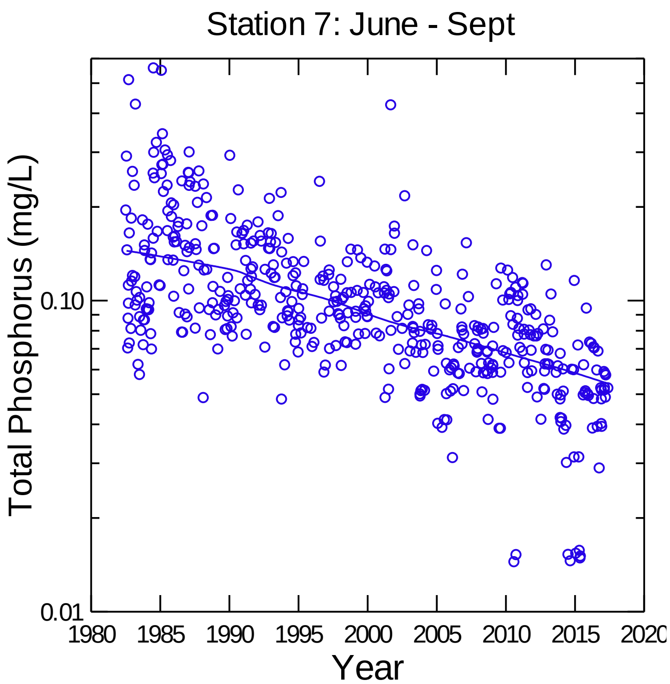
Volatile suspended solids have consistently declined over the study period in the cove (Figure 96). The LOWESS trend line has declined from 20 mg/L in 1984 to about 4 mg/L in 2017. VSS has demonstrated a significant linear decline at a rate of 0.6 mg/L per year or a total of 20 mg/L over the study period (Table 17).

Figure 96. Long term trend in Volatile Suspended Solids (Fairfax County Lab Data). Station 7. Gunston Cove.



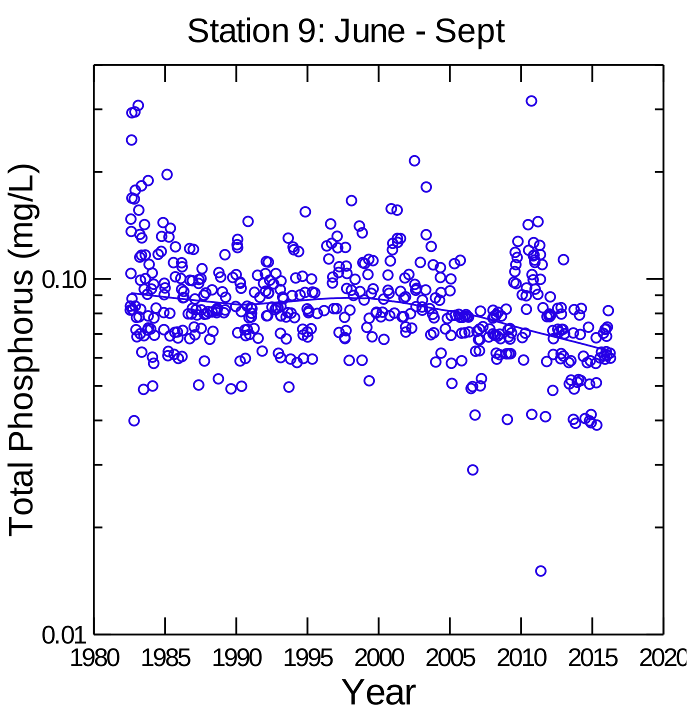
In the river the trend line for volatile suspended solids (VSS) was steady from 1984 through the mid 1990's, but decreased from 1995 to 2005. Trend line values of about 7 mg/L in 1984 dropped to about 4 mg/L by 2016 (Figure 97). VSS in the river demonstrated a significant linear decline at a rate of 0.13 mg/L per year or 4.2 mg/L since 1984 (Table 17).

Figure 97. Long term trend in Volatile Suspended Solids (Fairfax County Lab Data). Station 9. Potomac mainstem.



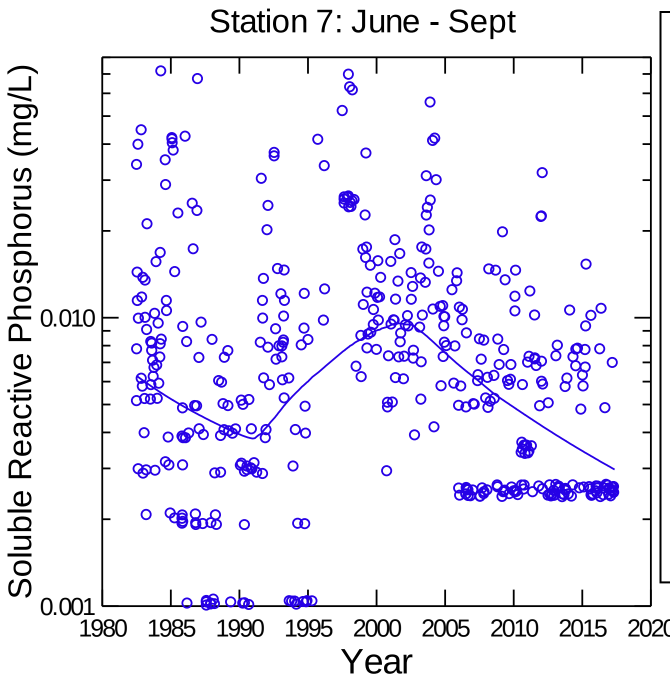
In the cove, total phosphorus (TP) has undergone a consistent steady decline since the late 1980’s (Figure 98). By 2016 the trend line had dropped to 0.06 mg/L, more than half of the starting level. Linear regression over the entire period of record indicated a significant linear decline of -0.004 mg/L per year or 0.13 mg/L over the entire study period (Table 17).

Figure 98. Long term trend in Total Phosphorus (Fairfax County Lab Data). Station 7. Gunston Cove.



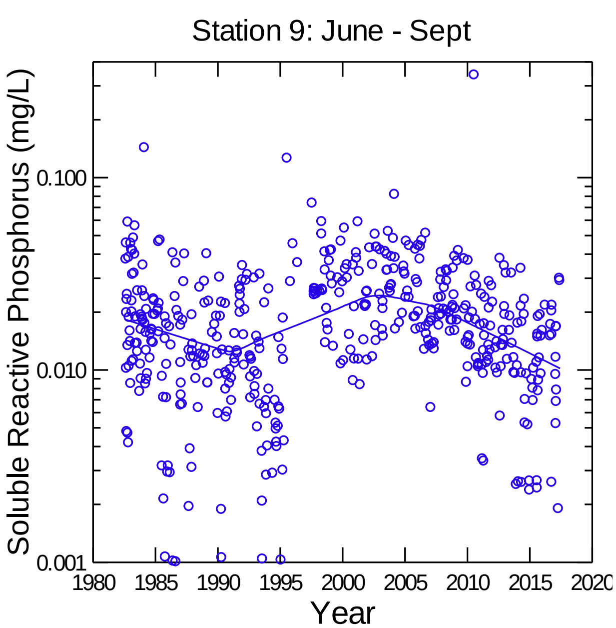
Total phosphorus (TP) values in the river have shown less of a trend over time (Figure 99). Values were steady through about 2000, then declined somewhat. TP exhibited a slight, but significant linear decrease in the river over the long term study period with a very modest slope of -0.001 mg/L per year (Table 17).

Figure 99. Long term trend in Total Phosphorus (Fairfax County Lab Data). Station 9. Potomac mainstem.



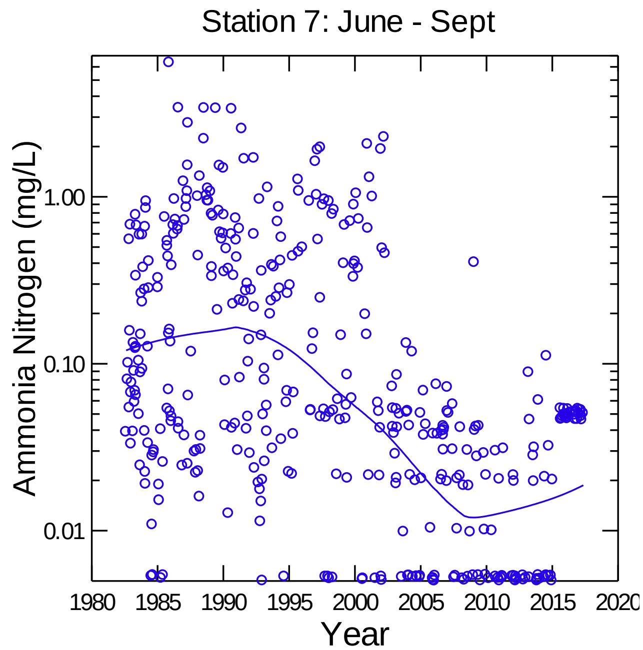
Soluble reactive phosphorus (SRP) declined in the cove during the first few years of the long term data set, but demonstrated an increase to near its initial level by 2000 (Figure 100). Since then a decline has ensued. (Table 17). One possibility is that less SRP is entering the cove water; another is 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 100. Long term trend in Soluble Reactive Phosphorus (Fairfax County Lab Data). Station 7. Gunston Cove.



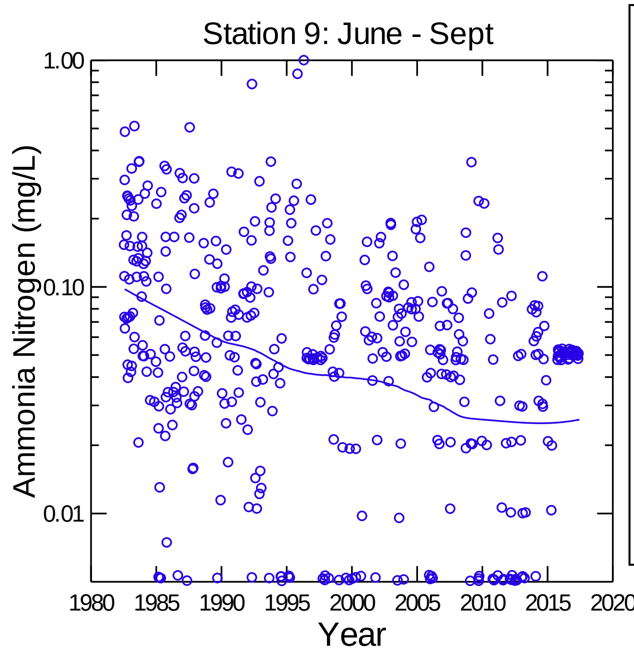
Soluble reactive phosphorus (SRP) in the river has generally been present at higher levels than in the cove, but has undergone a similar decline-resurgence-decline (Figure 101). Linear regression was not significant (Table 17). There were a significant number of non-detect values, but fewer than in the cove.

Figure 101. Long term trend in Soluble Reactive Phosphorus (Fairfax County Lab Data). Station 9. Potomac mainstem.



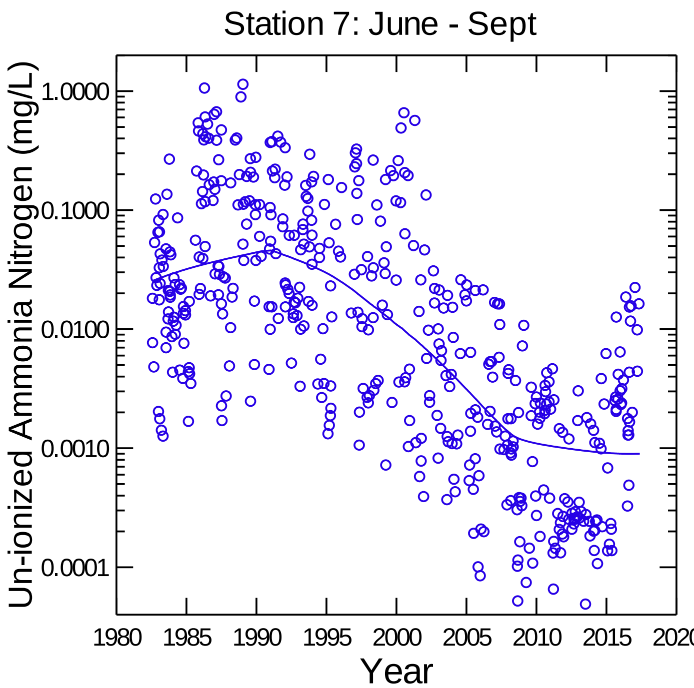
Ammonia nitrogen levels were very variable over the long term study period in the cove, but a trend of decreasing values is evident from the LOWESS trend line (Figure 102). Since 1989 the trend line has decreased from about 0.2 mg/L to about 0.02 mg/L. Linear regression has revealed a significant decline over the entire period of record with a rate of 0.017 mg/L per year yielding a total decline of 0.58 mg/L (Table 17). Note the increase in values below the detection limit over time (clustered at bottom of graph). This is making the detection of trends increasingly uncertain.

Figure 102. Long term trend in Ammonia Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



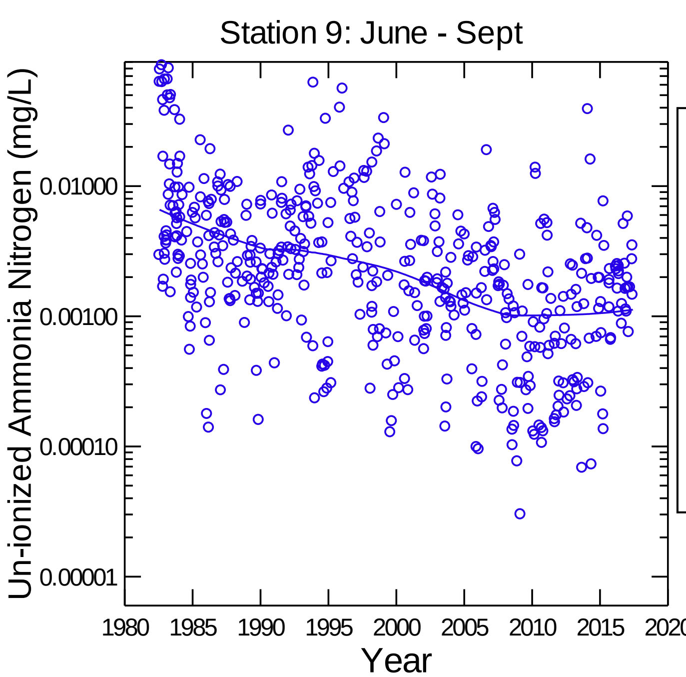
In the river a decreasing trend in ammonia nitrogen has also been observed over most of the study period (Figure 103). Between 1983 and 1999 the trend line dropped from 0.1 mg/L to 0.04 mg/L. Since 1999 it has continued to decline and is now at about 0.02 mg/L. Overall, in the river ammonia nitrogen has demonstrated a significant decline over the study period at a rate of 0.003 mg/L per year or a total of 0.09 over the study period (Table 17). Again, the number of non-detects is increasing.

Figure 103. Long term trend in Ammonia Nitrogen (Fairfax County Lab Data). Station 9. Potomac mainstem.



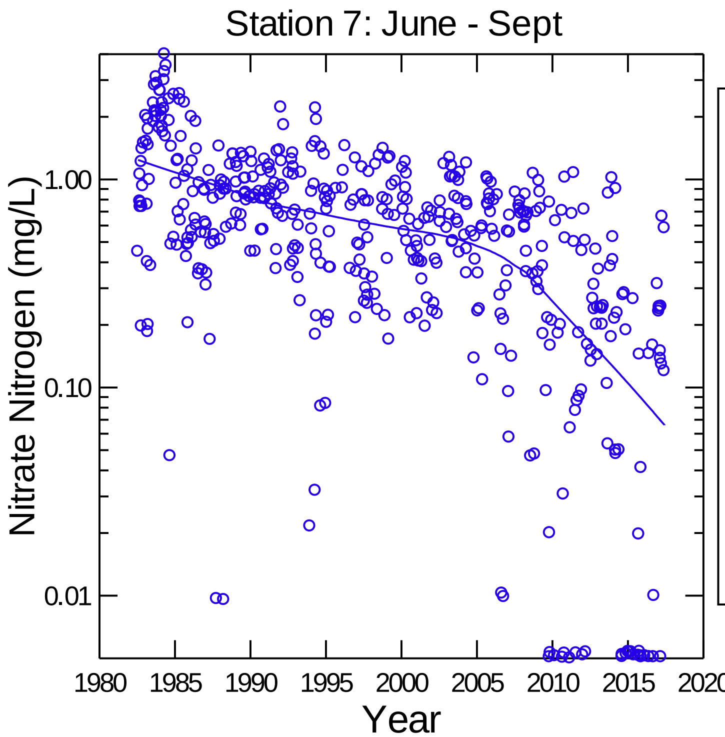
Un-ionized ammonia nitrogen in the cove demonstrated a clear increase in the 1980's with a continuous decline since that time (Figure 104). The LOWESS trend peaked at about 0.05 mg/L and is now about 0.0005 mg/L. When considered over the entire time period, there was a significant decline at a rate of 0.004 mg/L per year or a total of 0.15 mg/L over the 33 years (Table 17). Note that these values are dependent on ammonia nitrogen which has been showing increasing incidence of non-detects.

Figure 104. Long term trend in Un-ionized Ammonia Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



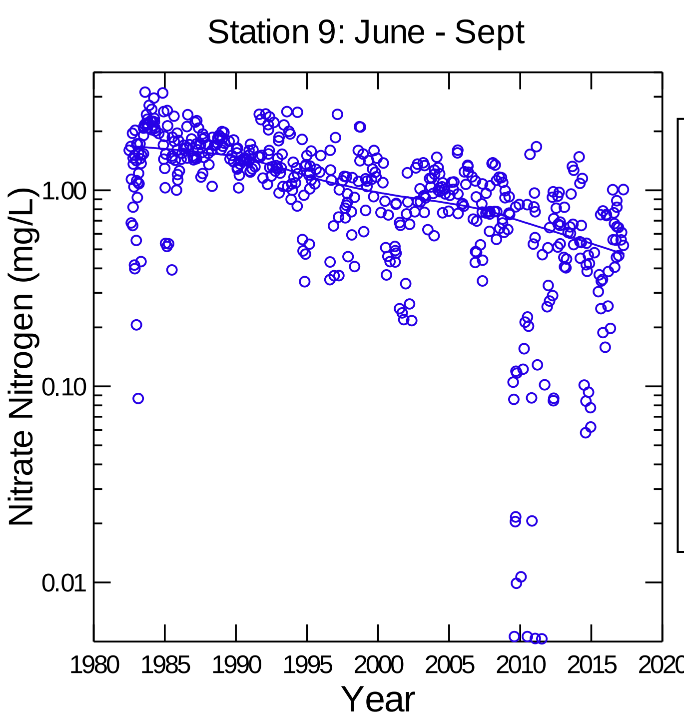
Un-ionized ammonia nitrogen in the river declined fairly consistently over the entire study period (Figure 105). LOWESS values have dropped from about 0.007 mg/L to about 0.0009 mg/L. Linear regression analysis over the entire period of record suggested a significant decline at a rate of 0.0003 units per year (Table 17).

Figure 105. Long term trend in Un-ionized Ammonia Nitrogen (Fairfax County Lab Data). Station 9. Potomac mainstem.



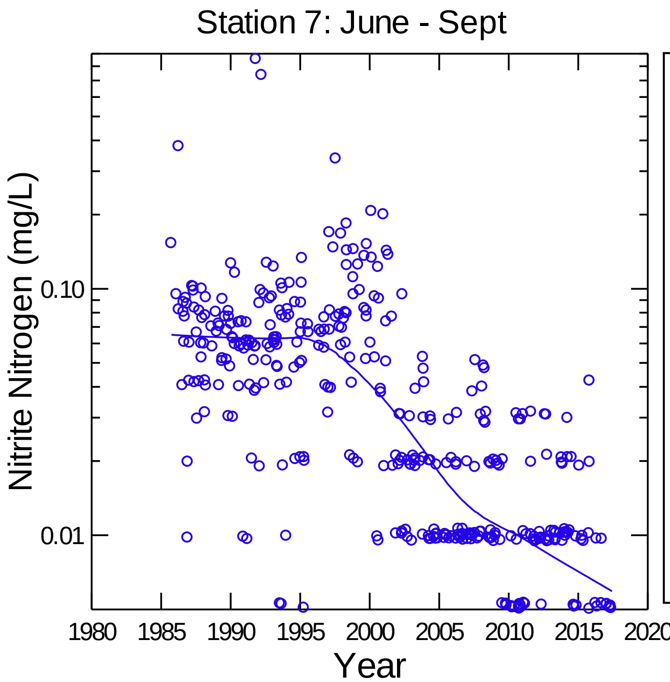
Nitrate nitrogen has demonstrated a steady decline in the cove over the entire period of record (Figure 106). The trend line was at about 1 mg/L in 1983 and by 2017 was below 0.05 mg/L. Linear regression suggested a decline rate of 0.035 mg/L per year yielding a total decline of 1.1 mg/L over the long term study period (Table 17). Note the large number of non-detect values in recent years.

Figure 106. Long term trend in Nitrate Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



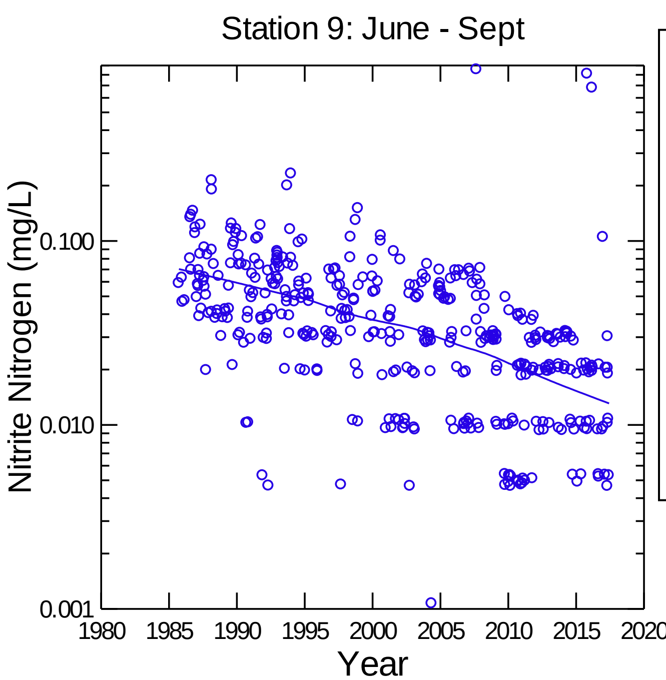
In the river nitrate nitrogen has declined steadily since about 1985 (Figure 107). The trend line dropped from 1.5 mg/L in the mid 1980’s to 0.4 mg/L in 2017. Linear regression indicated a rate of decline of -0.04 mg/L per yr which would have yielded a 1.3 mg/L decrease in nitrate nitrogen over the study period (Table 17).

Figure 107. Long term trend in Nitrate Nitrogen (Fairfax County Lab Data). Station 9. River mainstem.



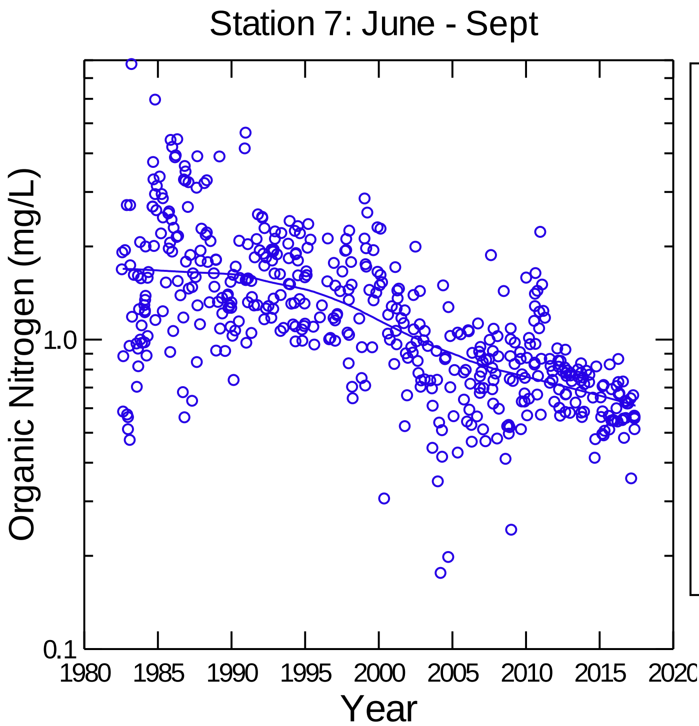
The trend line for nitrite nitrogen indicated steady values at about 0.06-0.07 mg/L through 1999 (Figure 108). Since then there is clear evidence for a decline with the LOWESS line dropping below 0.01 in 2017. Linear regression revealed a significant decline with a slope of 0.003 mg/L per year when the entire period of record was considered (Table 17). Most values in recent years have been at or below the detection limits.

Figure 108. Long term trend in Nitrite Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



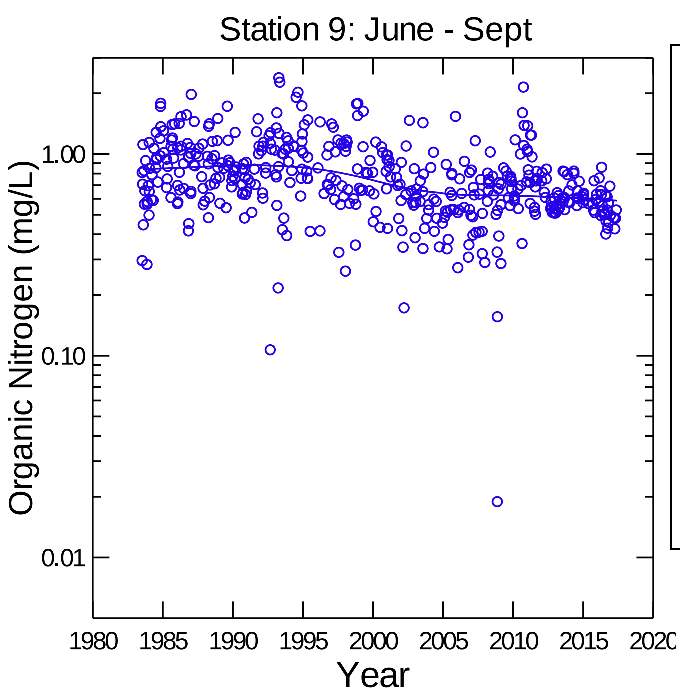
Nitrite nitrogen in the river demonstrated a pattern of decrease during the long term study period (Figure 109). The LOWESS line dropped from 0.07 mg/L in 1986 to less than 0.02 mg/L in 2017. Linear regression indicated a significant linear decline at a rate of 0.001 mg/L per year or 0.03 mg/L over the study period (Table 17).

Figure 109. Long term trend in Nitrite Nitrogen (Fairfax County Lab Data). Station 9. Potomac mainstem.



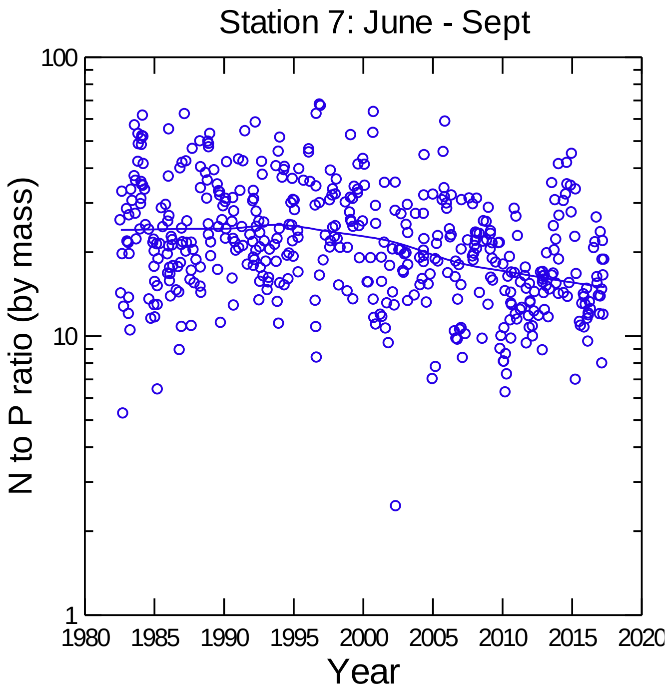
Organic nitrogen in the cove was fairly high in the 1980's and has since undergone a consistent decline through 2017 (Figure 110). In 1983 the trend line was at 1.5 mg/L and dropped below 0.7 mg/L by 2017. Regression analysis indicated a significant decline over the study period at a rate of about 0.047 mg/L per year or a total of 1.5 mg/L over the whole study period (Table 17).

Figure 110. Long term trend in Organic Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



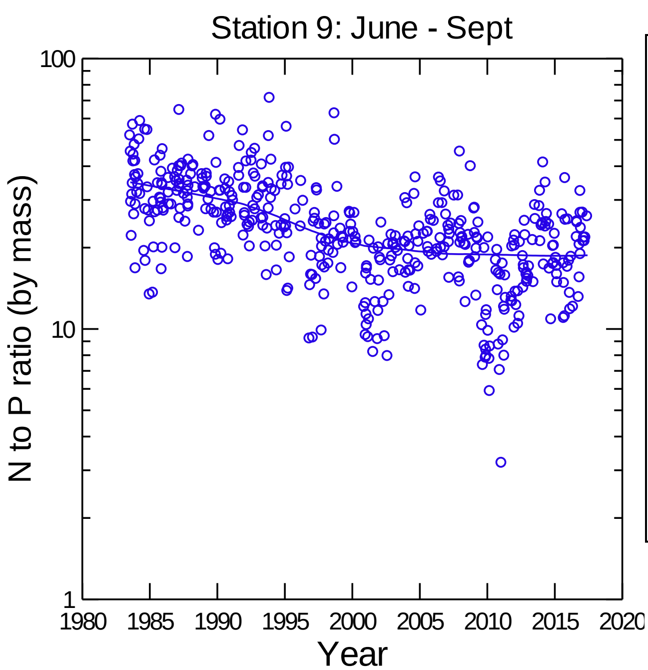
In the river organic nitrogen was steady from 1984 through 1995 and since then has shown perhaps a modest decline (Figure 111). The LOWESS line peaked at about 0.9 mg/L and has dropped to about 0.7 mg/L. Regression analysis indicated a significant linear decline at a rate of 0.01 mg/L when the entire period of record was considered for a total decline of 0.3 mg/L (Table 17).

Figure 111. 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 15 by 2017 (Figure 112). Regression analysis over the period of record indicates a statistically significant decline at a rate of 0.35 per year or about 11 units over the entire period (Table 17). This ratio is calculated using nitrate, TKN, and TP values and are less accurate when any of those are below detection limits.

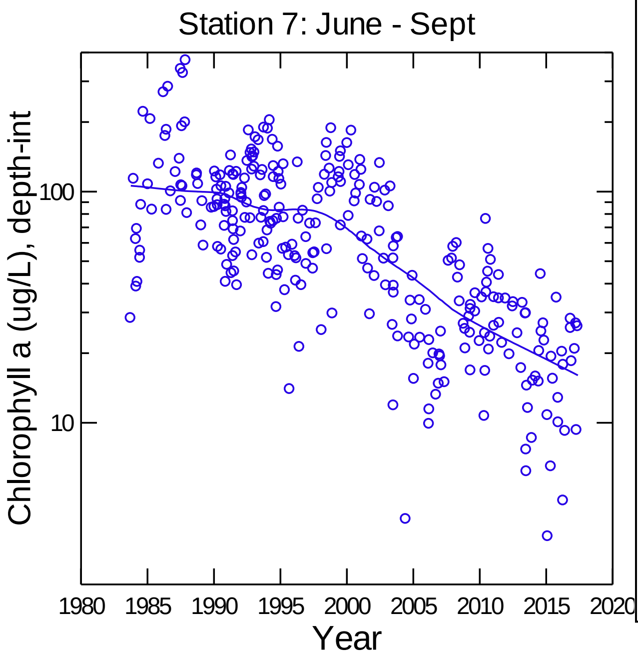
Figure 112. Long term trend in N to P Ratio (Fairfax County Lab Data). Station 7. Gunston Cove.



Nitrogen to phosphorus ratio in the river exhibited a strong continuous decline through about 2000 and has declined more slowly since then (Figure 113). The LOWESS trend line declined from about 35 in 1984 to 20 in 2017. Linear regression analysis confirmed this decline and suggested a rate of 0.56 units per year or a total of 20 units over the long term study period (Table 17).

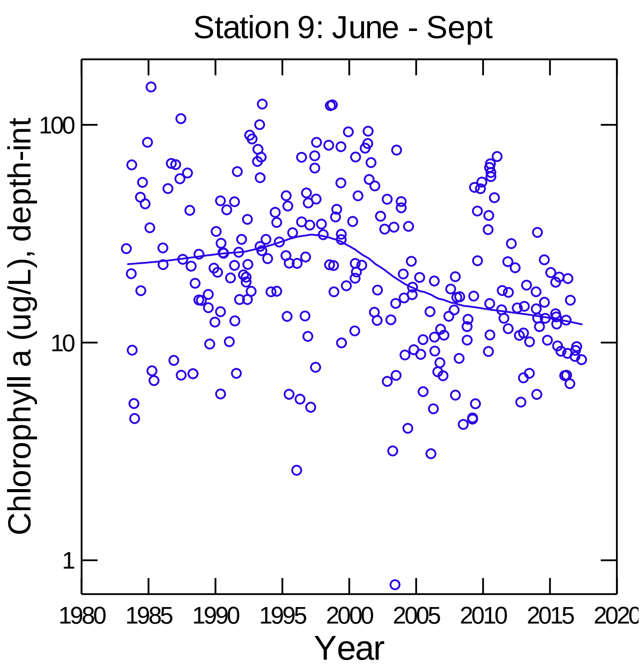
Figure 113. Long term trend in N to P Ratio (Fairfax County Lab Data). Station 9. River mainstem.

C. Phytoplankton Trends: 1984-2017



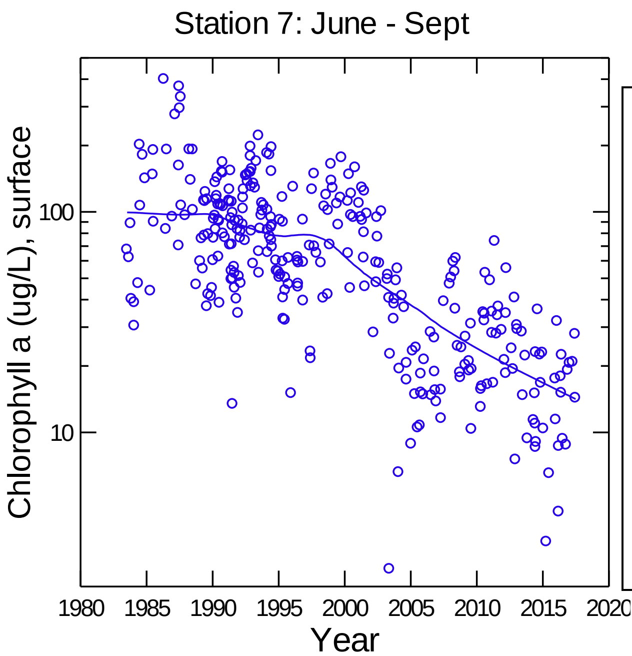
After increasing through much of the 1980's, depth-integrated chlorophyll *a* in the cove demonstrated a gradual decline from 1988 to 2000 and a much stronger decrease since then (Figure 114). The LOWESS line has declined from about 100 µg/L to less than 15 µg/L in 2017. The observed decrease has resulted 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 3.8 µg/L per year or 125 µg/L over the 32-year long term data set (Table 16).

Figure 114. Long term trend in Depth-integrated Chlorophyll *a* (GMU Lab Data). Station 7. Gunston Cove.



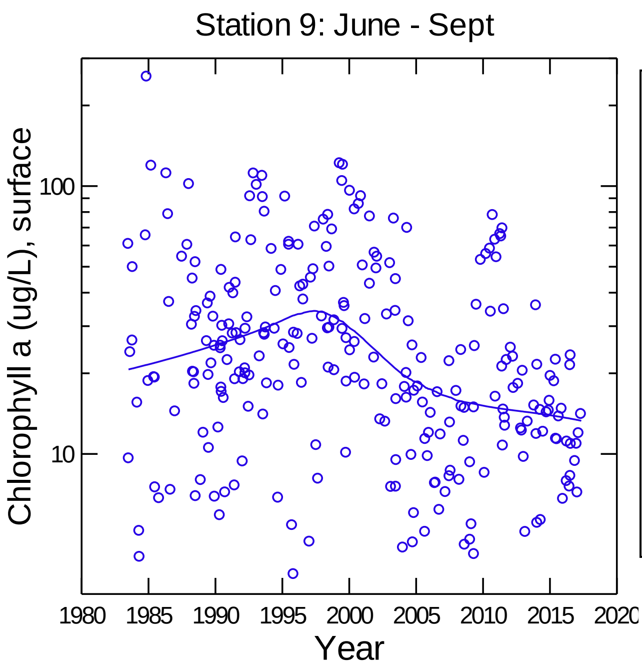
In the river depth-integrated chlorophyll *a* increased gradually through 2000 with the trend line rising from 20 to 30 µg/L (Figure 115). This was followed by a strong decline through about 2005 reaching about 18 µg/L with a further gradual decline to date. Regression analysis revealed a significant linear decline at a rate of 0.7 µg/L/yr when the entire period is considered (Table 16) yielding a total decline of about 22 ug/L.

Figure 115. Long term trend in Depth-integrated Chlorophyll *a* (GMU Lab Data). Station 9. River mainstem.



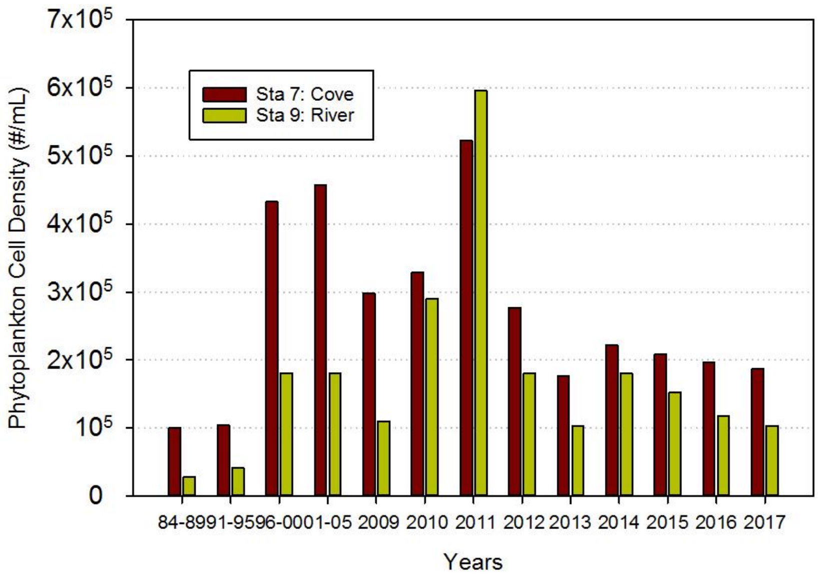
Surface chlorophyll *a* in the cove also exhibited a clear decline over the long term study period, especially since 2000 (Figure 116). Trend line values of about 100 µg/L in 1988 dropped to less than 15 µg/L in 2017. Linear regression confirmed the linear decline and suggested a rate of 3.9 µg/L per year or 128 µg/L over the entire study (Table 16).

Figure 116. Long term trend in Surface Chlorophyll *a* (GMU Data). Station 7. Gunston Cove.



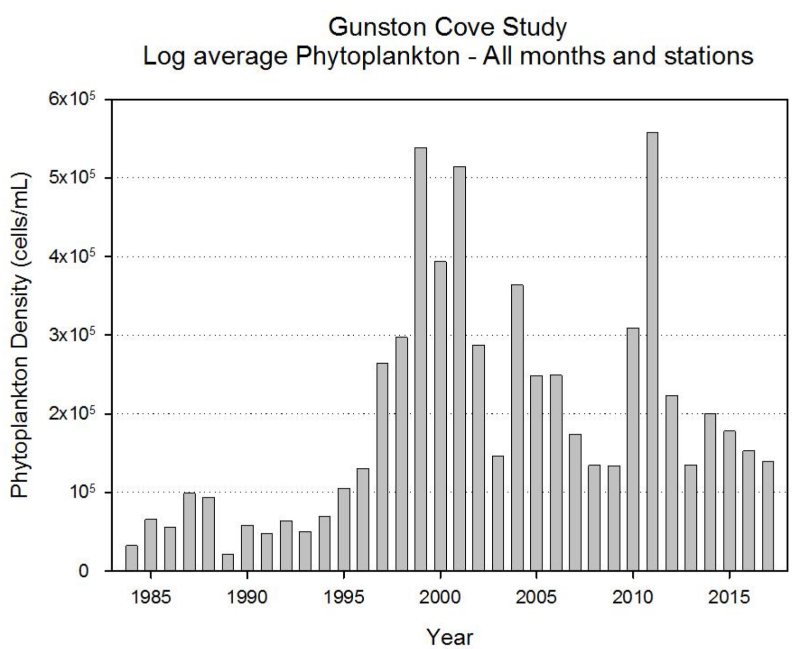
In the river the LOWESS line for surface chlorophyll *a* increased slowly from 1983 to 2000 and then declined markedly through 2005 (Figure 117). Values have stabilized since then at about 15 µg/L. Linear regression revealed a significant decline in surface chlorophyll across this period with a rate of 0.80 µg/L/yr or about 25 µg/L over the whole period (Table 16).

Figure 117. Long term trend in Surface Chlorophyll *a* (GMU Data). Station 9. River mainstem.



Phytoplankton cell density in both the cove and the river in 2017 was similar to values observed since 2012 (Figure 118). While cell density does not incorporate cell size, it does provide some measure of the abundance of phytoplankton and reflects the continuing decrease in phytoplankton in the study area which is expected with lower nutrient loading and should help improve water clarity.

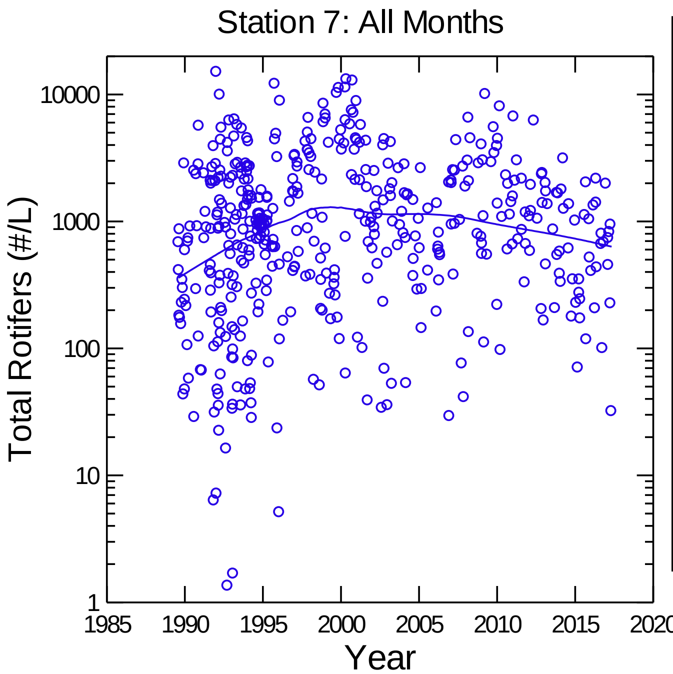
Figure 118. Interannual Comparison of Phytoplankton Density by Region.



By looking at individual years (Figure 119), we see that phytoplankton densities in 2017 remained lower than the high levels observed during the 1995 to 2005 period.

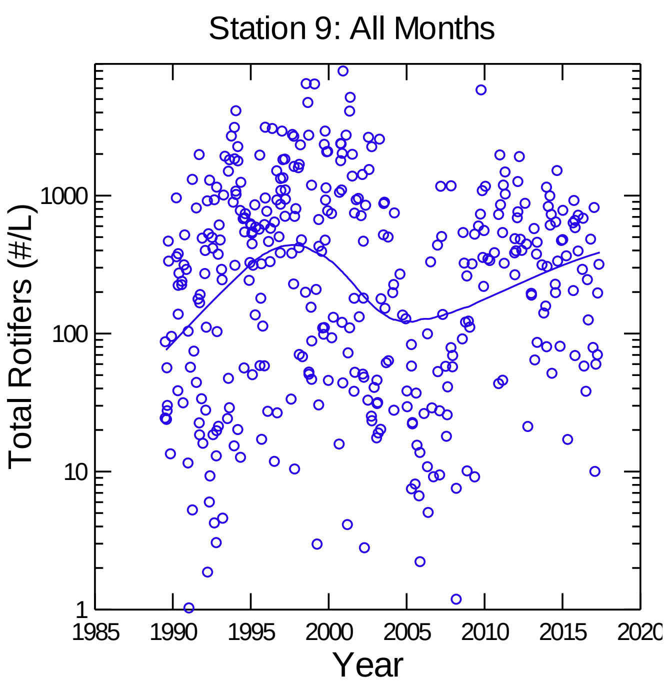
Figure 119. Interannual Trend in Average Phytoplankton Density.

D. Zooplankton Trends: 1990-2017



In the Cove total rotifers continued to exhibit a slow decline after an initial decade (1990-2000) of steady increase (Figure 120). The LOWESS fit line indicated about 800/L in 2013, 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 18).

Figure 120. Long term trend in Total Rotifers. Station 7. Gunston Cove.



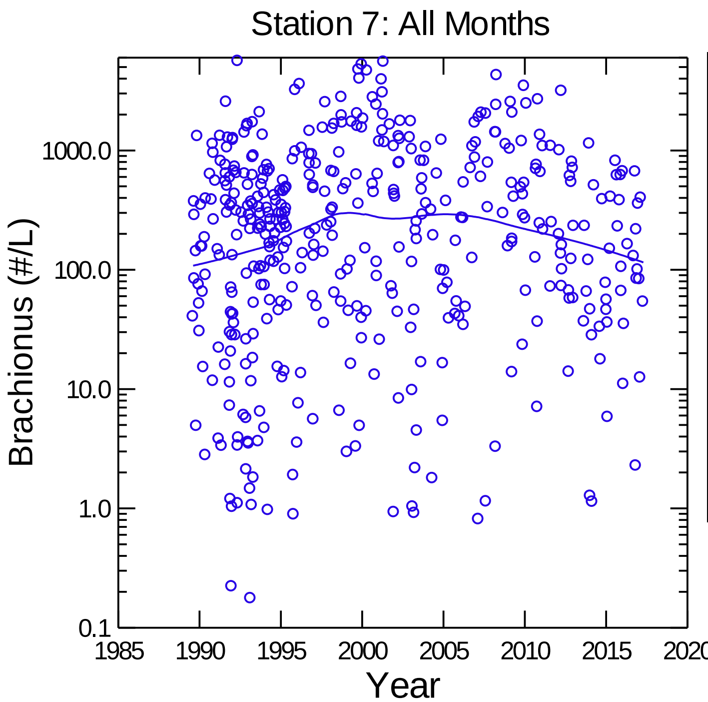
In the Potomac mainstem, rotifers exhibited an initial increase from 1990 to 1998, followed by a decline from 1999 to 2005 and more recently another increase (Figure 121). Trend line values in 1990 were about 80/L and now are about 500/L approaching 1998 values. However, when the entire 1990-2016 period was considered, total rotifers did not exhibit a significant linear trend in the river (Table 18).

Figure 121. Long term trend in Total Rotifers. Station 9. River mainstem.

Table 18
Correlation and Linear Regression Coefficients
Zooplankton Parameters vs. Year for 1990-2017
All Nonzero Values Used, All Values Logged to Base 10

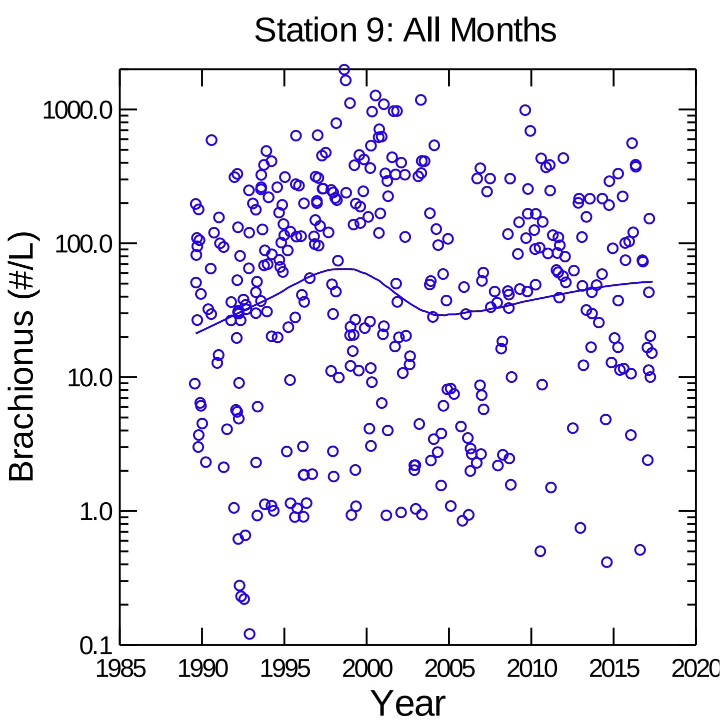
Parameter	Station 7 Corr. Coeff.	Station 7 Reg. Coeff.	Station 7 Signif.	Station 9 Corr. Coeff.	Station 9 Reg. Coeff.	Station 9 Signif.
Brachionus (m)	0.067 (437)	---	---	0.042 (360)	---	---
Conochilidae (m)	0.134 (384)	0.011	0.008	0.045 (302)	---	---
Filinia (m)	0.084 (379)	---	---	0.166 (259)	-0.014	0.007
Keratella (m)	0.298 (448)	0.028	<0.001	0.129 (373)	0.013	0.013
Polyarthra (m)	0.124 (422)	0.012	0.011	0.065 (345)	---	---
Total Rotifers (m)	0.112 (465)	0.009	0.016	0.026 (385)	---	---
Bosmina (m)	0.030 (266)	---	---	0.022 (317)	---	---
Diaphanosoma (M)	0.170 (366)	-0.027	0.001	0.155 (270)	-0.020	0.011
Daphnia (M)	0.039 (287)	---	---	0.019 (189)	---	---
Chydorid cladocera (M)	0.122 (252)	0.013	0.053	0.035 (174)	---	---
Leptodora (M)	0.218 (211)	-0.025	0.001	0.302 (153)	-0.029	<0.001
Copepod nauplii (m)	0.424 (444)	0.030	<0.001	0.235 (381)	0.020	<0.001
Calanoid copepods (M)	0.166 (531)	-0.020	<0.001	0.002 (404)	---	---
Cyclopoid copepods (M)	0.068 (492)	---	---	0.022 (390)	---	---
Adult and copepodid copepods (M)	0.072 (560)	---	---	0.015 (425)	---	---

n values (# of data points) are shown in Corr. Coeff. column in parentheses.
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.



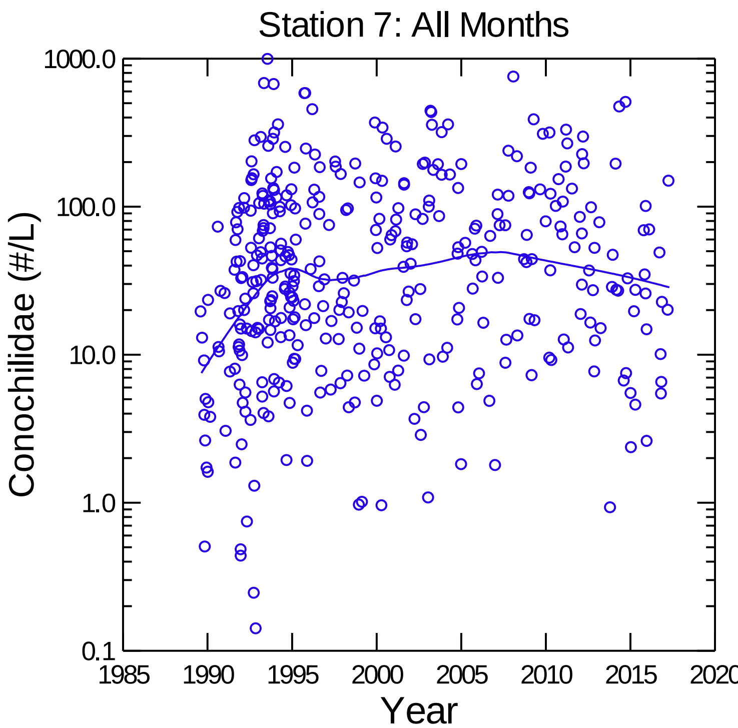
Brachionus is the dominant rotifer in Gunston Cove and the trends in total rotifers are generally mirrored in those in *Brachionus* (Figure 122). The LOWESS line for *Brachionus* suggested about 150/L in 2016, only slightly greater than the 100/L found in 1990. No linear trend was found over the study period (Table 18).

Figure 122. Long term trend in *Brachionus*. Station 7. Gunston Cove.



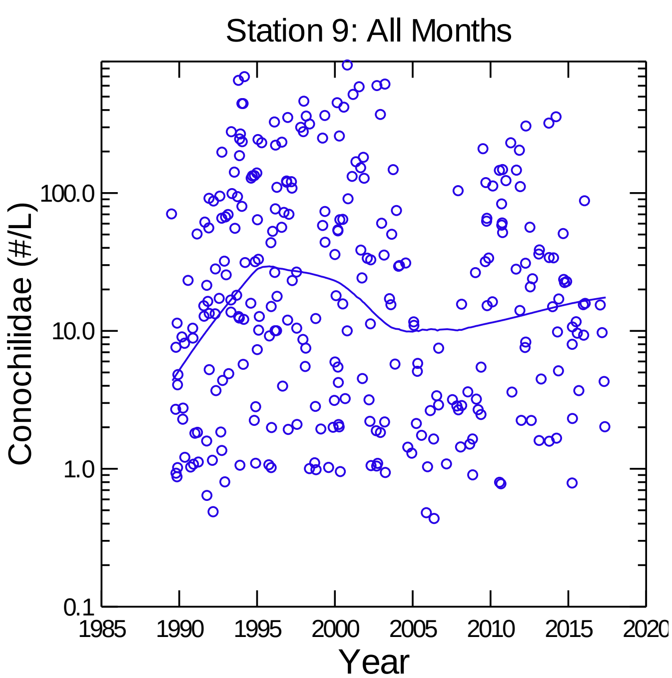
Brachionus was found at lower densities in the river. In the river the LOWESS line for *Brachionus* increased through 2000, but dropped markedly from 2000-2005. Since 2005 an increase has been noted, with the LOWESS value in 2017 of about 60/L, higher than the initial 20/L and near the previous peak of 80/L in 1999 (Figure 123). No linear trend was indicated when the entire study period was considered (Table 18).

Figure 123. Long term trend in *Brachionus*. Station 9. River mainstem.



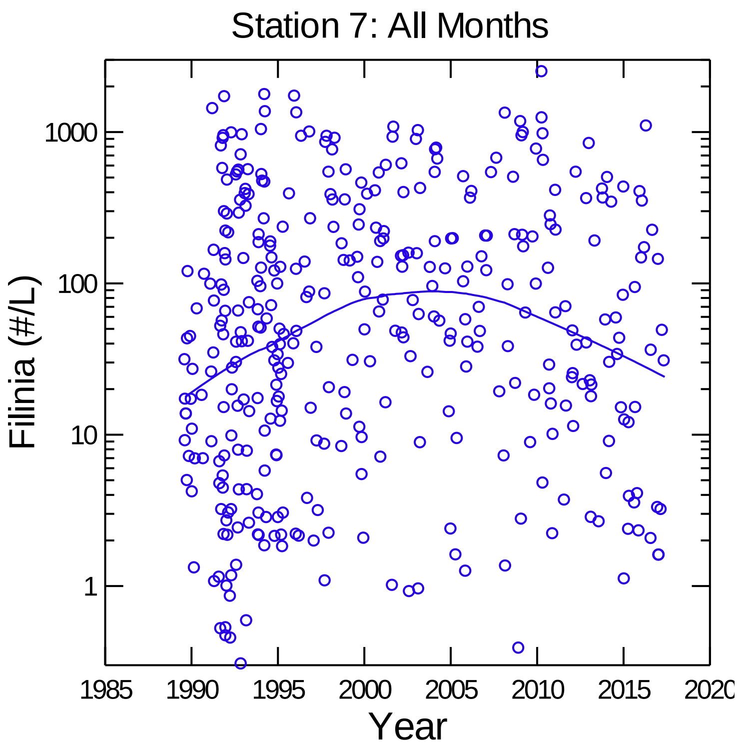
Conochilidae increased strongly from 1990-1995 and since then has leveled off. In 2016 the LOWESS trend line stood at about 40/L (Figure 124). This was well above levels of about 5/L in 1990. Over the entire period of record, a significant linear increase was found (Table 18).

Figure 124. Long term trend in Conochilidae. Station 7. Gunston Cove.



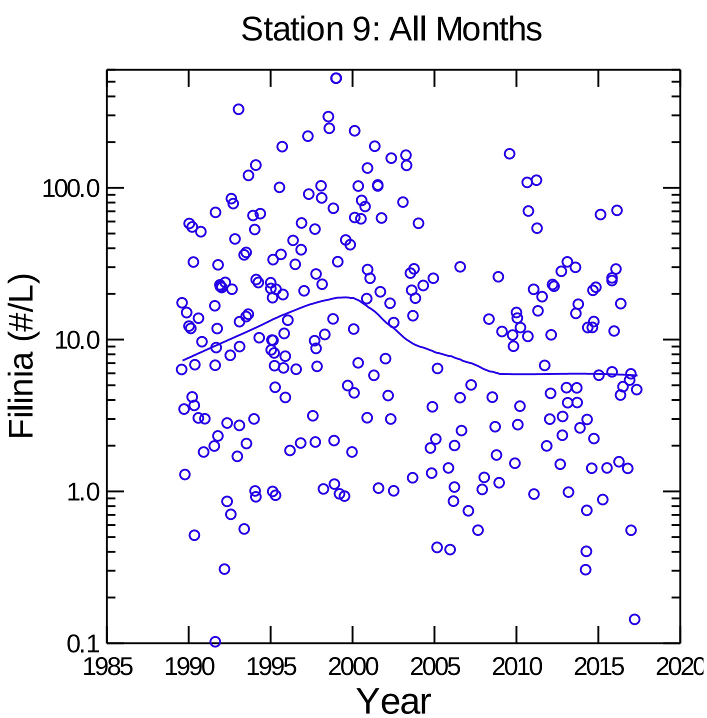
In the river, Conochilidae exhibited a strong increase in the early 1990's similar to that observed in the cove (Figure 125). This was followed by a period of decline and recently a renewed increase. The trend line has gone from 3/L in 1990 to 35/L in 1995 to 10/L in 2005 to 25/L in 2016. When the entire period of record was examined, there was not a significant linear trend (Table 18).

Figure 125. Long term trend in Conochilidae. Station 9. River mainstem.



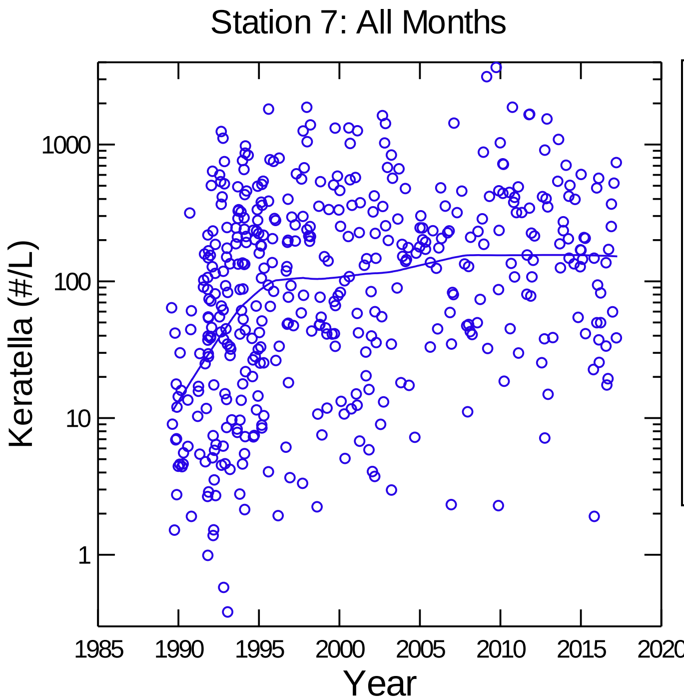
In the cove *Filinia* exhibited a steady increase from 1990 through 2000 rising from about 20/L to nearly 100/L (Figure 126). It has shown a gradual decline in recent years to about 30/L. When the entire period of record was considered, there is evidence for a linear increase in the cove despite the recent declines (Table 18).

Figure 126. Long term trend in *Filinia*. Station 7. Gunston Cove.



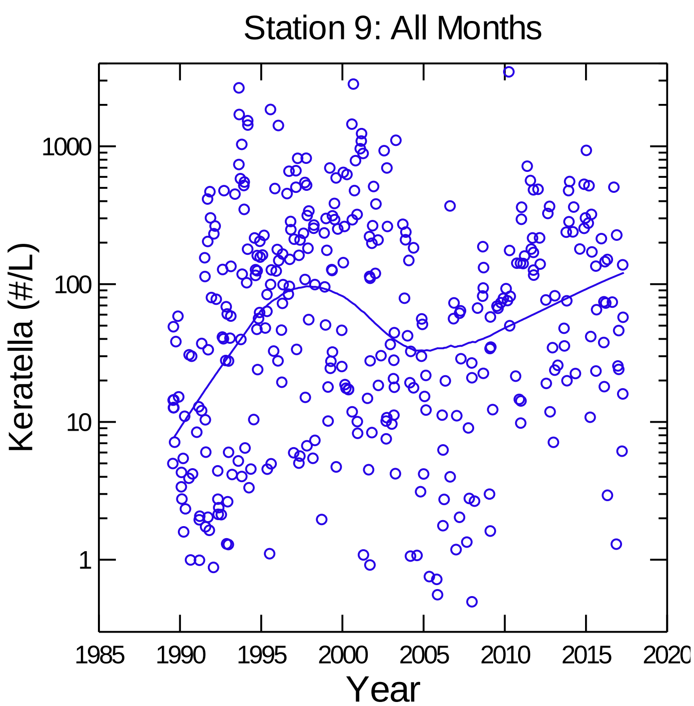
In the river *Filinia* demonstrated an increase through about 2001, declined from 2000-2005 and remained steady since. The trend line indicates about 6/L in 2017, about equal to the 7/L in 1990, but well below the peak of 20/L in 2000 (Figure 127). When the entire period of record was examined, there was a barely significant negative linear trend (Table 18).

Figure 127. Long term trend in *Filinia*. Station 9. River mainstem.



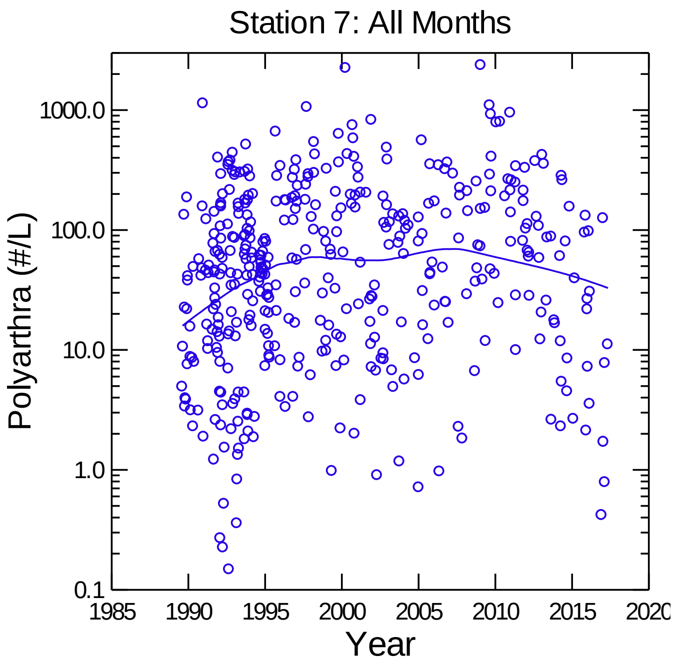
Keratella increased strongly from 1990 to 1995 and has shown a milder increase since then with the trend line approaching 200/L in 2017 (Figure 128). When the entire period of record was examined, there was a significant linear increase (Table 18).

Figure 128. Long term trend in *Keratella*. Station 7. Gunston Cove.



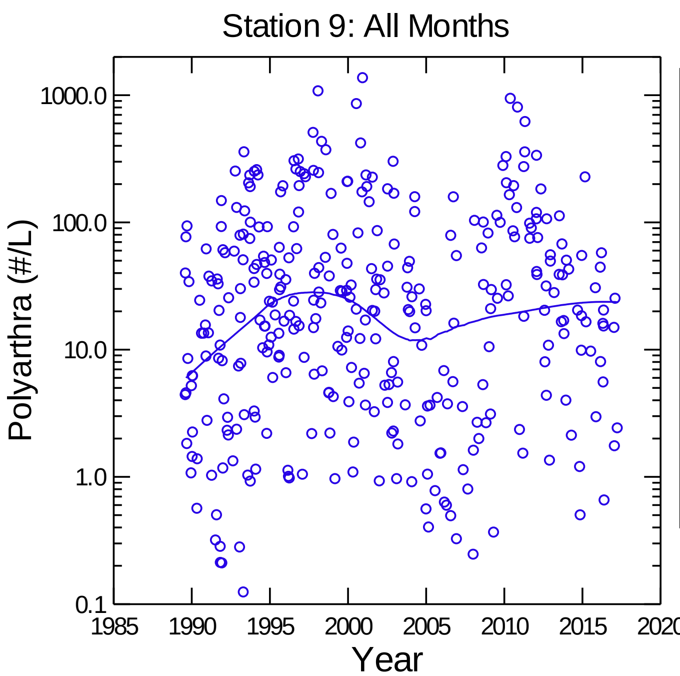
In the river *Keratella* increased from less than 10/L in 1990 to peak values of about 100/L in the mid to late 1990's (Figure 129). The trend line then declined to about 25/L, but since 2005 it has increased to about 200/L. Linear regression showed evidence of a linear increase when the entire study period was considered (Table 18).

Figure 129. Long term trend in *Keratella*. Station 9. River mainstem.



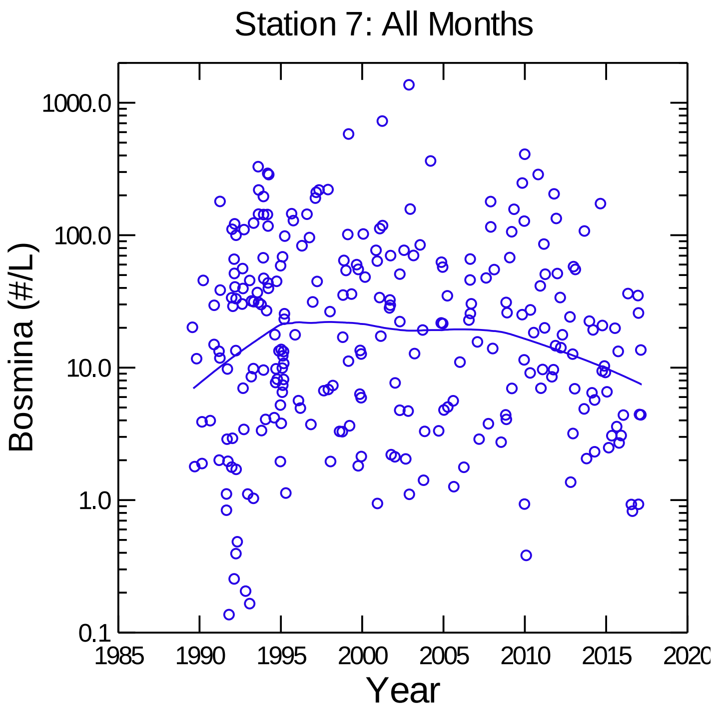
The trend line for *Polyarthra* in the cove increased steadily from 1990 to about 2000 rising from 15/L to about 60/L (Figure 130). Since 2000 densities have increased more slowly with the trend line reaching about 80/L by 2016. Regression analysis indicated a significant linear increase when the entire period of record was examined (Table 18).

Figure 130. Long term trend in *Polyarthra*. Station 7. Gunston Cove.



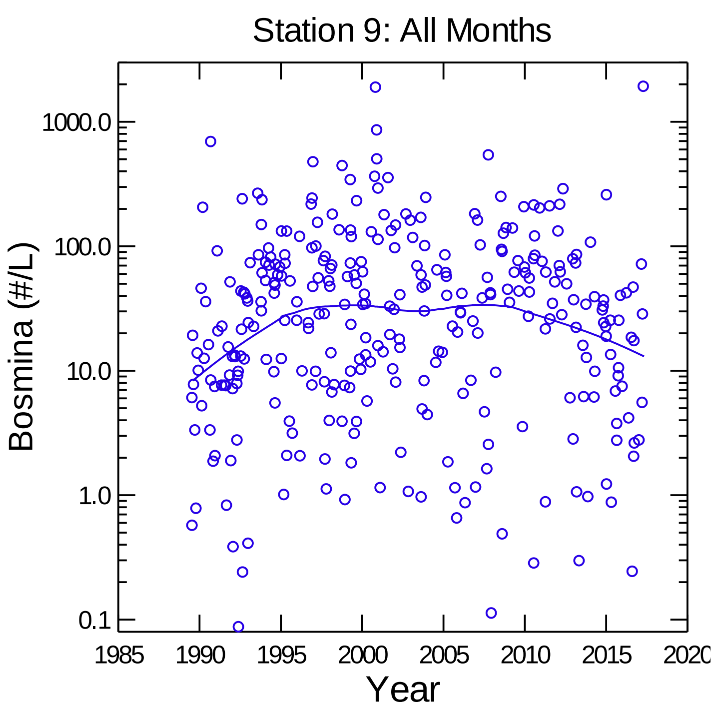
In the river *Polyarthra* showed a marked increase from 1990 to 2000 and then a decline to 2005. Recently values have increased again and by 2016 the trend line reached 50/L (Figure 131). Linear regression analysis did not indicate a significant positive trend over the period of record (Table 18).

Figure 131. Long term trend in *Polyarthra*. Station 9. River mainstem.



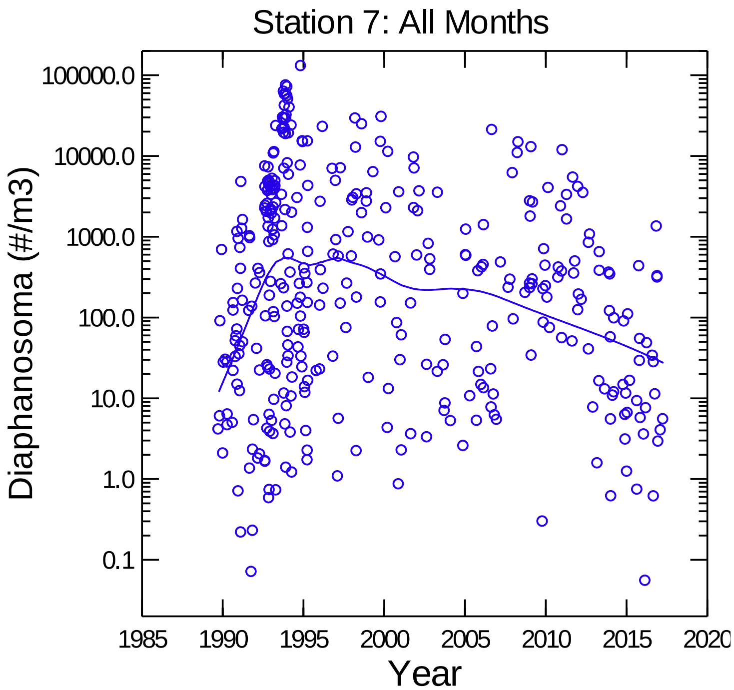
The trend line for *Bosmina* in the cove showed an increase from 8/L in 1990 to about 20/L in 2000 (Figure 132). Since 2000 densities have declined. Linear regression did not indicate a significant trend in the cove over the entire period of record (Table 18).

Figure 132. Long term trend in *Bosmina*. Station 7. Gunston Cove.



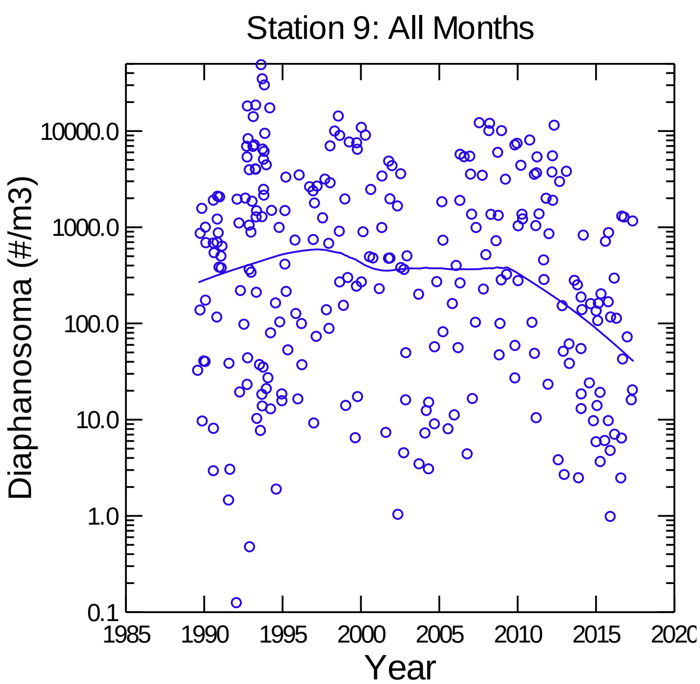
In the river mainstem the LOWESS curve for *Bosmina* increased from 1990 to 1995, and remained rather constant from 1995 to 2010 at about 30/L (Figure 133). Recently, it has declined. Regression analysis did not indicate a significant linear increase over the entire period of record (Table 18).

Figure 133. Long term trend in *Bosmina*. Station 9. River mainstem.



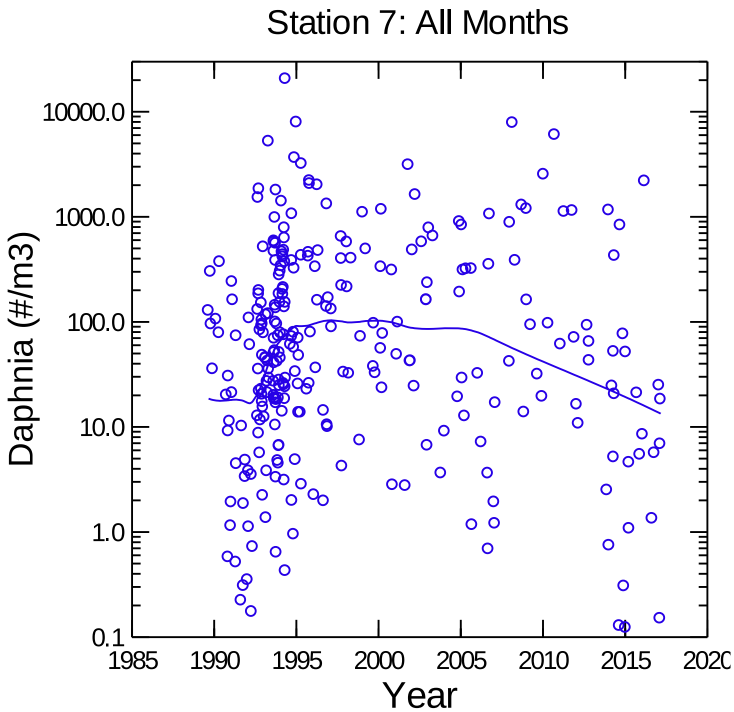
Diaphanosoma increased strongly in the early 1990s from about 12/m^3 nearly 1000/m^3. It gradually declined through 2016 to about 40/m^3 (Figure 134). Many 2016 values were below 100/m^3. Linear regression analysis of the entire period of record indicated a significant decline (Table 18).

Figure 134. Long term trend in *Diaphanosoma*. Station 7. Gunston Cove.



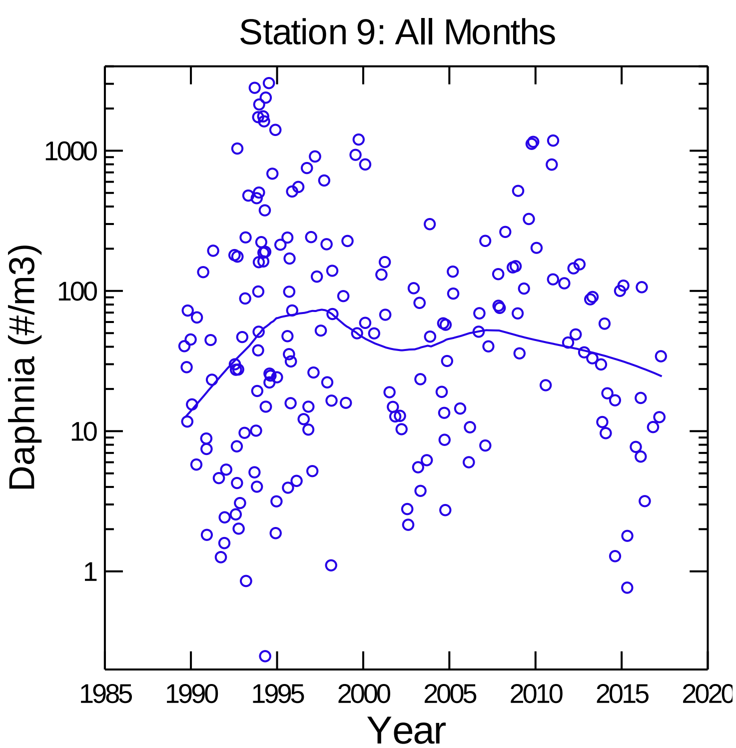
In the river the LOWESS line suggested a generally stable pattern in *Diaphanosoma* until 2010 until a decline set in (Figure 135). The trend line value of 40/m^3 found in 2017 compared with values as high as 600/m^3 in 1999. Regression analysis indicated significant declining trend over the period of record (Table 18).

Figure 135. Long term trend in *Diaphanosoma*. Station 9. River mainstem.



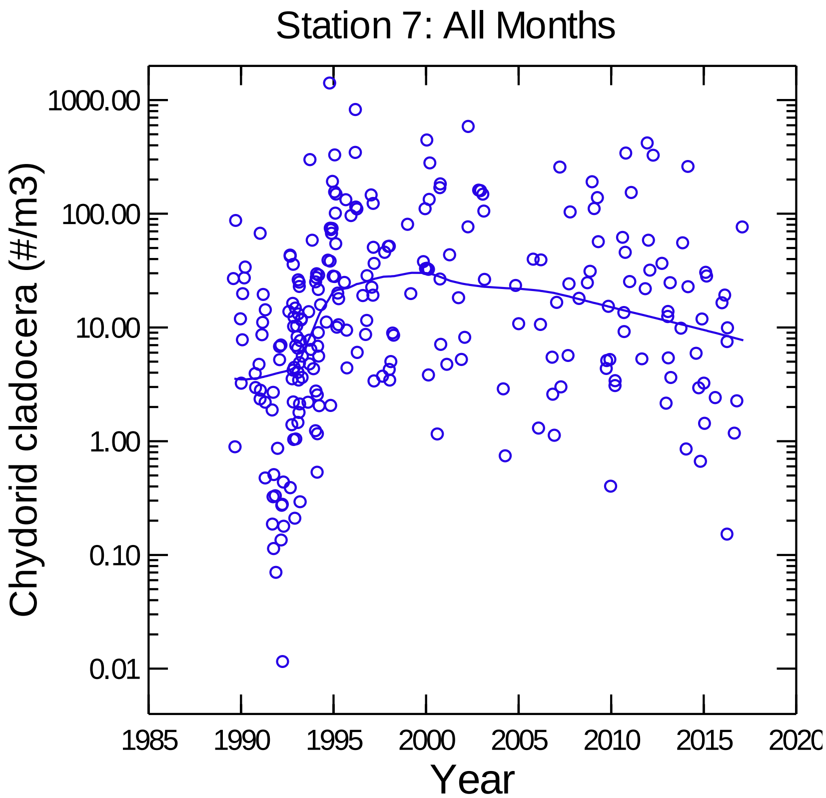
Daphnia in the cove has declined slowly since 1995 from about 100/m^3 to 30/m^3 (Figure 136). This is up slightly from the low of about 20/m^3 in the early 1990's. Regression analysis examining the entire period of record was not significant (Table 18).

Figure 136. Long term trend in *Daphnia*. Station 7. Gunston Cove.



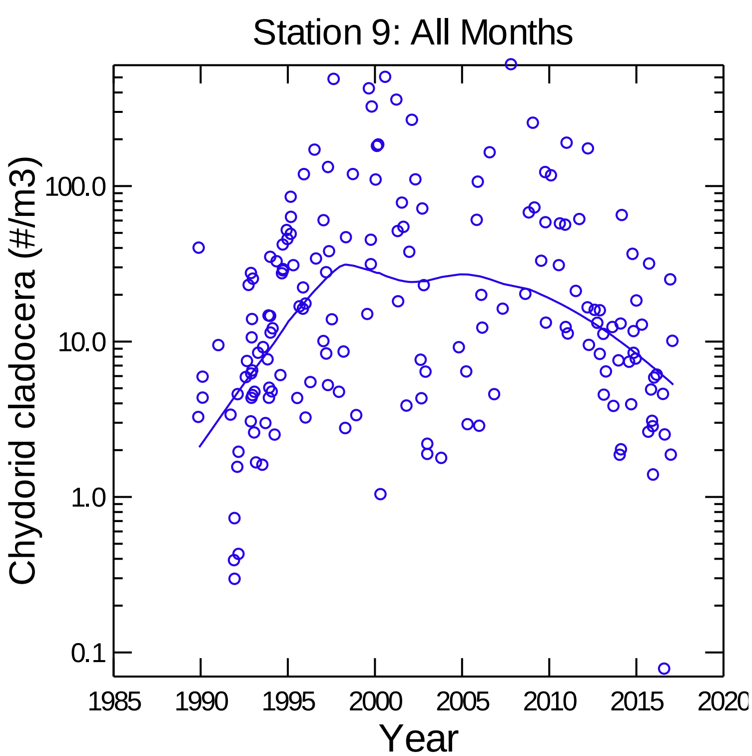
Daphnia in the river increased early on, but has since declined slightly (Figure 137). The trend line in 2017 approached 25/m^3, only slightly higher than the level observed at the beginning of the record in 1990. Regression analysis did not indicate a significant positive trend over the study period (Table 18).

Figure 137. Long term trend in *Daphnia*. Station 9. River mainstem.



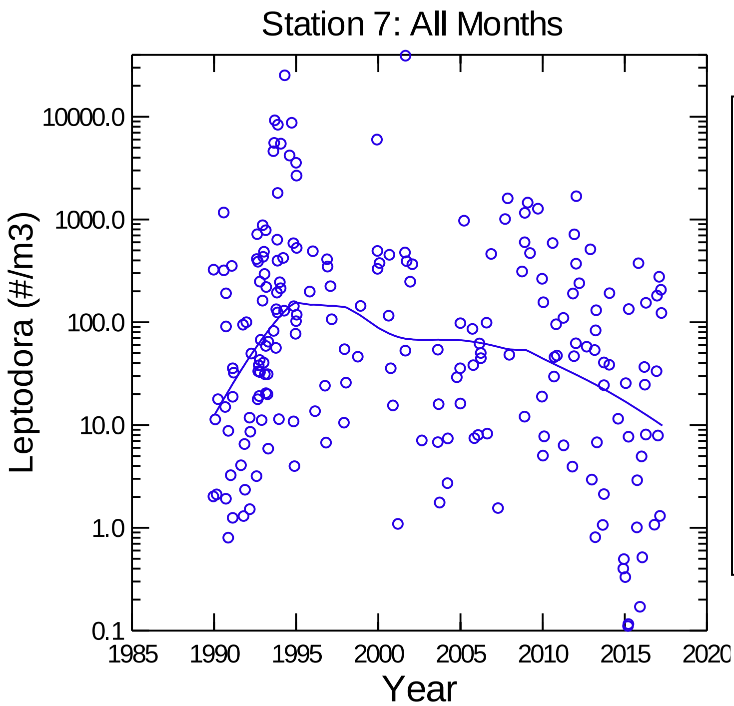
Chydorid cladocera in the cove have maintained a consistent population of about 8-10/m^3, substantially higher than the low of 4/m^3 in the early 1990's, but below trend line values of 30/m^3 observed in 2000 (Figure 138). Regression analysis gave evidence for a slight linear increase over the study period (Table 18).

Figure 138. Long term trend in Chydorid Cladocera. Station 7. Gunston Cove.



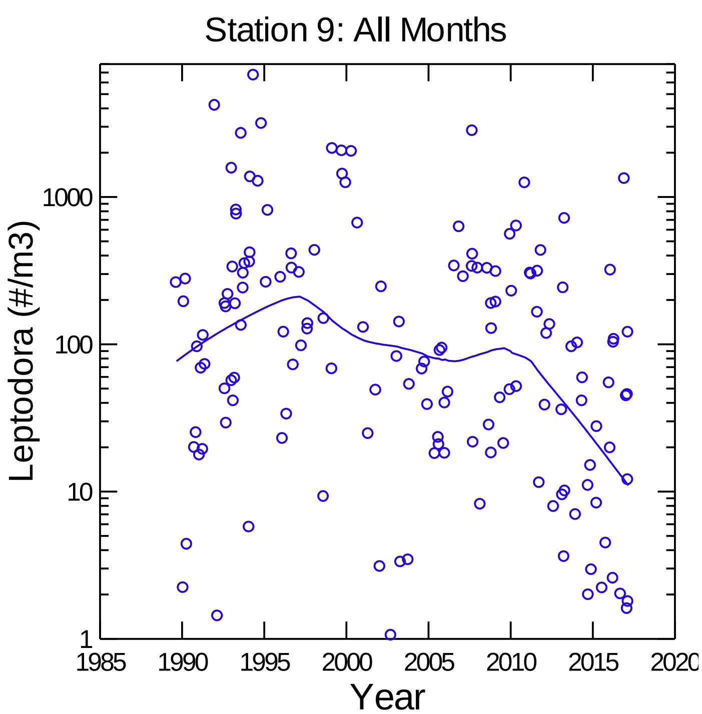
In the river chydorids continued a gradual decrease to about 7/m^3, slightly above the low of about 2/m^3 in the early 1990's (Figure 139). There was no evidence for a significan linear trend (Table 18).

Figure 139. Long term trend in Chydorid Cladocera. Station 9. River mainstem.



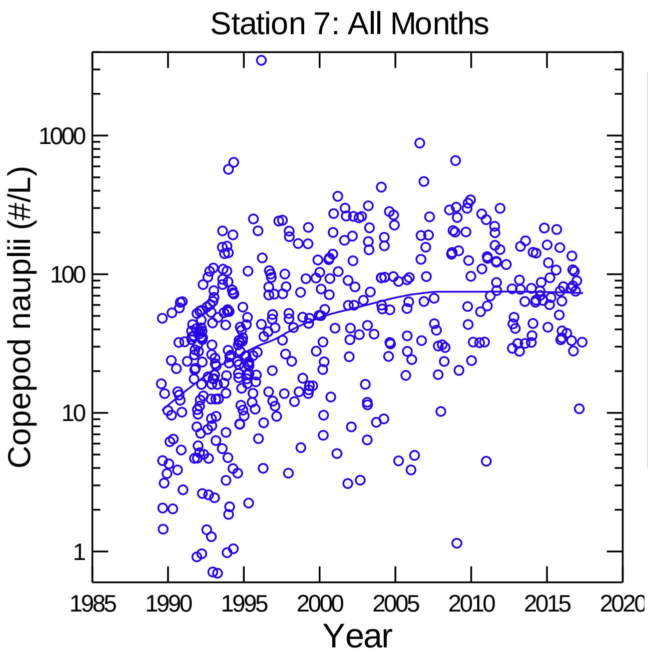
In the cove the trend line for *Leptodora*, the large predaceous cladoceran, has gradually decreased to about 10/m^3, down from its high of about 150/m^3 in 1994, and similar the 1990 value (Figure 139). There was weak evidence for a significant negative linear trend in *Leptodora* over the entire study period (Table 18).

Figure 140. Long term trend in *Leptodora*. Station 7. Gunston Cove.



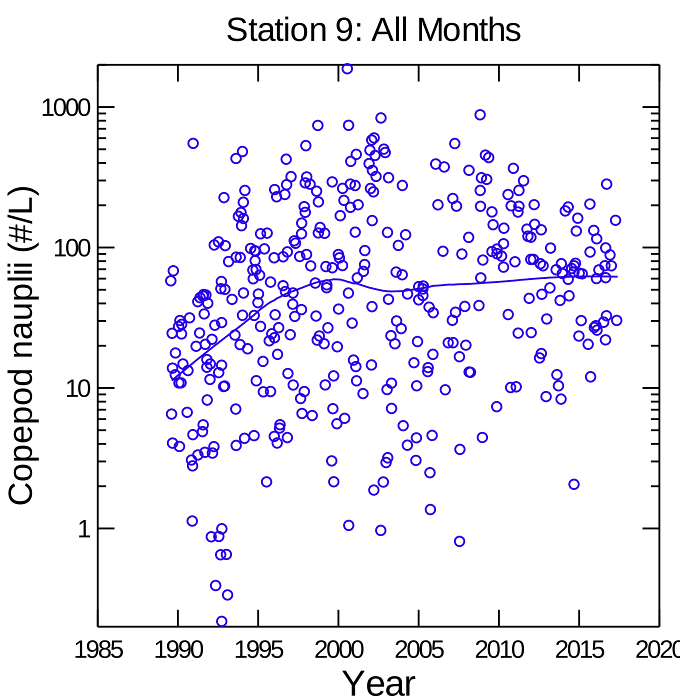
In the river, *Leptodora* densities continued a general decline which began in 1995 resulting in trend line values of about 10/m^3 for 2017 (Figure 141). These values are almost equal to those observed in 1990, and are well below the peak of 200/m^3 in 1994. Linear regression analysis detected a significant linear trend when the whole study period was considered (Table 18).

Figure 141. Long term trend in *Leptodora*. Station 9. River mainstem.



Copepod nauplii, the immature stages of copepods, continued their upward trend in the cove reaching almost 90/L (Figure 141). 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 18).

Figure 142. Long term trend in Copepod Nauplii. Station 7. Gunston Cove.



In the river, copepod nauplii showed a gradual increase since 2005 (Figure 142). The 2017 LOWESS trend line value was about 70/L, up from an initial value of 10/L in 1990, similar to the previous peak. A significant linear increase was found for nauplii over the study period (Table 18).

Figure 143. Long term trend in Copepod Nauplii. Station 9. River mainstem.

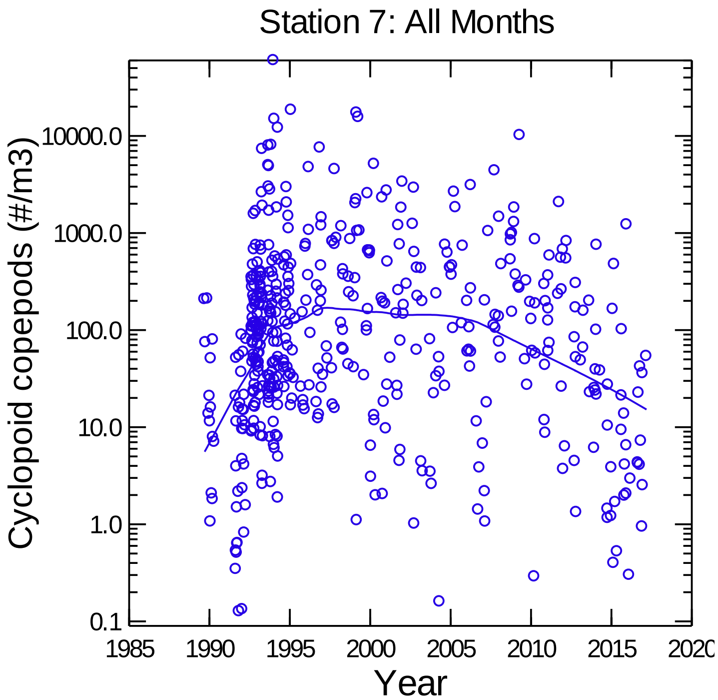


Figure 144. Long term trend in Cyclopoid Copepods. Station 7. Gunston Cove

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 200/m^3 (Figure 143). Cyclopoid copepods did not exhibit a significant linear trend in the cove over the study period (Table 18).

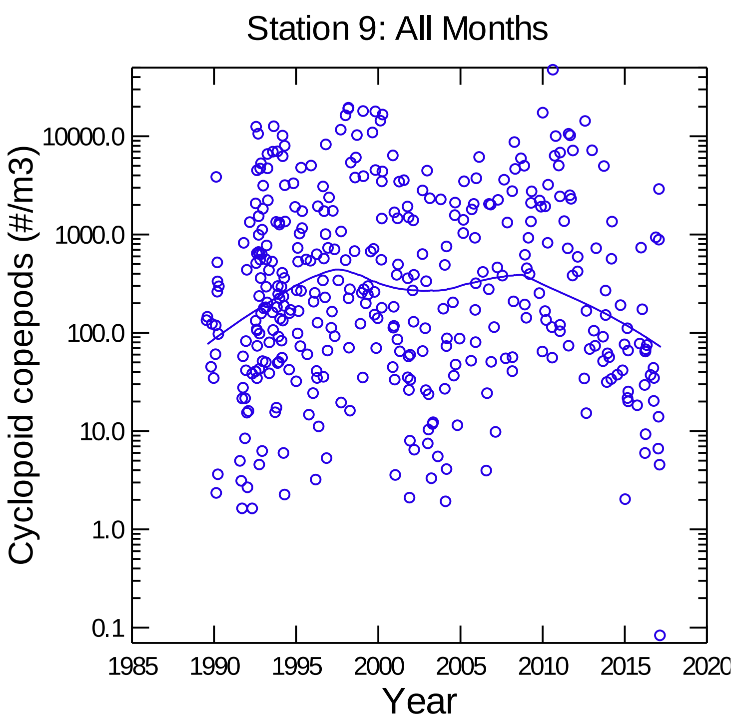
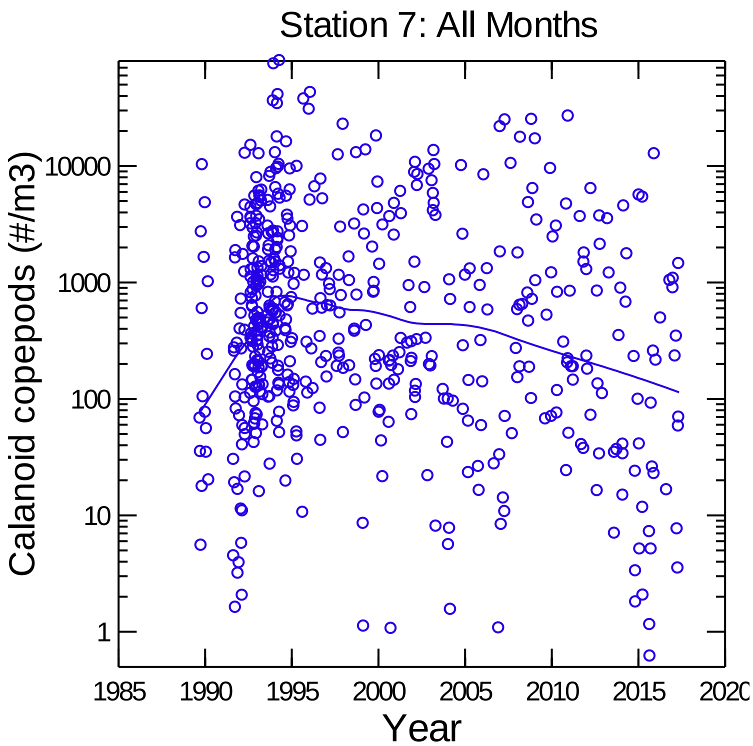


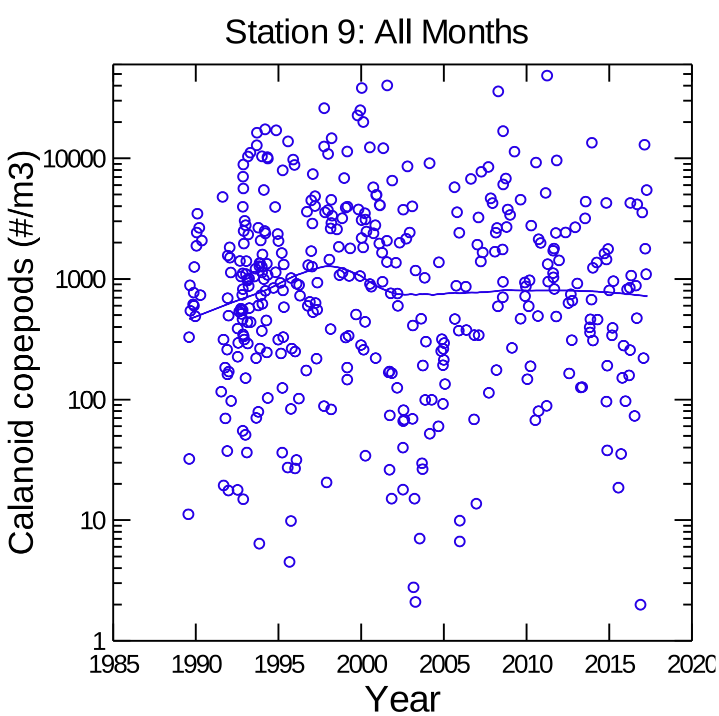
Figure 145. Long term trend in Cyclopoid Copepods. Station 9. River mainstem

Cyclopoid copepods have shown several cycles over the period (Figure 144). The trend line has varied from 90/m^3 to about 400/m^3. In 2017 cyclopoids were at a low point. No linear increase was found when the entire study period was considered (Table 18).



Calanoid copepods (Figure 146) in the cove increased greatly in the early 1990’s to near 1000/m^3 and then has gradually declined to about 100/m^3.

Figure 146. 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 remained pretty constant at about 700/m^3 (Figure 147).

Figure 147. Long term trend in Calanoid Copepods. Station 9. River mainstem

E. Ichthyoplankton Trends: 1993-2017

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), Atherinids (Inland Silversides), and Yellow Perch, all exhibited a spike in density in 1995 followed by a decline in numbers until about 2008. The declines in Clupeid larvae were followed by increases starting in 2010 (Figure 148; Table 19). Especially 2010-2012 showed very high density of these larvae, while numbers decreased again in 2013. With continued relatively low densities from 2014 to 2017, the high densities of 2010-2012 appear to be a peak rather than a rebound to higher densities. The trend goes up a bit again in 2017; it will be interesting to see if we are heading for another peak. It is possible that this is natural variation, and that these populations rely on a few highly successful yearclasses. A moratorium on river herring since 2012 may be allowing the numbers to increase over time.

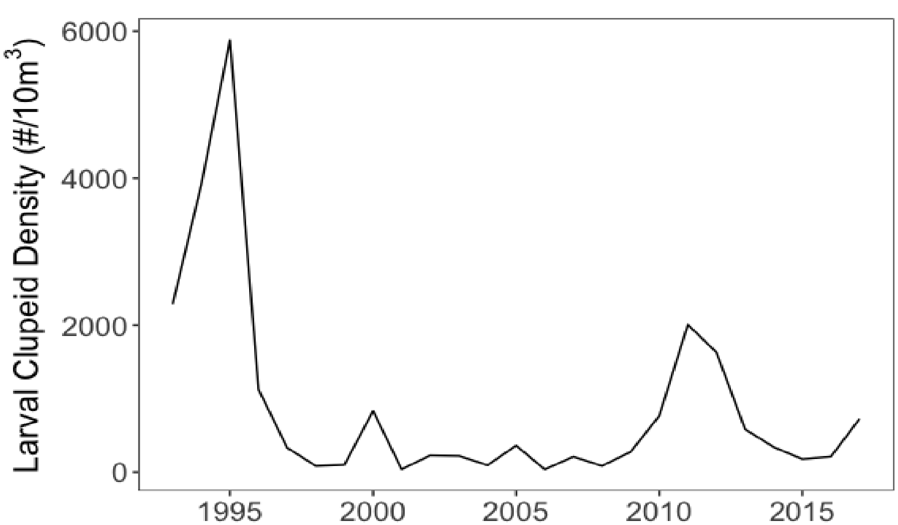
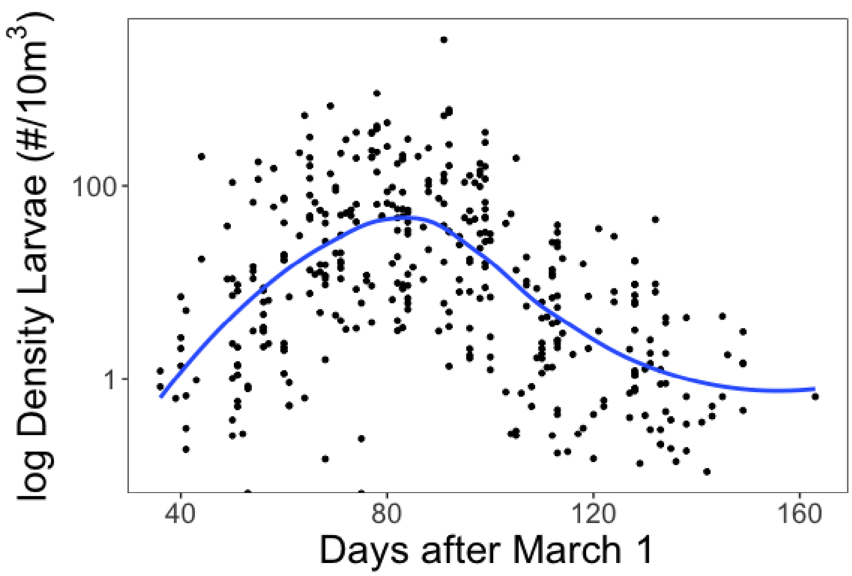


Figure 148. Long-term trend in Clupeid Larvae (abundance 10 m^{-3}).

Table 19. Density of larval fishes Collected in Gunston Cove and the Potomac mainstem (abundance per m^3).

Year	All *Alosa* Spp	All *Dorsoma* Spp	All *Lepomis* Spp	All *Morone* Spp	*Perca flavescens*	*Menidia beryllina*
2017	312	148	41	62	1	5
2016	105	87	2	87	0	7
2015	41	29	0	2	0	21
2014	0	0	0	0	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	0	0	0	0	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

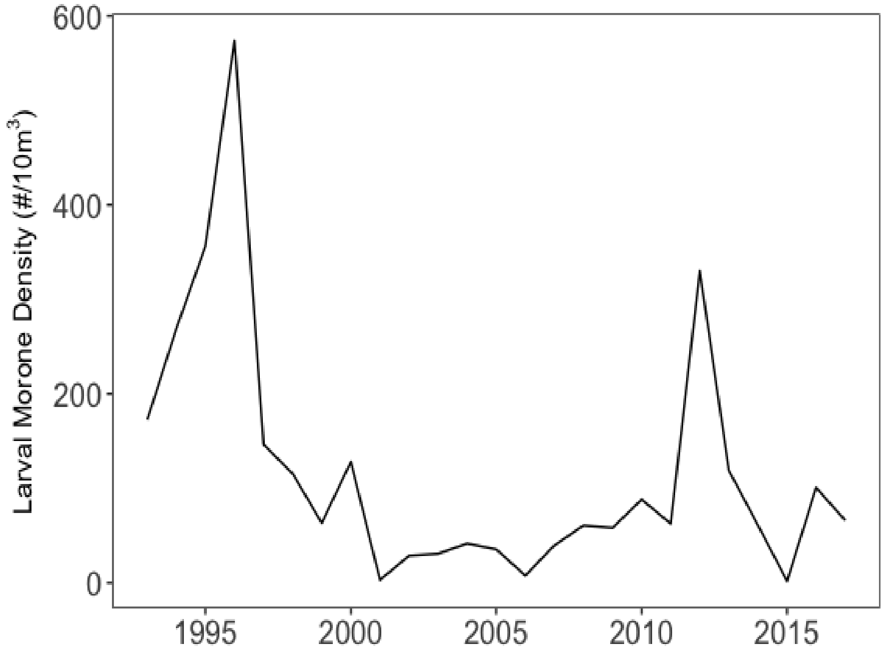
The peaks in abundance over the season reflect characteristic spawning times of each species (Figures 149, 151, 153, and 155). Clupeid larval density shows a distinct peak mid-May (Figure 149). Clupeid larvae are dominated by Gizzard Shad, which spawns later in the season than river herring (Alewife 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. The earliest peak is from Yellow Perch (Figure 155), which may even be at its highest before our sampling starts. An early peak is also seen for *Morone sp*., which is mostly White Perch (Figure 155). White Perch begin spawning early and larval densities slowly taper off. Consequently, White Perch larvae are found throughout most of the sampling season. Silversides have a less pronounced peak in late May/early June, with low densities continuing to be present throughout the season (Figure 153).



The seasonal pattern in clupeid larvae for 1993-2017 (Figure 149) shows that a peak in density occurs about 80 days after March 1, or mid-May.

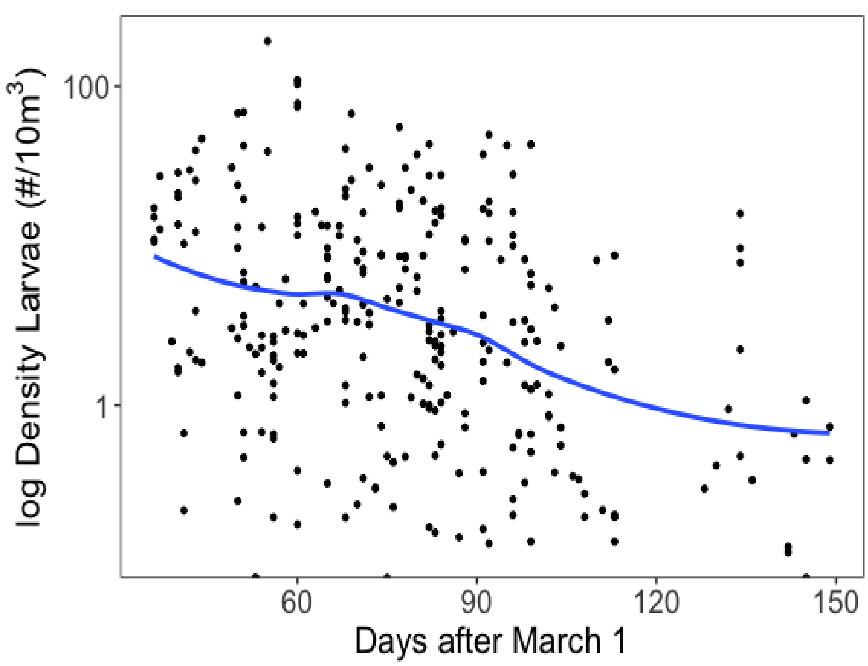
Figure 149. Seasonal pattern in Clupeid larvae (*Alosa sp*. and *Dorosoma sp*.; abundance 10 m^{-3}). The x-axis represents the number of days after March 1.

The long-term trend in annual average density of *Morone* larvae shows a high similarity with that of Clupeid larvae (Figure 150). 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 151), 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.



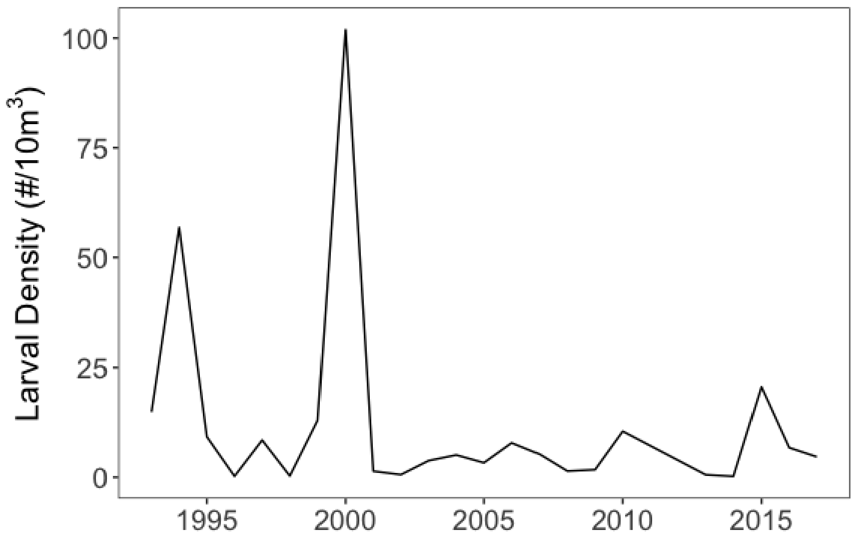
The trend in number of White Perch and Striped Bass larvae per 10 m^3 since 1993 is depicted in the graph in Figure 150. Two peaks are observed in 1995 and 2012 with low densities in other years.

Figure 150. Long term trend in *Morone sp.* larvae (abundance 10 m^{-3}).



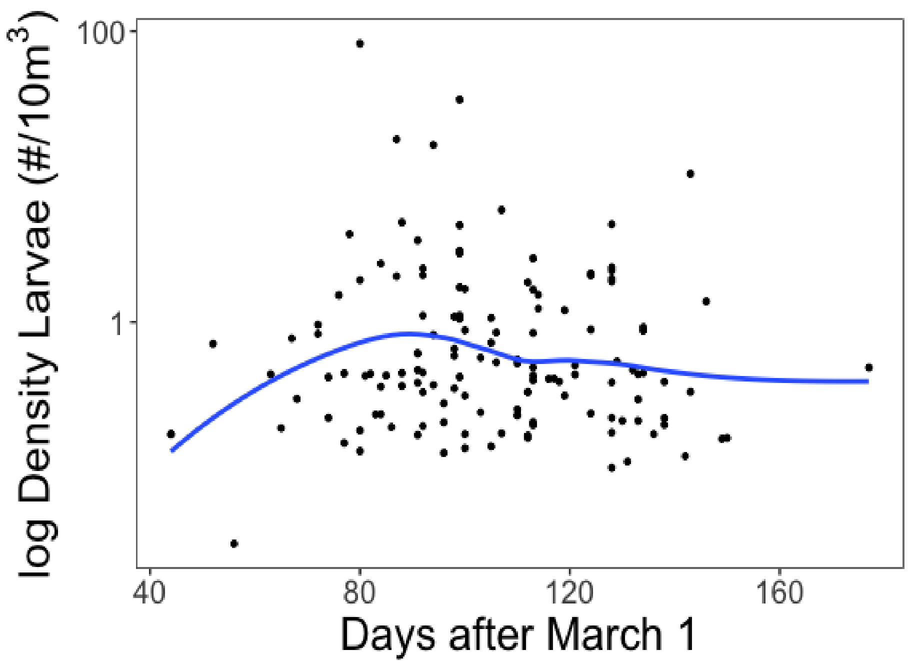
The seasonal density of *Morone* sp. larvae per 10 m^3 is shown in Figure 151. A small peak can be seen about 60 days after March 1 followed by declines in density thereafter. This small peak occurs end of April, while highest densities are at the start of the sampling season.

Figure 151. Seasonal pattern in *Morone sp.* larvae (abundance 10 m^{-3}). X-axis represents days after March 1st.



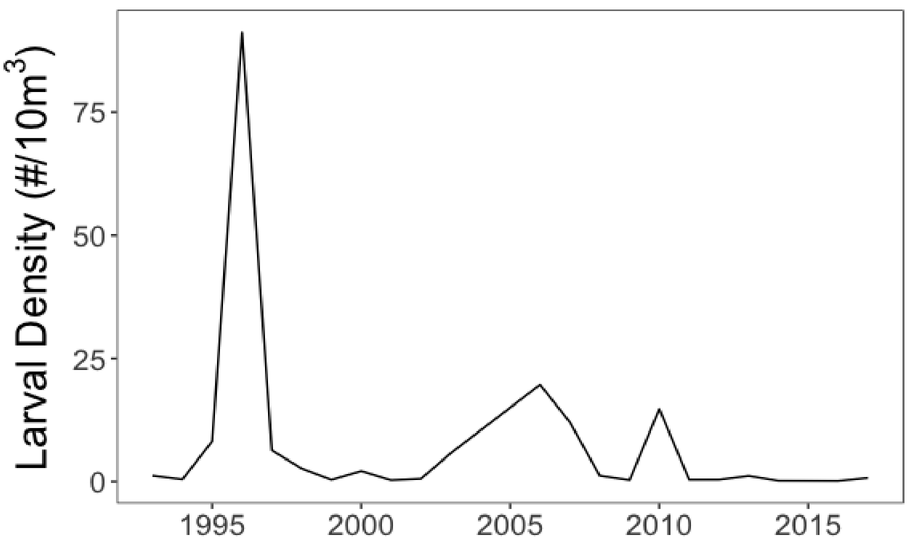
The long-term trend in density of Inland Silverside is presented in Figure 152. After a high peak in 2000, densities have been moderate to low with some small peaks in 2006, 2010, and 2015.

Figure 152. Long-term trend in *Menidia beryllina* larvae (abundance 10 m^{-3}).



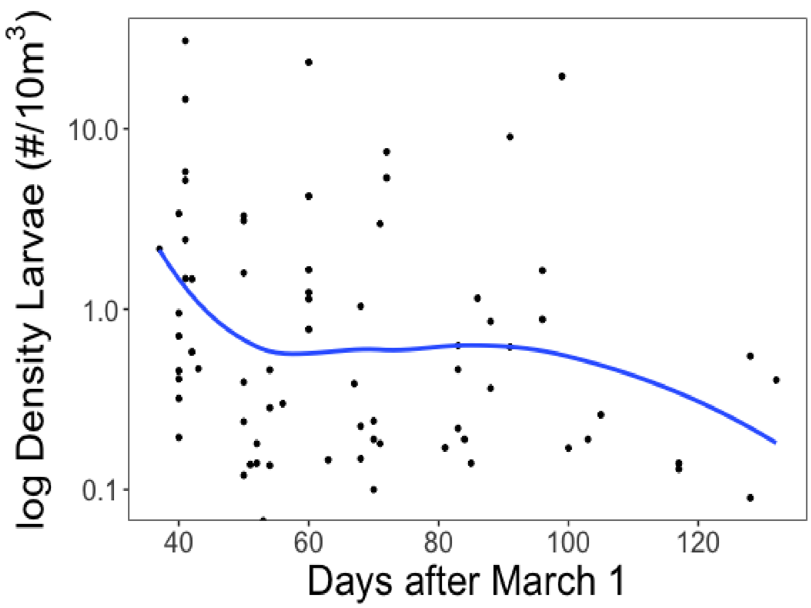
The seasonal occurrence of Inland Silverside per 10m^3 is shown in a LOWESS graph in Figure 153. The pattern shows maximum density around 90 days after March 1, or around the first week of June.

Figure 153. Seasonal pattern in *Menidia beryllina* larvae (abundance 10 m^{-3}). 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 154. 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 a LOWESS graph in Figure 155. 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 155. Seasonal pattern in *Perca flavescens* larvae (abundance 10 m^{-3}). The x-axis represents the number of days after March 1.

F. Adult and Juvenile Fish Trends: 1984-2017

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 20, Figure 156). 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 156). 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 157). On average, catch rates of fishes within the cove are approximately the same over the time of the survey; in other words, there is no significant increasing or decreasing trend over time. The overall catch rate for the inner cove (stations 7 and 10) in 2017 is similar to previous years and about the average of the last three years. Trawl catches in station 7 and 10 were dominated by White Perch and Spottail Shiner. Pumpkinseed (a sunfish) was represented in the catches with high abundance as well. Strong cohorts punctuated White Perch catch rates in 1993, 2007, 2010, 2012, and 2015. Overall, White Perch catches have remained similar and stable over the period of record. The higher frequency of strong year-classes after 2005 results in an overall small increase in trend starting that time.

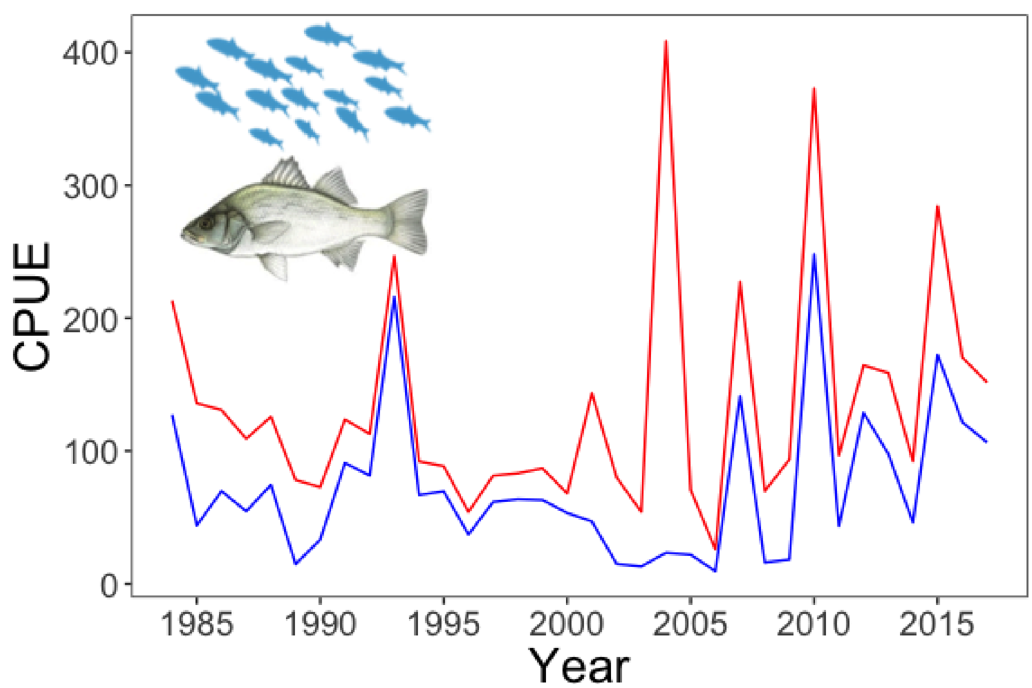


Figure 156. Trawls. Annual Averages. All Species (red) and White Perch (blue). Cove Stations 7 and 10. 1984-2017.

Table 20. Mean catch per trawl of adult and juvenile fishes at Stations 7 and 10 combined. 1984-2017.

Year	All Species	White Perch	All Alosa Spp.	Blueback Herring	Alewife	Gizzard Shad	Bay Anchovy	Spottail Shiner	Brown Bullhead	Pumpkin seed
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	0.2	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	0.2	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	0.2	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	70.7	22.0	34.6	12.1	17.3	1.1	0.0	6.4	0.0	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
1998	83.2	63.8	3.0	2.2	0.8	0.5	3.7	6.4	0.9	1.6
1997	81.4	61.7	2.9	1.9	1.0	5.0	2.6	2.9	1.5	1.2
1996	54.1	37.1	8.5	4.0	4.4	0.5	0.2	2.6	0.5	2.0
1995	88.6	69.7	6.2	4.1	2.1	0.4	3.0	3.0	1.9	1.8
1994	92.2	66.9	0.8	0.8	0.0	0.1	0.5	6.2	3.2	2.7
1993	246.6	216.0	2.0	1.4	0.6	1.4	0.6	7.3	4.5	3.4
1992	112.8	81.5	0.2	0.2	0.0	0.9	0.8	2.4	11.5	5.1
1991	123.7	90.9	1.5	1.0	0.5	8.1	2.6	2.9	12.5	1.7
1990	72.8	33.3	25.1	21.9	3.2	0.1	1.1	1.1	10.0	0.5
1989	78.2	14.9	16.4	16.1	0.2	42.1	0.2	0.5	3.0	0.6
1988	125.8	74.5	20.3	10.5	7.0	12.7	8.3	1.9	5.3	0.9
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

*Station 10 not sampled late July – September **Station 10 not sampled in August, *** station 10 not sampled in August-September, ****Station 10 not sampled in June-September.

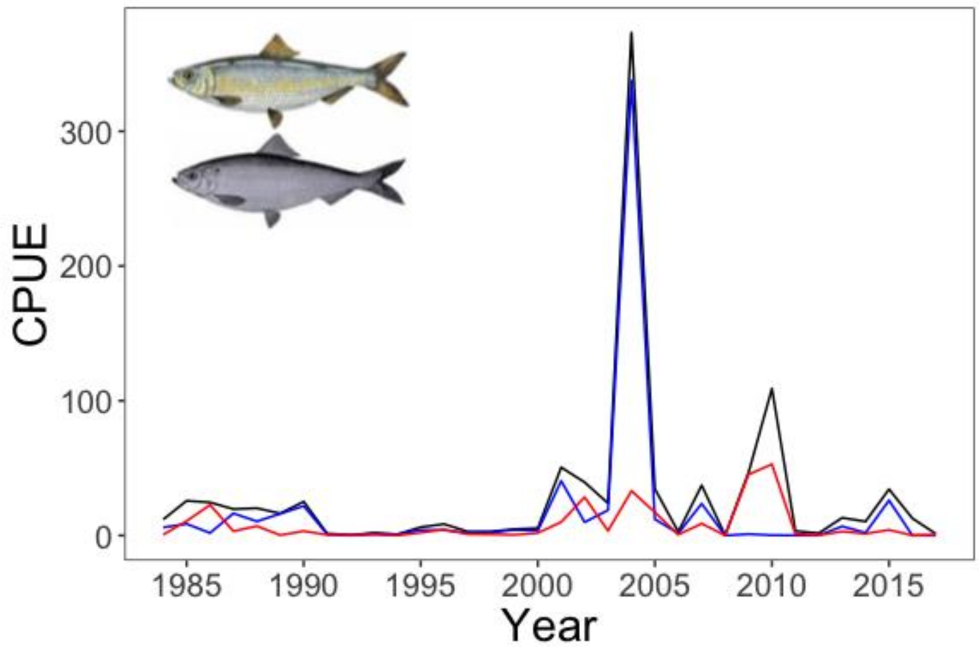


Figure 157. Trawls. Annual Averages. Blueback Herring (blue) and Alewife (red) and *Alosa sp*. (unidentified herring or shad; black). Cove Stations 7 and 10.

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 relative small part of the catch between 1991 and 2000; and moderate to large proportion of the catch from 2001 to 2015. 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 156; Figure 157).

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, 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 not previously reported.

Mean catch at station 9 in 2017 was similar to the previous year, but below the long-term mean (54; Table 21). The total catch at station 9 may be declining over time, and it would be interesting to pursue the research question whether and how blue catfish invasion has played a role in that. Blue catfish is regularly collected at station 9 the last 15 years, and hardly ever at the inner cove stations. Before 2017, Blue catfish was never collected at the inner cove station, but a few were collected there too in 2017. The mean catch of all stations combined in 2017 is lower than the long-term mean of 103 (Table 22). There was high variability between stations, with mean catch per trawl at station 9 at an all-time low (Table 24). The presence and location of SAV beds is partially responsible for the variability. Trawling is impeded at station 10 in the summer, until trawling becomes impossible at varying dates late summer (Table 23). This is likely responsible for the lower catch in station 10 than station 7. It is clear from the lower catch per trawl in station 9 than 7 and 10, that the inner cove is preferred habitat for fishes.

Table 21. Mean catch per trawl of selected adult and juvenile fishes for all months at Station 9. 1988-2017

Year	All Species	All Alosa Spp.	Alewife	Blueback Herring	White Perch	Bay Anchovy	Spottail Shiner	Brown Bullhead	Channel Catfish	Blue Catfish	Tessellated Darter
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	1.1	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	91.1	15.0	14.7	0.3	36.5	12.1	1.8	0.0	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
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	49.6	0.0	0.0	0.0	37.2	0.0	1.1	0.9	0.0	9.2	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	31.9	0.2	0.2	0.0	17.4	0.2	0.2	4.4	0.0	8.5	0.1
1994	31.9	0.0	0.0	0.0	13.4	0.1	0.0	2.4	0.0	6.3	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	67.9	0.1	0.1	0.0	42.4	1.9	0.1	1.3	0.0	13.2	0.4
1990	101.5	0.1	0.1	0.0	50.6	0.0	0.1	5.5	0.0	39.9	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

Table 22. Mean catch per trawl of selected adult and juvenile fishes for all months at Stations 7, 9, and 10 combined. 1984-2017.

Year	All Species	White Perch	All Alosa Spp.	Blueback Herring	Alewife	Gizzard Shad	Bay Anchovy	Spottail Shiner	Brown Bullhead	Channel Catfish	Blue Catfish
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	78.2	27.3	27.4	7.7	16.3	0.7	4.4	4.7	0.0	7.3	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
1998	62.9	46.8	2.0	1.4	0.6	0.4	2.6	4.3	0.7	0.0	2.1
1997	70.8	53.5	2.0	1.3	0.7	3.3	1.7	2.3	1.3	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	74.0	53.3	3.8	2.5	1.3	1.1	3.0	2.3	1.9	0.0	4.8
1994	87.2	63.8	1.3	1.2	0.1	0.1	0.6	6.6	1.7	0.0	2.1
1993	162.4	131.7	2.3	2.0	0.4	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	150.5	82.5	18.2	13.1	5.1	5.4	26.6	2.9	4.7	0.0	2.6
1990	69.1	31.6	19.9	16.5	3.4	0.1	0.8	2.4	4.4	0.0	7.1
1989	62.4	9.1	26.4	25.8	0.6	20.8	0.6	0.4	1.4	0.0	0.6
1988	79.1	32.9	18.7	14.4	3.3	6.5	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 23. The number of trawls per station in each month at Stations 7, 9, and 10 in each year

Year	Station	2	3	4	5	6	7	8	9	10	11	12
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
2017	10	0	0	1	2	0	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
2016	10	0	0	1	2	1	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
2015	10	0	0	1	2	0	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
2014	10	0	0	1	2	2	0	0	0	0	0	0
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
2013	10	0	0	1	2	2	1	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
2012	10	0	0	1	2	2	0	0	0	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
2011	10	0	0	1	2	3	2	0	1	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
2010	10	0	0	1	1	2	2	0	0	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
2009	10	0	0	1	2	2	2	3	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
2008	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
2007	10	0	0	1	2	2	2	2	1	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
2006	10	0	0	1	2	2	1	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
2005	10	0	0	1	2	2	1	2	0	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
2004	10	0	0	0	1	2	2	1	1	0	0	0
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
2003	10	0	1	2	2	2	2	1	1	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
2002	10	0	0	2	2	2	2	2	2	1	1	1
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
2001	10	0	1	2	2	1	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
2000	10	0	1	2	2	3	2	3	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
1999	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
1998	10	0	1	2	2	2	2	2	2	1	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
1997	10	0	1	2	2	2	2	2	2	2	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
1996	10	0	1	2	1	2	2	1	2	1	1	1
1995	7	0	1	2	2	2	2	2	2	2	1	0
1995	9	0	1	2	2	2	2	2	2	2	1	0
1995	10	0	1	2	2	2	2	2	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
1994	10	0	1	1	1	2	2	0	2	2	1	0
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
1993	10	0	0	1	2	2	3	2	2	2	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
1992	10	0	1	1	1	1	1	1	1	1	1	1
1991	7	0	1	1	1	1	1	1	1	1	1	0
1991	9	0	1	1	1	1	1	1	1	2	1	0
1991	10	0	1	1	1	1	1	1	1	1	1	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
1990	10	0	1	1	1	1	1	1	1	1	0	0
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
1989	10	1	1	1	1	1	1	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
1988	10	0	1	1	1	2	2	2	2	1	1	0
1987	7	0	1	1	1	1	1	1	1	1	1	0
1987	10	0	1	1	1	1	1	1	1	1	0	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
1986	10	0	2	1	1	1	1	1	1	1	1	0
1985	7	0	0	1	1	1	0	1	1	2	1	0
1985	10	0	0	1	1	1	0	1	1	2	1	0
1984	7	0	1	2	4	2	4	2	5	5	2	1
1984	10	0	1	2	4	3	4	2	4	5	2	1

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

Year	7	9	10
2017	188.0	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	104.6	91.1	24.1
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	111.5	49.6	51.4
1996	73.9	13.8	31.5
1995	107.6	31.9	69.6
1994	122.2	31.9	62.1
1993	377.1	31.2	116.1
1992	155.5	29.0	70.2
1991	173.9	67.9	73.6
1990	77.2	101.5	68.4
1989	52.6	14.2	103.8
1988	154.6	19.2	96.9
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

Gizzard Shad catch rates in trawls in 2017 were low which contributes to a pattern of low abundance after a high peak in 1989 (Figure 158). Smaller peaks later occurred in 1991, 1997, 2008, and 2012, that were all an order of magnitude lower than the 1989 peak. Bay Anchovy catch rates in 2017 were low like they were in the last two years at inner cove stations, and 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. Further years will determine whether sporadic peaks continue to occur, or if the ecosystem of the inner cove has now shifted to a state (e.g. reduced open water/SAV bed ratio) that is less favorable for Bay Anchovy.

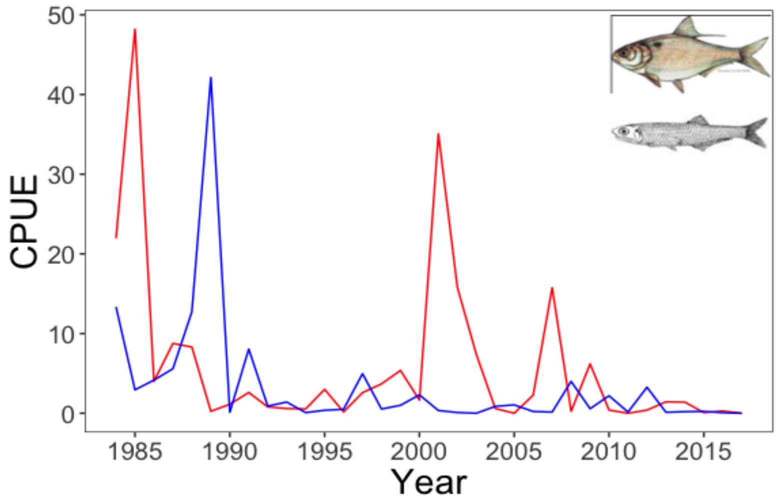


Figure 158. Trawls. Annual Averages. Cove Stations 7 and 10. Gizzard Shad (blue) and Bay Anchovy (red).

Spottail Shiner and sunfishes (Bluegill and Pumpkinseed) have been consistently collected in the majority of all trawl and seine samples (Figure 159). 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, and 2015 (Figure 159). We collected an unprecedented high number of Spottail Shiner specimens in 2015. These individuals were mostly juveniles, indicating relatively high reproductive success as measured by this survey. 2017 had a much lower average catch again, but not to the extent that it changed the increasing trend in time. The trends for pumpkinseed showed lower overall abundance, with a decrease in abundance after a 2008 peak, until a small peak occurred again in 2017.

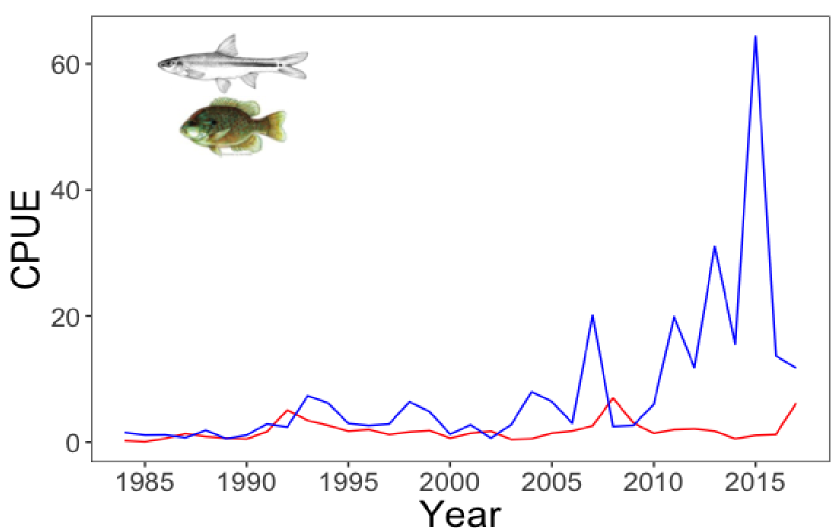


Figure 159. Trawls. Annual Averages. Spottail Shiner (blue) and Pumpkinseed (red). Cove Stations 7 and 10.

Very few Brown Bullhead specimens were captured in trawls in 2017, continuing a declining trend that has proceeded continuously since the start of the survey (Figure 160a). The fyke nets do collect Brown Bullhead in low amounts; in 2017, we only collected 1 Brown Bullhead in the fyke nets.

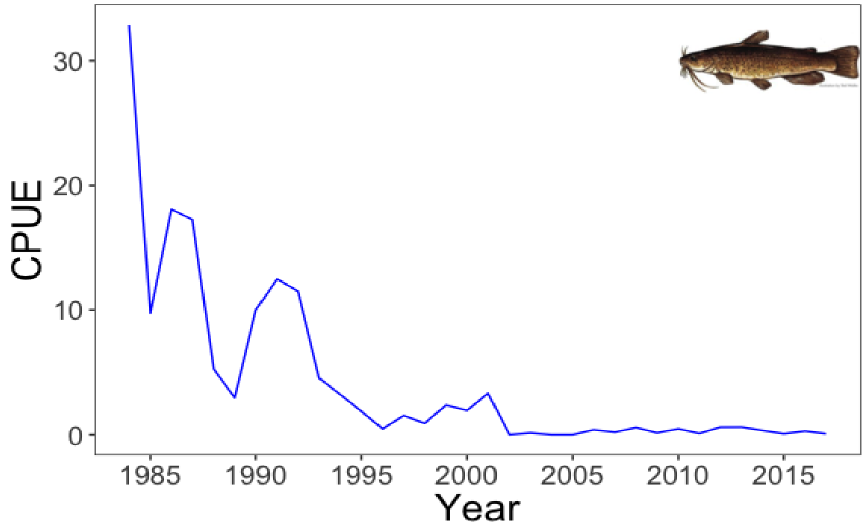


Figure 160a. Annual Averages. Brown Bullhead. Cove Stations 7 and 10.

Tessellated Darter was consistently encountered at low abundance in trawl samples. While average values remain low, the second highest peak in the period of record was recently observed in 2014, and the mean per trawl was relatively high in 2017 again (Figure 160b).

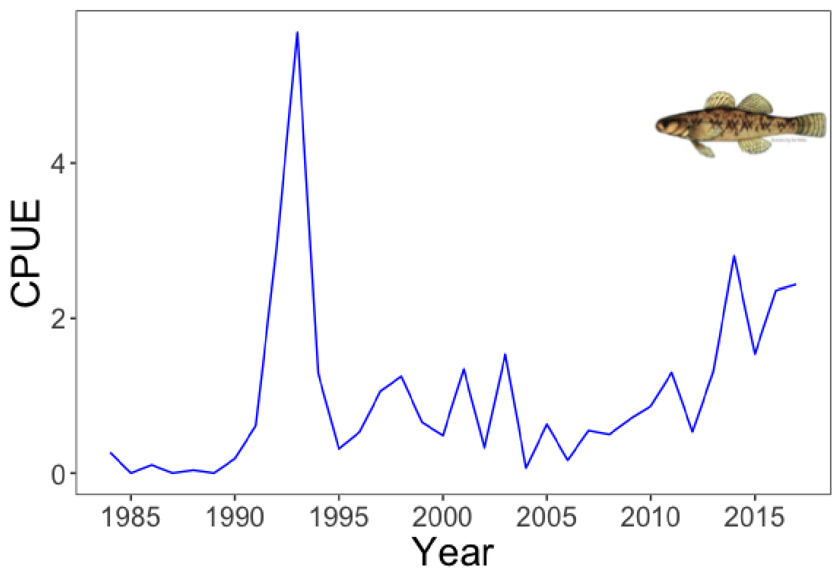


Figure 160b. Trawls. Annual Averages of Tessellated Darter (*Etheostoma olmstedi*). Cove stations 7 and 10.

At the river channel station (station 9), catches in 2017 were similar to the last four years (Figure 161), and slightly higher than 2016. As in the inner cove, much of the variation at station 9 is directly attributable to the catch of White Perch. The fact that total catch in 2017 was low was not because of a lower amount of White Perch. Lower numbers of Alosines were mostly responsible for the difference.

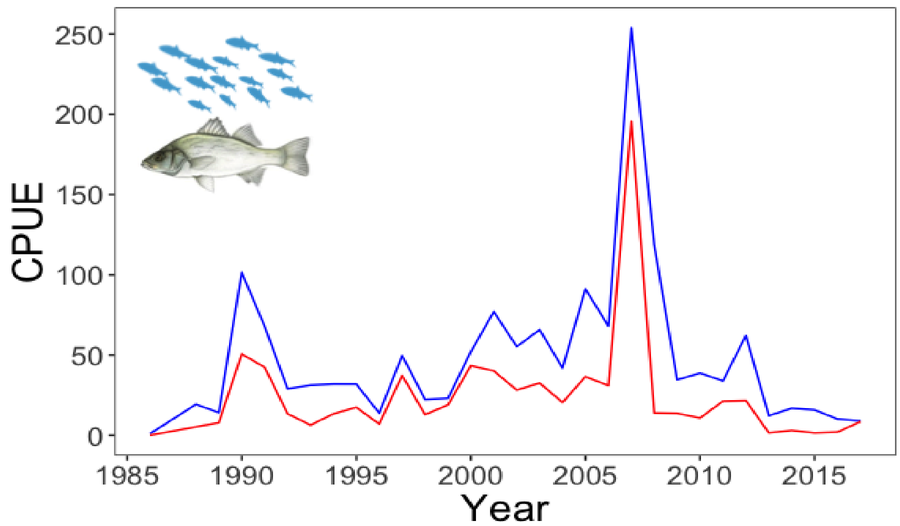


Figure 161. Trawls. Annual averages. River Station (9). Total catch (blue), White Perch (red).

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 162). 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, while American Eel has been rare since 1994.

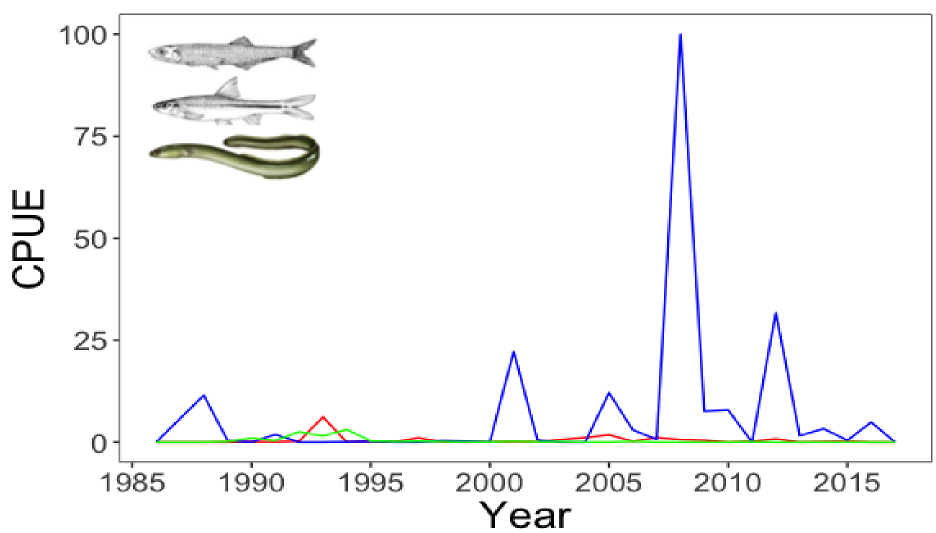


Figure 162. Trawls. Annual Averages. River Station (9). Bay Anchovy (Blue) Spottail Shiner (red) American eel (green).

Catch rates for native catfish species have been variable and low at station 9 since 2007 (Figure 163), with only a small peak from Channel catfish in 2011. No Brown Bullhead or Channel Catfish were observed in 2017. Long-term mean trends identify a decline in both Brown Bullhead and Channel Catfish (Figures 163). One species that warrants close attention is the invasive Blue Catfish, which was positively identified on the survey in 2001 and has been captured in high numbers relative to Channel Catfish and Brown Bullhead ever since (Figure 163). 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 established itself in 2001 with relatively high numbers, but the trend has remained flat since then, and even may be somewhat declining (Figure 163). The system may have reached a new stable state that includes Blue Catfish in relative high numbers, and Channel Catfish and Brown Bullhead in low numbers. Continued monitoring in the growth of this population is warranted. Of note is that we are not capturing very large specimens with the otter trawl, and very large blue catfishes have been reported in this area.

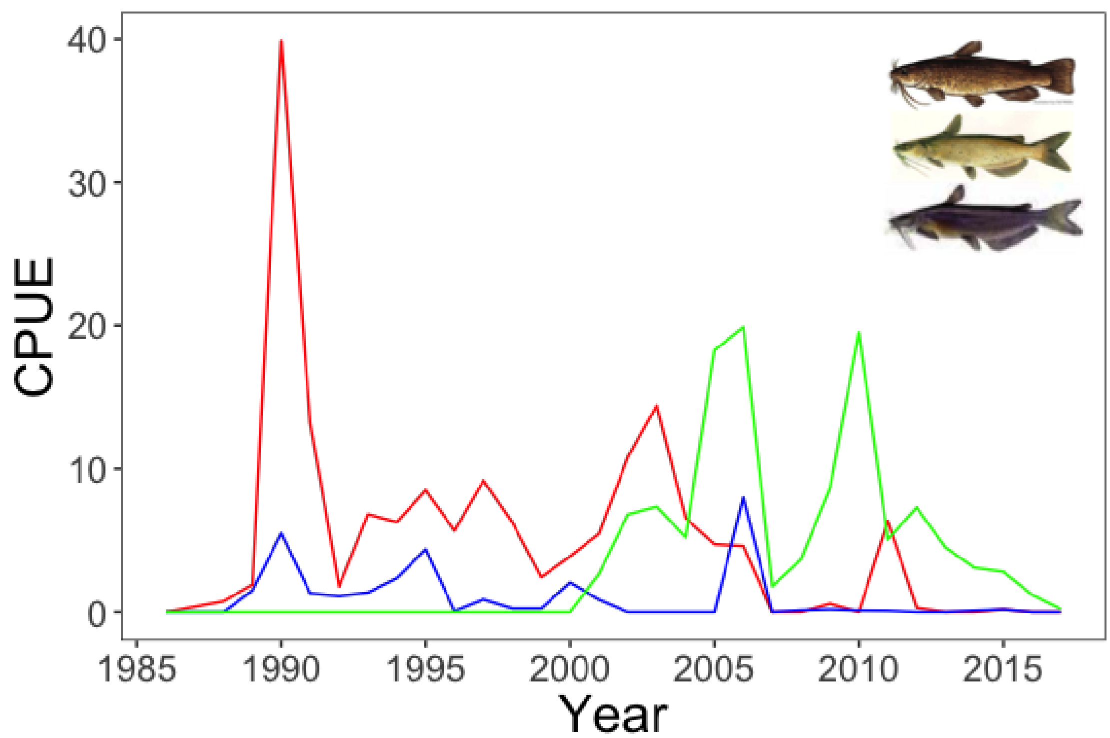


Figure 163. Trawls. Annual Averages. River Station (9). Brown Bullhead (blue), Channel Catfish (red), and Blue Catfish (green).

Station 9 represented low catch rates for the demersal species Tessellated Darter and Hogchoker (Figure 156). High catches have not occurred since 2004 (Figure 164) and neither of the two species was captured at station 9 in 2017. The mean annual trend seems to indicate a general decline in catch rates for each of these species in our Potomac mainstem site over the time-span of the survey (Figure 164).

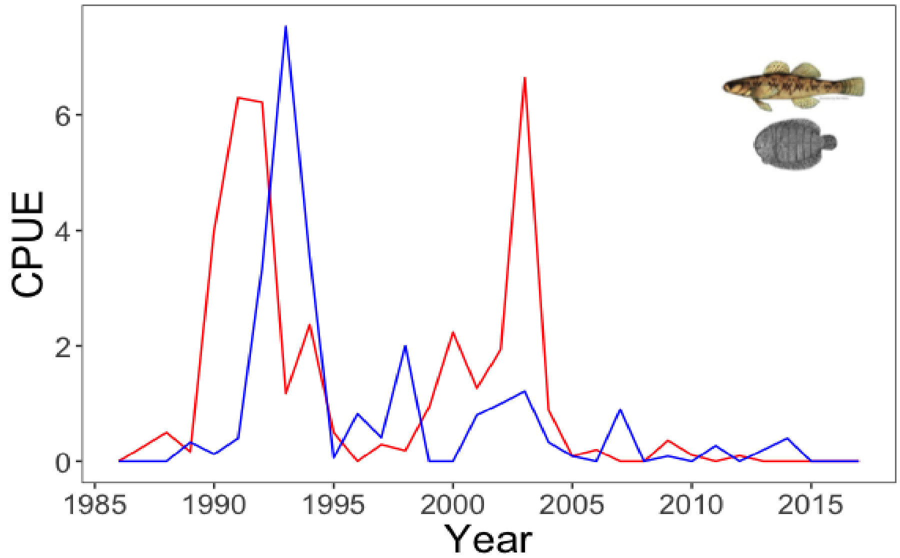


Figure 164. Trawls. Annual Averages. Tessellated Darter (blue) hogchoker (red). River Station (9).

Seines and fyke nets

Overall Patterns

Mean annual seine catch rates were generally higher than trawl catch rates (Table 25). The long-term trend of seine catches shows a stable pattern of catches amidst inter-annual variability (Figures 165). The overall pattern shows a very slight increase in catches over the course of the survey, although 2017 had below average abundance (Figure 165). 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 25). The number of seine tows over the period of record is shown in Table 26. Fyke nets collected more specimens in 2017 than the previous year, and similar to abundances in previous years. Collections were dominated by sunfishes. Like previous years, the relative contribution of other species in fyke nets is different than collected with trawl or seine nets. The fyke nets mainly represents SAV-associated species such as Banded Killifish and several species of sunfishes.

Table 25. Mean Catch per Seine of Selected Adult and Juvenile Fishes at all Stations and all Months. 1985-2017.

Year	All Species	White Perch	Banded Killifish	Blueback Herring	Alewife	All Alosa Spp	Spottail Shiner	Inland Silverside
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	0.2	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	230.4	37.8	139.9	1.2	6.7	9.0	10.7	6.6
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	107.5	14.1	37.0	19.5	1.6	21.1	5.0	16.1
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	215.1	31.7	44.1	71.8	0.2	71.9	18.8	6.5
1990	118.4	41.1	27.6	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	49.0	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	19.9
1985	120.2	36.8	11.7	0.0	0.1	0.2	13.2	29.3

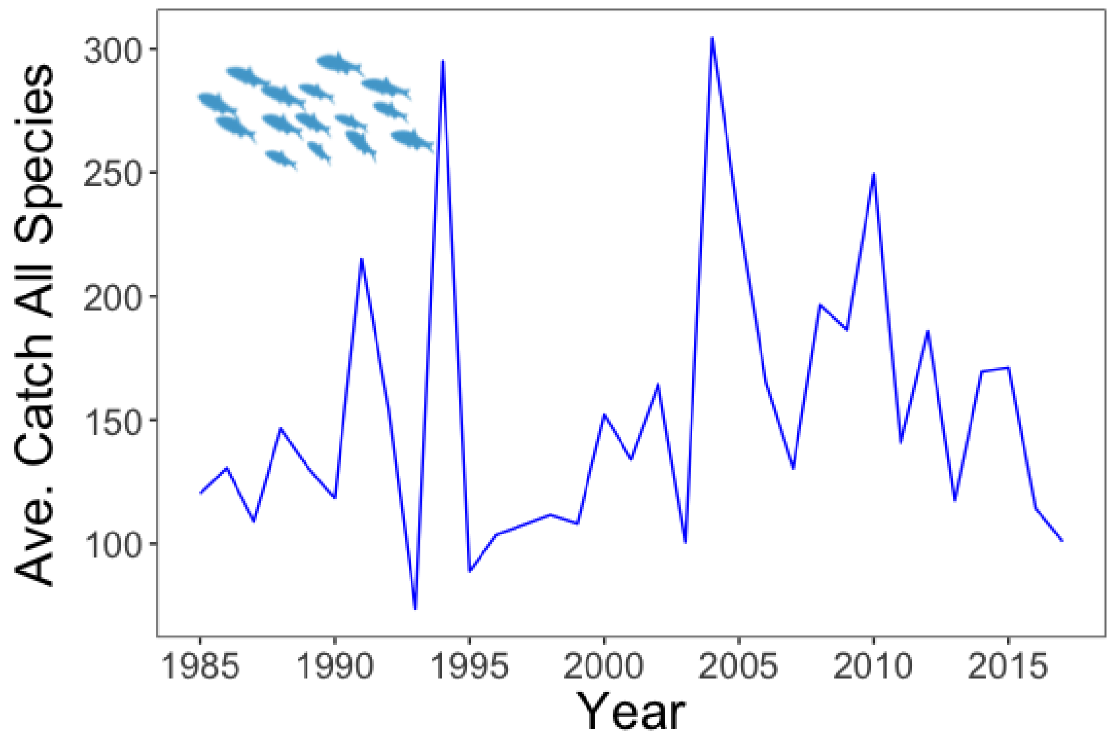


Figure 165. Seines. Annual Average over Stations 4, 4A, 6, and 11. All Species. 1985-2017.

Table 26. The number of seines in each month at Station 4, 4B, 6, and 11 in each year. 1985-2017.

Year	Station	1	2	3	4	5	6	7	8	9	10	11	12
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
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	0	0	0	0	0
2005	6	0	0	0	1	2	2	1	0	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
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	2	2	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
1991	6	0	0	1	1	1	1	1	1	1	1	0	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

Overall, Banded Killifish and White Perch have been the dominant species in seine samples throughout the survey. In 2017, the general trend of decreasing White Perch catches and increasing Banded Killifish catches over the period of record continues (Figure 166). 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, and a new stable state in the relative contribution of these two species may have been reached. Subsequent years will determine whether this is indeed the case.

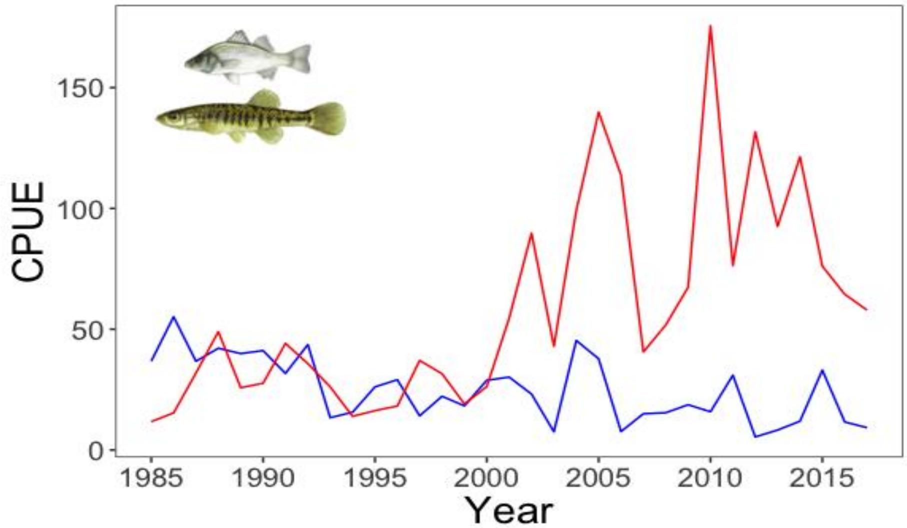


Figure 166. Seines. Annual Average Stations 4, 4A, 6, and 11. White Perch (blue) and Banded Killifish (red). 1985-2017.

Over the course of the survey mean annual seine catch rates of White Perch have exhibited a gradual decline (Figures 166). An important factor is the pronounced increase in SAV, which until 2012 was not effectively sampled and could potentially represent a significant alternative habitat for White Perch. 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). 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 is present within the SAV beds as well. Fyke nets did efficiently sample the SAV beds, and were dominated by SAV-associated species like Banded Killifish and sunfishes. Additional abundant species in the fyke nets in 2017 were Inland Silverside and Goldfish. 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.

Long-term trends in mean annual catch rates for the two dominant species in seine hauls have exhibited a negative association (r=-0.427) over the course of the survey. White Perch mean catches have declined steadily since the beginning of the survey, while Banded Killifish numbers have increased since the start of the survey, and experienced a prominent increase since 1999 (Figure 166).

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.

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 159). Typically, less than 10 of either species were captured in a single sample. Though very variable, long-term trends indicate a decline in overall catches of Alewife and Blueback Herring. These species are both 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. If successful, the moratorium (on fishing) may results in an increase in river herring over time in future years. We added the category ‘all *Alosa sp*.’ to Figure 167 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, and 2015. 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. The abundances in 2016 and 2017 were lower than 2015 again, but still relatively high compared to the average of the period of record (see Anadromous Report).

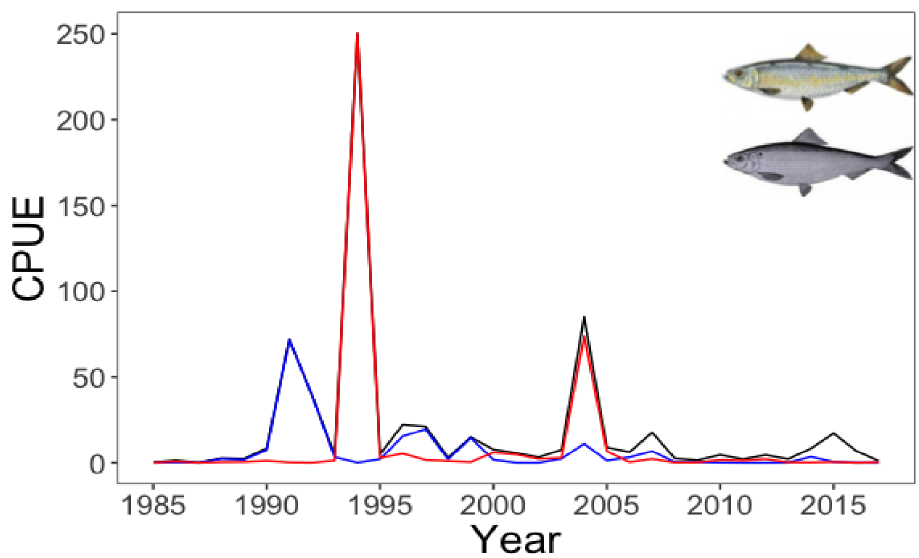


Figure 167. Seines. Annual Average over 4, 4A, 6, and 11 Stations. Blueback Herring (blue), Alewife (red), and all Alosa sp (black; Blueback Herring, Alewife, Hickory Shad, American Shad, and unidentified Herring and Shad species). 1985-2017.

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 168). Highest peaks occurred in 1999 and 2004 for Inland Silverside and Spottail Shiner respectively (Figure 168). After these high peaks, Inland Silverside remains relatively abundant with small peaks in 2006, 2008, 2012, and 2017, while Spottail Shiner decreases. Like 2016, Inland Silverside had a high abundance in the fyke nets, and was the third most abundant species in fyke nets in 2017. While the fyke nets did capture a high proportion of Spottail Shiner in 2014, only five were collected in 2017. With the variable record within the SAV-beds as represented by the fyke net catches, similar to the record of trawl catches, these species do not seem to have particularly concentrated in SAV beds, but rather have remained moderately abundant throughout the Cove and the survey when all gear is considered.

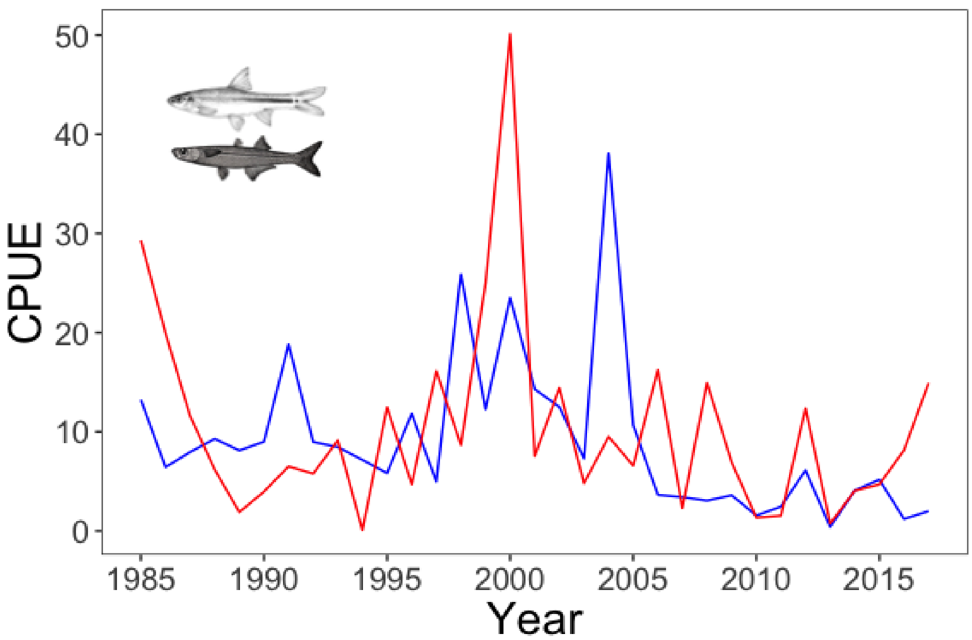


Figure 168. Seines. Annual Average over 4, 4A, 6, and 11 Stations. Spottail Shiner (blue) and Inland Silverside (red). 1985-2017.

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. 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. More fyke net collections 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.

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 could be an indication of the start of a recovery since a moratorium on fishing was imposed in 2012. However, the numbers were not as high in 2016 and 2017. The large cohort of spawning adults of Blueback Herring and Alewife in Accotink Creek and Pohick Creek, as reported in the 2015 Anadromous Report, could be the start of increasing numbers in years to come.

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 this year by calculating the Simpson's Index of Diversity for each year from 1984 to 2017 (Figure 169). The Simpson's Index of Diversity (calculated as $1-(\boldsymbol{\Sigma}\ (n_i/N)^2)$) was 0.75 in 2017, and shows no increasing or decreasing trend over time. In this index the communities with higher diversity have higher values (approaching 1). Calculating the index shows that the Cove represents a healthy and stable diversity. Overall, the fish species found in Gunston Cove are characteristic of Potomac River tributaries.

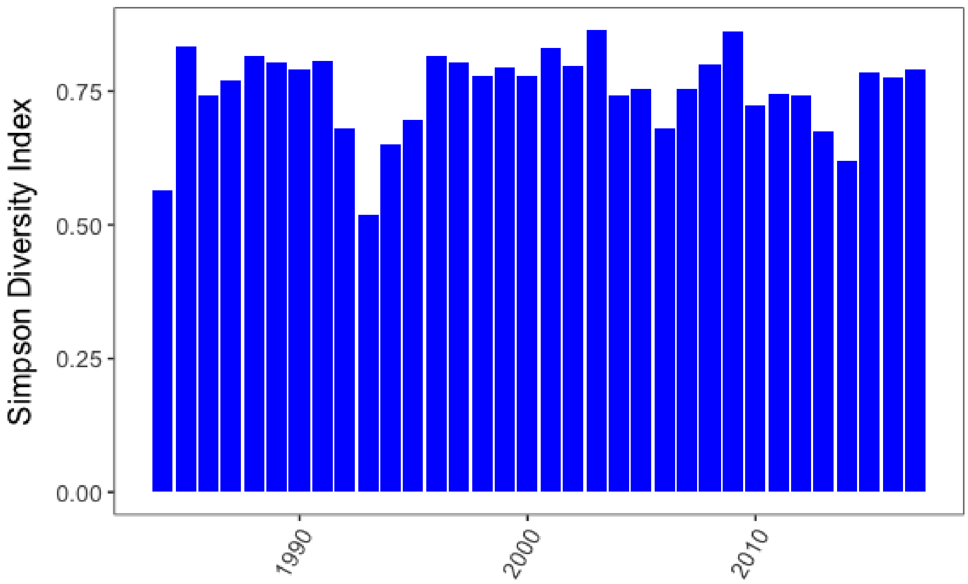


Figure 169. Simpsons Diversity Index of fish species collected in Gunston Cove from 1984-2017.

Summary

In 2017 ichthyoplankton was dominated by clupeids, most of which were Alewife, Gizzard Shad and Blueback Herring, and to a lesser extent, American Shad, and Hickory Shad. White Perch was relatively dominant as well, but with an order of magnitude lower abundance than clupeids. Sunfishes and Inland Silverside was found in relatively high densities as well. *Morone* species (White Perch and Striped Bass) were mostly found in the Potomac mainstem, confirming their affinity for open water. Other taxa were found in very low densities similar to previous years. Larval density showed two distinct peaks in 2017, one at the start of May and one mid-June. Both peaks are driven by Clupeids, with the Alewife and Blueback herring larvae mostly represented with the first peak, and Gizzard Shad larvae with the second peak. 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). 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 collected mostly several species of sunfish and Banded Killifish, which are indeed species know to be associated with SAV.

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) may be able to sustain the Alosine populations at higher levels than before 2015. We might see the cohort that was spawn in 2015 return to spawn themselves in 2018. 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.

G. Submersed Aquatic Vegetation (SAV) Trends: 1994-2017

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. Maps of SAV coverage in the Gunston Cove area are available on the web site for the years 1994-2016 except for 2001 and 2011. Data was not available in 2011 due to severe weather and poor imagery issues. A plot of SAV vs. Chlorophyll *a* and Secchi disk depth revealed that chlorophyll remained at near record low levels in 2016 and that Secchi depth was near its all-time high (Figure 170). These values reflect the sustained partial recovery of Gunston Cove from eutrophication.

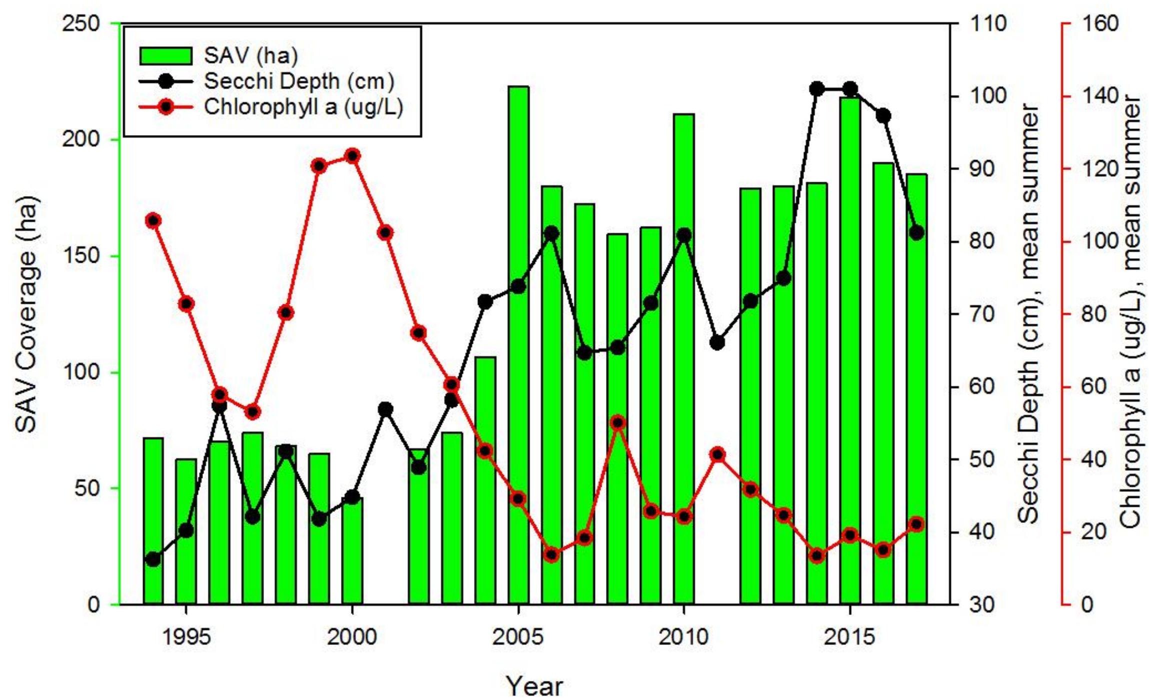


Figure 170. Gunston Cove SAV Coverage. Graphed with average summer (June-September) Depth-integrated Chlorophyll a (µg/L) and Secchi Depth (cm) measured at Station 7 in Gunston Cove. (2016 values are estimates).

H. Benthic macroinvertebrates

Benthic invertebrates have been monitored in a consistent fashion since 2009. Those data are assembled below (Table 27) and trends are generally consistent among years. The composition of the benthic macroinvertebrate community at these two sites 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 SAV has become more established gastropods are becoming more abundant an chironmids (midge larvae) are declining. In the river sediments are coarser and are comprised of a mixture of bivalve shells (mainly *Corbicula*) and sand/silt. This type of substrate is supportive of a wider array of species.

Oligochaetes are generally the most abundant taxon at both stations. In 2012 and 2013 chironomids were the most abundant taxa, but they declined strongly in 2014 and 2015. Amphipods are have generally occurred sporadically at low levels in the cove, but in substantial numbers in the river. In 2014 amphipods were the most abundant organism in the river, but returned to second place in 2015, 2016 and 2017. Isopods have been commonly found in the river since 2010 and sporadically in the cove; they reached their highest densities in both sites in 2016. Turbellaria (flatworms) and Hirundinea (leeches) are found in low numbers sporadically at both sites and were present in several river samples in 2014. The consistent finding of even small numbers of taxa other than chironomids and oligochaetes in the cove is encouraging and could be the result of improved water quality conditions in the cove.

Table 27. Benthic macroinvertebrates: annual averages (#/petite ponar)

Taxon	Station 7 (#/petite ponar)					Station 9 (#/petite ponar)				
	2009-13 Avg	2014	2015	2016	2017	2009-13 Avg	2014	2015	2016	2017
Oligochaeta	46.2	26.1	45.1	17.2	13.5	69.6	9.7	98.2	39.1	40.4
Amphipoda	1.6	1.7	4.4	3.4	5.5	23.5	32.6	33.9	11.9	10.2
Chironomidae	39.5	2.3	3.7	11.6	2.0	1.3	0.4	5.3	1.1	1.3
Corbicula	0.1	--	0.9	0.8	0.3	8.4	--	3.9	0.9	0.5
Gastropoda	0.4	--	11.9	0.8	0.3	5.2	--	12.4	1.2	0.2
Isopoda	0.02	0.1	0.7	1.2	0.4	1.9	1.7	6.4	6.8	2.1
Turbellaria	0.1	0	0.7	0.5	0	0.7	2.9	6.3	1.1	0
Hirundinea	0.4	0.2	0.6	0.1	0	0.2	1.2	0.1	0	0
Total	88.7	30.4*	68.2	36.4	21.9	111.1	48.5*	217.1	66.3	54.7

For 2009-10, n=8 per station; for 2011-12, n=6 per station; for 2013, 2015 and 2016, n=15 per station; for 2014, n=14 per station.

*Note that molluscs were not enumerated in 2014 due to processing error.

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Anadromous Fish Survey - 2017

Draft Final Report
June 2018

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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. Moreover, a replacement stocking program continues (Jim Cummins, pers. comm.). The Virginia Department of Game and Inland Fisheries has also released some of the larvae at the boat ramp in Pohick Bay Regional Park in Gunston Cove (Mike Odom, USFWS; pers. comm.). Prior to the 1900s, spawning occurred in the river as high as Great Falls (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.

The 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. The 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*). Both 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 2017 sampling are presented below. Since the 2015 report, we have included a summary table 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 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 outdrifting 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. We have continued this sampling protocol in 2017 in Pohick Creek and Accotink Creek.

Methods

We conducted weekly sampling trips from March 24th to May 25th in 2017. 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 20 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 attached to the net opening was multiplied with a factor of 0.0049 to gain volume filtered (m^3). Larval density ($\#/10m^3$) per species was calculated using the following formula:

Larval density ($\#/10m^3$) = 10N/(0.0049*(flow meter start reading-flow meter end reading))
Where N is the count of the larvae of one species in one sample.
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:
Depth (m) x Width (m) x Velocity (m/s) = Discharge (m^3/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. Sampling dates and procedures completed during each sampling event are listed in Table 1.

Table 1. Procedures completed each sampling date

Date	Pohick Creek Block net	Pohick Creek Plankton nets	Pohick Creek Cross-section	Pohick Creek YSI	Accotink Creek Block net	Accotink Creek Plankton nets	Accotink Creek Cross-section	Accotink Creek YSI
3/24/17	Y	Y	Y	Y	Y	Y	Y	Y
3/31/17	Y	Y	Y	Y	Y	Y	Y	Y
4/7/17	N*	Y	Y	Y	N*	Y***	Y	Y
4/14/17	Y	Y	Y	Y	Y	Y	Y	Y
4/20/17	Y	Y	Y	Y	Y	Y	Y	Y
4/27/17	Y	Y	Y	Y	Y	Y	Y	Y
5/4/17	Y	Y	Y	Y	Y	Y	Y	Y
5/11/17	N*	N**	N**	N**	N*	Y***	N*	Y
5/18/17	Y	Y	Y	Y	Y	Y	Y	Y
5/25/17	N*	Y****	N*	Y	N*	Y	N*	Y

*Water flow was too high to safely set the block net or cross the creek to conduct a cross-section.
** Could not gain access to the site due to weather conditions.
*** Plankton Tow was shortened to 15 minutes due to high amount of debris in samples.
****Plankton Tow was shortened to 10 minutes due to high amount of debris in samples.

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. Our identification skills have improved over the time of the survey, and we do now distinguish Alewife from Blueback Herring in the larval stage as well as the adult stage. With the improved identification skills, we discovered that Blueback Herring sightings are common enough in our samples 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 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 were 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 or were dying in the net 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):
Egg # = -90,098 + 588.1(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 7 out of the 10 weeks, we approximated total abundance of spawning Alewife and Gizzard Shad 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:
Total catch/168 hours * 1680 hours = 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 Gizzard Shad 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 (probably otters) tearing holes in our nets in early 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 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 2017 spanned a total of 10 weeks, during which we collected 38 ichthyoplankton samples, and 7 adult (block net) samples. We collected less adult clupeids than we did in 2015, which saw unprecedented high numbers, but more than we did in the years prior to 2015 (since the consistent block net collection method started in 2008) and similar to 2016. 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 captured 5 adult Hickory Shad specimens in Pohick Creek.

The abundance of confirmed *Alosa* larvae was a little bit lower than last year (144 versus 184 last year). There were more unidentified clupeids, with 683 unidentified clupeids versus 108 last year, which could be *Alosa* or *Dorosoma*; Gizzard Shad). The unidentified larvae were too damaged to be identified to the species level, which likely occurred through a combination of high flow and high larval densities in the net. We also collected 44 identified Gizzard Shad larvae. We found that the *Alosa* larvae consisted of Blueback Herring and Alewife larvae (Table 2). Like last year, we did find adults of Hickory Shad, but no larvae.

Table 2. Larval and adult abundances of clupeids collected in both creeks in 2017.

	Pohick		Accotink	
Species	# Larvae	# Adults	# Larvae	# Adults
Alewife	98	73	41	17
Blueback Herring	1	24	4	0
Hickory Shad	0	5	0	0
Gizzard Shad	12	6	32	2
Unknown Clupeid	77	0	606	0

In 2017, as well the three previous years, *Dorosoma cepedianum* (Gizzard Shad) larvae were not the most abundant anymore. This is a good sign, since the reason for that are the increases in anadromous Alosines in our samples.

We measured creek discharge at the same locations and times where ichthyoplankton samples were taken. Discharge was more variable in Accotink Creek than Pohick Creek and ranged from 0.16 to 10.62 $m^3 s^{-1}$, while Pohick Creek ranged from 1.36 to 9.48 $m^3 s^{-1}$. Both creeks showed a similar discharge pattern though (Figure 2). On average and as in previous years, the discharge in Accotink Creek was lower than in Pohick Creek, with 2.07 $m^3 s^{-1}$ in Accotink Creek and 3.81 $m^3 s^{-1}$ in Pohick Creek. Average flow was higher in both creek than previous year. 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 12.5 and 20.7 million cubic meters for Accotink and Pohick creeks, respectively (Table 3).

Larval density of Alewife exhibited a peak in Accotink Creek in mid-April and mid-May (Figure 3a). Larval densities in Pohick Creek were lower and showed a small peak in mid-April. Given the observed mean densities of larvae and the total discharge, the total production of Alewife larvae was estimated at over 5 million and close to 4 million for Accotink Creek and Pohick Creek, respectively (Table 3). Blueback Herring larval density was lower leading to total larval production estimates of 983 thousand and 20 thousand for Accotink Creek and Pohick Creek, respectively.

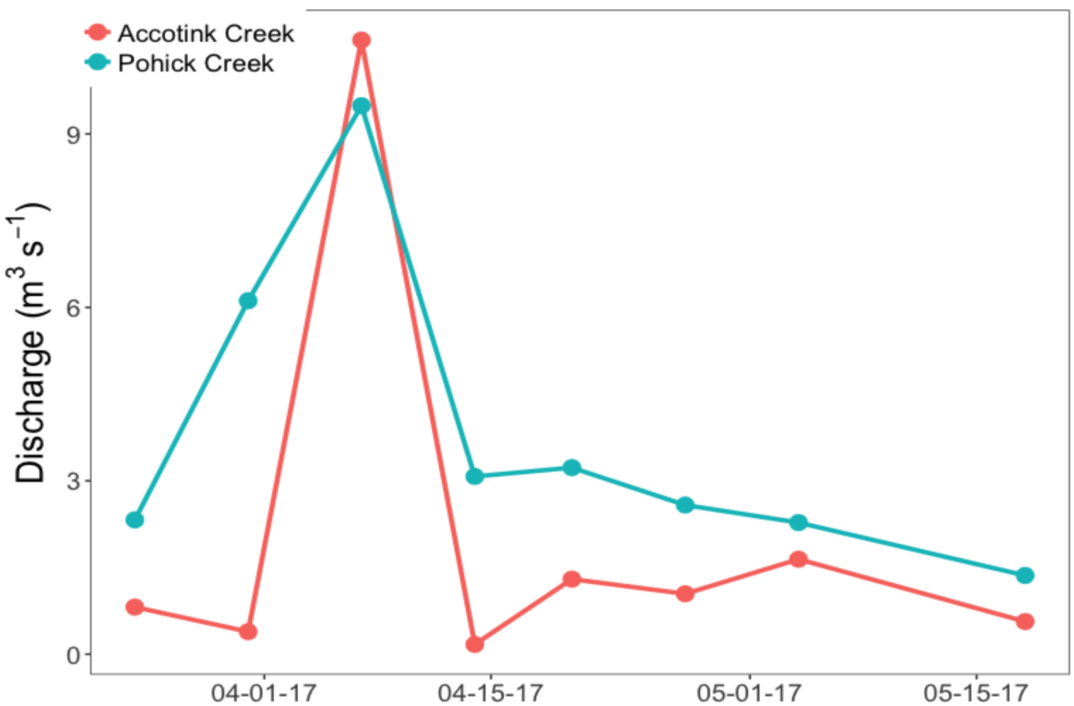

Figure 2. Discharge rate measured in Pohick and Accotink creeks during 2017.

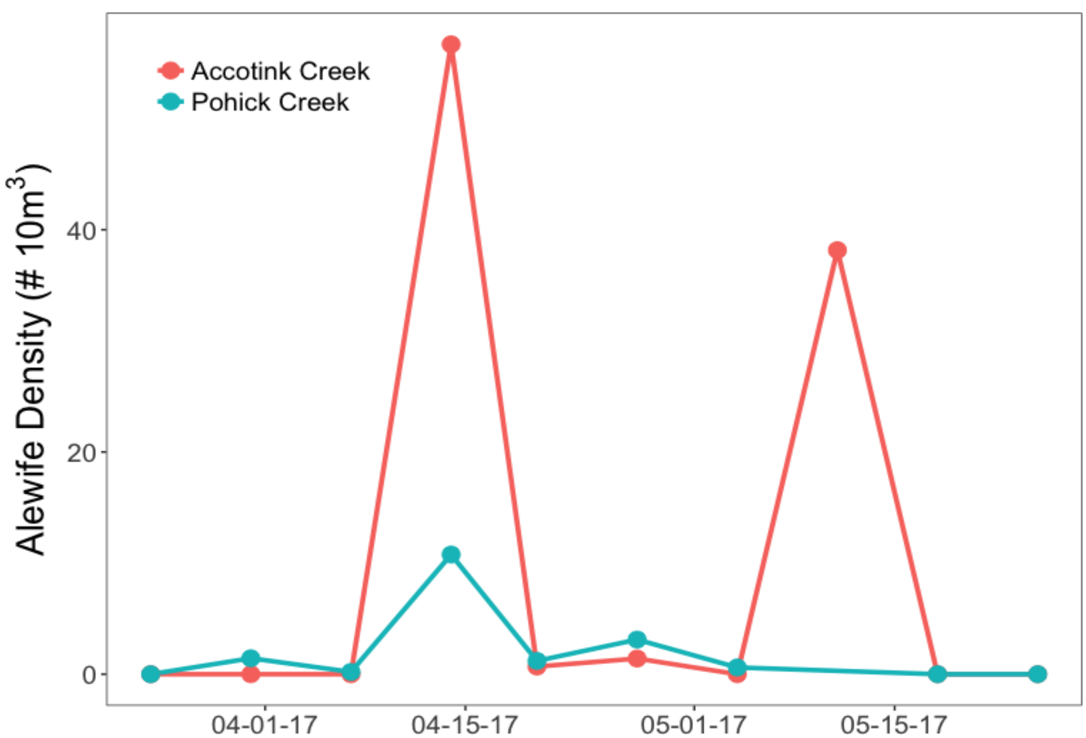

Figure 3a. Density of larval alewife in # 10 m^{-3} observed in Pohick Creek and Accotink Creek in 2017.

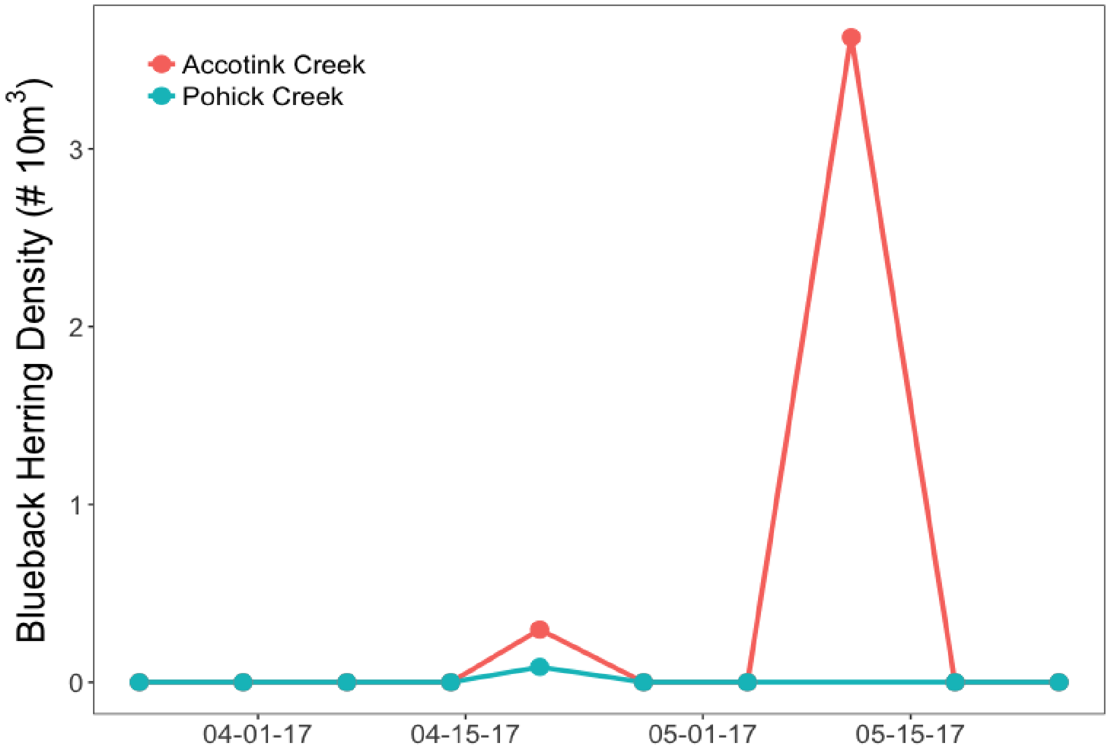

Figure 3b. Density of larval blueback herring in # 10 m^{-3} observed in Pohick Creek and Accotink Creek in 2017.

Table 3. Estimation of Alewife and Blueback Herring fecundity and spawner abundance from Accotink and Pohick creeks during spring 2017.

	Accotink Creek	Pohick Creek
Mean discharge (m^3 s^{-1})	2.07	3.806
Total discharge (m^3)	12,519,360	20,716,819
Alewife		
Mean density of larval Alewife (10 m^{-3})	4.026	1.926
Total Larval Production	5,040,795.11	3,989,138.63
Adult Alewife Mean Standard Length (mm)	248.35	222.89
Alewife Fecundity	88,586.11	71,333.19
Sex Ratio	NA*	0.074
Estimated number of female Alewife	NA*	54
Estimated total number of Alewife	170	730
Blueback Herring		
Mean density of larval Blueback (10 m^{-3})	0.3924	0.0096
Total Larval Production	982,519.37	19,796.07
Adult Blueback Mean Standard Length (mm)	NA**	212.83
Blueback Fecundity	NA**	64,514.79
Sex Ratio	NA**	0.263
Estimated number of female Blueback	NA	63
Estimated total number of Blueback	NA	240

*No adult female Alewife were collected in Accotink Creek
**No adult Blueback Herring were captured in Accotink Creek block nets.

In the block nets, a moderately high number of adults were captured for both Alewife and Blueback Herring; 90 and 24 respectively (Table 2). Both species were collected in unprecedented high numbers in 2015 relative to the rest of the period of record, and like 2016, the abundance was a lot lower again in 2017. Of those captured, 33 Alewife and 14 Blueback Herring were sexed, providing us with sex ratios (Table 3). We were unable to get a sex ratio in Accotink creek this year. Skewed sex ratios in fish populations are common. The total abundance of spawning Alewife was estimated to be 730 in Pohick Creek during the period of sampling, and 170 in Accotink Creek. The size of the spawning population of Blueback Herring could not be measured in Accotink Creek because we didn’t collect any adults (but must have been present because larvae were found), and 240 in Pohick Creek this year. Table 4 shows a summary of adult clupeid abundance collected in block nets from 2008-2017.

Table 4. Total adult catch per year using blocknets during the spawning season of four Clupeid species that occur in this area.

	Pohick Creek				Accotink			
Year	Blueback Herring	Hickory Shad	Alewife	Gizzard Shad	Blueback Herring	Hickory Shad	Alewife	Gizzard Shad
2008	0	0	8	2	0	0	0	0
2009	0	0	36	2	0	0	7	1
2010	0	31	110	0	0	0	77	0
2011	6	6	60	22	1	12	47	42
2012	7	3	58	5	0	0	12	2
2013	4	0	53	17	0	1	29	2
2014	18	6	61	21	0	1	8	28
2015	613	209	595	130	2	0	379	68
2016	80	21	94	8	9	0	76	108
2017	24	5	73	6	0	0	17	2

Discussion

We caught 90 adult Alewife and 24 adult Blueback Herring; we have positively identified Blueback Herring in this survey since 2011. We also collected 5 Hickory Shad. These numbers are an order of magnitude lower than what we collected in 2015, but not on the low end compared to what we have observed since at least 2008. The high abundance in 2015 could have been a combination of a strong year class, and the moratorium put in place in 2012. The estimated size of the spawning population of Alewife is still close to a thousand fishes in 2017. We estimated about a quarter of that for Blueback Herring, which were found in Pohick Creek only this year. This is likely a temperature effect. Blueback Herring prefer to spawn at higher temperatures than Alewife; >13 °C versus >10.5 °C for Alewife (Fay et al. 1983). By receiving effluent for the Noman Cole pollution control plant, Pohick creek is slightly warmer than Accotink Creek. A spawning population of Blueback Herring has firmly established in at least Pohick Creek since 2011, and we will continue to provide population parameters of Blueback Herring in our reports, rather than Gizzard Shad (which is not a river herring).

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 moratoria. The moratoria prohibit 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 (while the moratoria are 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, it would be interesting to see if the strong year class of 2015 results in strong return in 2018.

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 saw here in 2015; 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. The reduced numbers in 2016 and 2017 as compared to 2015 may be the result of a density-dependent effect. The current available habitat or resources may not have been able to support an order of magnitude larger river herring population, and the numbers declined again because of that. 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). For the Gunston Cove watershed, 2015 was a highly productive year, and 2017 was less productive, but still above the 2008-2014 average (Figure 4). While it is too soon to tell what the long-term effects of the moratorium will be, and to what extent it affects the abundances in Potomac River tributaries, continued monitoring will determine whether some pattern of higher abundances is maintained in subsequent years.

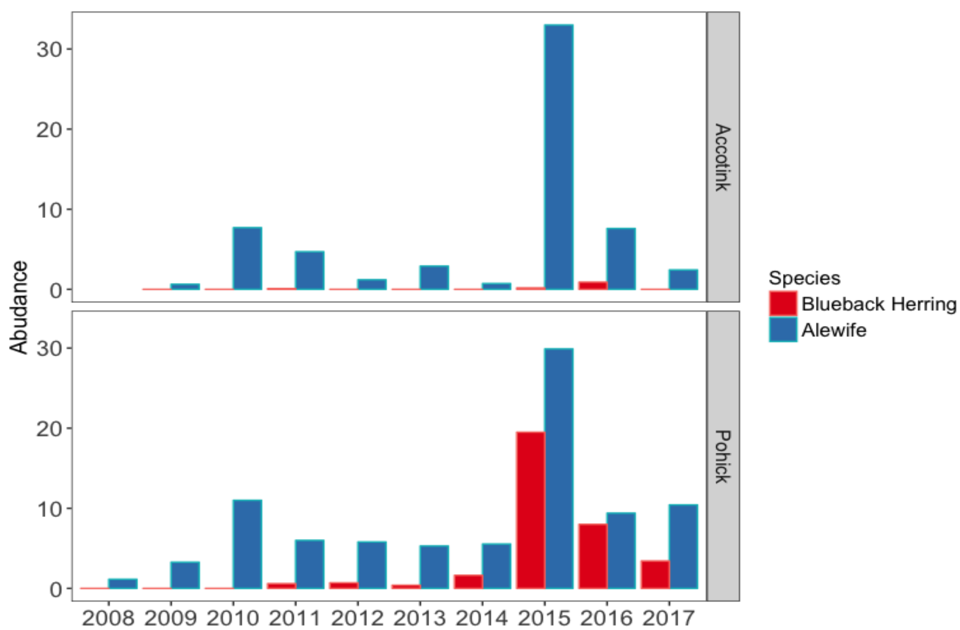

Figure 4. Abundance in catch per unit effort of Alewife and Blueback Herring collected with the block net in each year.

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Development of a Benthic Index of Biotic Integrity for the Tidal Freshwater Potomac River
2017

Draft Final Report
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Introduction

Biological communities may serve as excellent indicators of the quality of environment as bioindicators.. Bioindicators represent the impact of environmental stress on a habitat, community or ecosystem (Mcgeoch 1998; Hodkinson and Jackson 2005). The utility of using aquatic invertebrates for assessing environmental conditions has been widely recognized, and a variety of biological monitoring tools are based on aquatic invertebrates (Hellawell 1986; Rosenberg and Resh 1993; Hodkinson and Jackson 2005). Benthic aquatic communities, in particular, have proved useful as most members are fixed in location. Therefore, their presence is related to the overall conditions at that site. Benthic macroinvertebrates are among the most useful of all indicator organisms and are the community of choice in the bioassessment of flowing streams worldwide. This is because they have life cycles which are long enough to integrate over a significant amount of time but can recolonize an area relatively quickly if conditions improve. In addition, aquatic insect larvae as also used as bioindicators because they are abundant, easily collected, and represent the trophic connection between and lower plants and higher trophic predators (Hodkinson and Jackson, 2005). For example, the presence of the orders Ephemeroptera, Plecoptera and Trichoptera (EPT; mayfly, stonefly and caddisfly) in aquatic environments indicates good water quality as they are sensitive to pollution (Rosenberg and Resh 1993; Siegloch et al. 2017). Some species of chironomid (midge larvae) are more pollution tolerant and found in both good quality and bad quality water (Halpern and Senderovich 2015). In comparison, taxa groups such as Oligochaetes (i.e., worms) are found in poor quality water with low dissolved oxygen and high organic load. Thus, the presence and absence of such benthic invertebrates are good bioindicators of water body health. Biomonitoring these species, including examining community characteristics such as abundance, diversity, and richness, can be an invaluable way to track trends in water quality over time.

While examining the macroinvertebrate communities over time can give some indication of overall changes, the magnitude of those changes in relation to particular stressors is hard to pinpoint without an adequate undisturbed habitat with which to compare. Therefore, establishment of similar reference sites relatively free of stressors (e.g., anthropogenic) provides a way to document site-level changes to macroinvertebrate communities on a temporal scale. Such a method is called an index of biotic integrity, or IBI. The index assigns categorical values for different metrics (e.g., habitat, water quality, macroinvertebrate taxa diversity and abundance) by comparison with observations at reference sites. In general, higher IBI scores represent unimpaired or unstressed benthic community conditions.

Previously, we examined existing efforts which have been made to develop benthic indices of biotic integrity (B-IBIs) for tidal freshwater systems. In this report, we add to our compiled list of benthic taxa that have been found historically or are currently being collected in the tidal freshwater habitats of the Potomac River. The complete list is found at the end of this chapter (Appenix C-1) In addition, we met with several researchers in the local area to gauge interest in this project. We conducted a synoptic study encompassing 17 sites on the tidal freshwater

Potomac to get a fuller picture of the communities over the entire area.

Synoptic Survey in Potomac River mainstem and embayments

In order to obtain a better knowledge of the range of benthic invertebrate communities in the tidal freshwater Potomac River, we conducted a synoptic survey of most of the embayments and selected river sites. Triplicate petite ponar samples were collected at 17 sites along the Potomac River in October 2017, between Broad Creek (most northern) and the mainstem off Quantico Creek (most southern) (Table C-1). The total abundance and abundance by taxonomic groups is shown in Figure C-1 to C-3).

Taxonomic Groups: Annelid worms (including Oligochaetes, Polychaetes, and Leeches) were found in high numbers (total N = 2,478) over all the sites combined. Overall, they accounted for 64% of all benthic organisms found. Oligochaetes were the dominant taxonomic group, accounting for 63.3% of individuals.

Crustaceans (including Gammarid amphipods and isopods) were the second highest in abundance across all of the sites, accounting for 14% of all individuals (N = 553). Gammarid amphipods (scuds) dominated this group, accounting for 81.6% of all crustaceans observed.

The remainder of the taxonomic groups accounted for minor components of the overall diversity. These included Bivalvia (N = 88; 2.3% of total abundance), Platyhelminthes (i.e., flatworms) (N = 214; 5.5%), Insecta (N = 327; 8.4%), and Gastropods (N = 210; 5.4%). The bivalve group was dominated by the invasive Asian clam, *Corbicula fluminea*, which accounted for 86.4% of all bivalves documented. Other individuals were from the family Sphaeriidae and Unionidae. The gastropod (i.e., snails) group was composed of taxa from Valvatidae, Viviparidae, Coenidae, Pleuroceridae, Viviparidae, Physa, and Hydrobiidae. The most dominant family was Hydrobiidae, accounting for 84.76% of all gastropods found. Insects from multiple orders were found, but they were dominated by Chironomids (midges) which accounted for 95.4% of all insects. The remainder was composed of small numbers of phantom midges, damselflies, dragonflies, and caddisflies.

Spatial trends: The total and average abundance of organisms was highest at the mainstem site off of Quantico Creek (QT) (n=690) and lowest at Mattawoman Creek (MC) (n=48). There were no significant differences in benthic macroinvertebrate abundances, for total and each individual taxa group, between mainstem (n=5) and embayment (n=12) sites (Wilcoxon / Kruskal-Wallis Rank Sum Test, $p > 0.05$). The apparent large difference in total abundance of benthic macroinvertebrates between mainstem and embayment sites is due mostly to higher abundances of Annelids in mainstem sites.

Community comparisons: To investigate differences in benthic macroinvertebrate community composition, abundance of broader taxonomic groupings was fourth-root-transformed to decrease the importance of very abundant taxa. Transformed values were used to create a resemblance matrix using S17 Bray–Curtis similarity index (Bray & Curtis, 1957). These data were compared using site identification and overall location (M= mainstem, E= embayment) as factors, and non-metric multidimensional scaling plots (MDS) were generated to visualize differences. One-way analysis of similarity (ANOSIM) was used to determine whether significant differences in taxa assemblages existed between sites and, more broadly, between mainstem and embayment sites. SIMPER analysis was conducted on the fourth-root-transformed data to determine which taxa were driving the differences observed. ANOSIM, MDS and SIMPER analyses were performed using PRIMER 6 (Clarke & Gorley, 2006).

Results of the MDS analysis is presented in Figures C-4 and C-5. There was an overall significant difference in the benthic macroinvertebrate community between the 17 sites (Global R=0.629, p=0.001). The two taxa groups contributing most to the dissimilarity between sites were the Platyhelminthes and the Crustaceans (isopods and amphipods), which were the most variable in abundance of all the taxonomic groups. For example, Platyhelminthes ranged in abundance from 0 to 172 (found at 24% of sites), while crustaceans ranged from 0 to 228 (found at 59% of sites). In comparison, there was no significant difference in the benthic macroinvertebrate community between mainstem (n=5) and embayment (n=12) sites (Global R= 0.115, P=0.061).

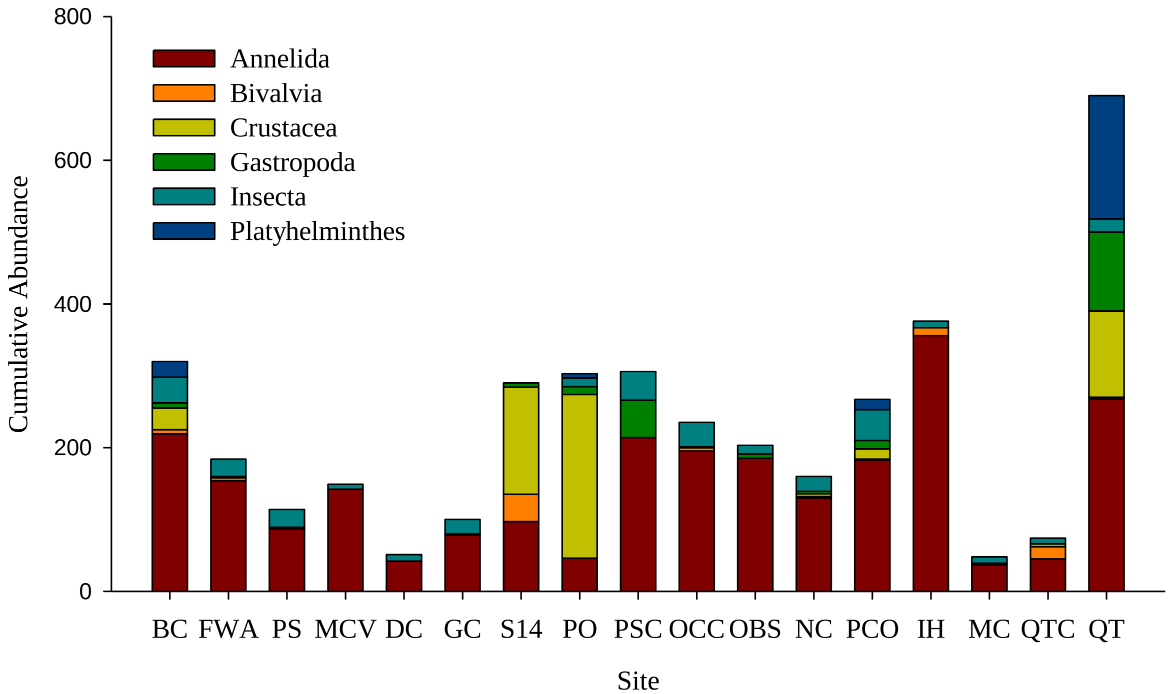

Figure C-1. Total abundance of benthic macroinvertebrate taxa in petite ponar samples collected in October 2017 separated by site, listed by the most northern (Broad Creek) to the most southern site (mainstem off of Quantico Creek). (n=3 for each station)

Site ID	Description	Mainstem or Embayment	GPS coordinates	Water Depth (m)	Sampling Date	Abundance: Total, average ± SE	Taxa Richness: Total, average ± SE
BC	Broad Creek	E	38º 41.963N, 77º 01.347W	1.3	Oct 6	320, 107 ± 17	6, 5.7 ± 0.3
FWC	Fort Washington Channel	M	38º 42.542N, 77º 02.605W	10.5	Oct 6	184, 61 ± 11	5, 3.7 ± 0.3
PS	Piscataway Creek	E	38º 41.963N, 77º 01.347W	1.3	Oct 6	114, 38 ± 4	4, 2.7 ± 0.3
MVC	Mount Vernon Channel	M	38º 41.920N, 77º 04.359W	7.8	Oct 6	149, 50 ± 8	2, 2 ± 0
DC	Dogue Creek	E	38º 41.859N, 77º 07.329W	1.5	Oct 23	51, 17 ± 2	2, 2 ± 0
GC	Gunston Cove Station 7	E	38º 40.573N, 77º 09.431W	2.4	Oct 23	100, 33 ± 6	3, 2.3 ± 0.3
S14	Belvoir Peninsula	M	38º 40.565N, 77º 07.417W	5	Oct 23	290, 97 ± 47	4, 4 ± 0
PO	Pomonkey Creek	E	38º 38.089N, 77º 06.322W	1.5	Oct 23	303, 101 ± 15	5, 4.3 ± 0.7
PSC	Potomac Science Center	E	38º 39.451N, 77º 14.045W	0.6	Oct 23	306, 102 ± 32	3, 3 ± 0
OCC	Occoquan Bay	E	38º 37.761N, 77º 13.896W	2	Oct 23	235, 78 ± 19	4, 2.7 ± 0.7
OBS	Occoquan Bay South	E	38º 36.555N, 77º 14.507W	2	Oct 23	203, 68 ± 9	3, 2.7 ± 0.3
NC	Neabsco Creek	E	38º 36.127N, 77º 15.671W	0.5	Oct 23	160, 53 ± 10	5, 3.3 ± 0.3
PCO	Powells Creek	E	38º 34.959N, 77º 15.682W	0.8	Oct 23	267, 89 ± 15	6, 5.3 ± 0.3
IH	Indian Head Channel	M	38º 34.235N, 77º 13.216W	4	Oct 23	376, 125 ± 17	3, 3 ± 0
MC	Mattawoman Creek	E	38º 33.922N, 77º 11.239W	1.5	Oct 23	48, 16 ± 6	3, 2 ± 0.6
QTC	Quantico Creek	E	38º 31.276N, 77º 16.545W	8.8	Oct 23	290, 97 ± 47	4, 3 ± 0.6
QT	Mainstem of Quantico Creek	M	38º 31.127N, 77º 17.289W	0.7	Oct 23	690, 230 ± 87	6, 5 ± 0.6

Table C-1. Sites sampled in October 2017, listed from north to south. Three replicate petite ponar grabs were conducted at each site. Total, average, and standard error (SE) are listed for both total abundance of benthic macroinvertebrates and taxa richness. Taxa richness is defined at the higher classification as Annelida, Bivalvia, Crustacea, Gastropoda, Insecta, and Platyhelminthes (max taxa richness of 6).

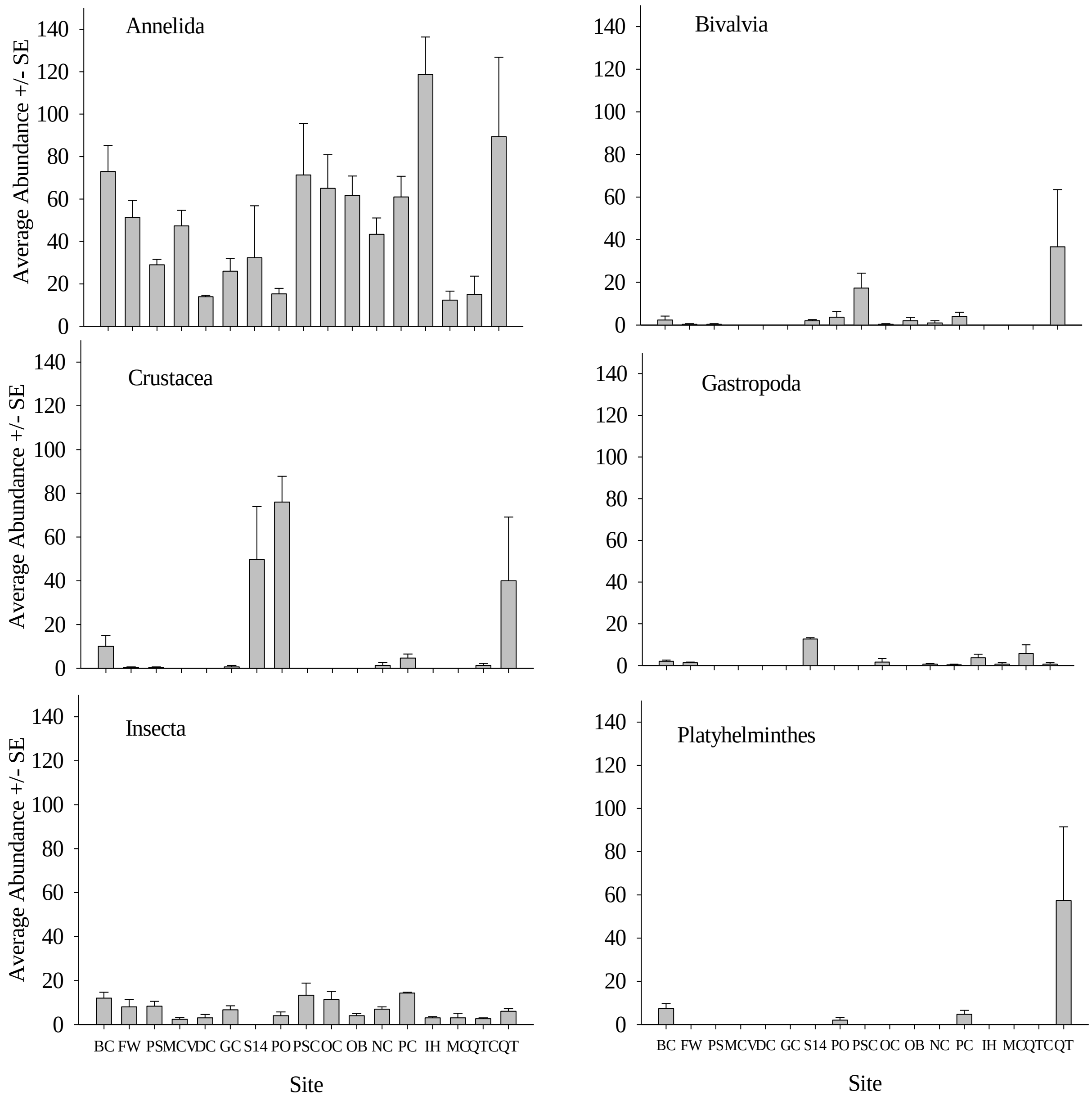

Figure C-2. Average abundance (± standard error) of benthic macroinvertebrate taxa in petite ponar samples collected in October 2017 separated by site, listed by the most northern (Broad Creek) to the most southern site (mainstem off of Quantico Creek), and by taxonomic group.

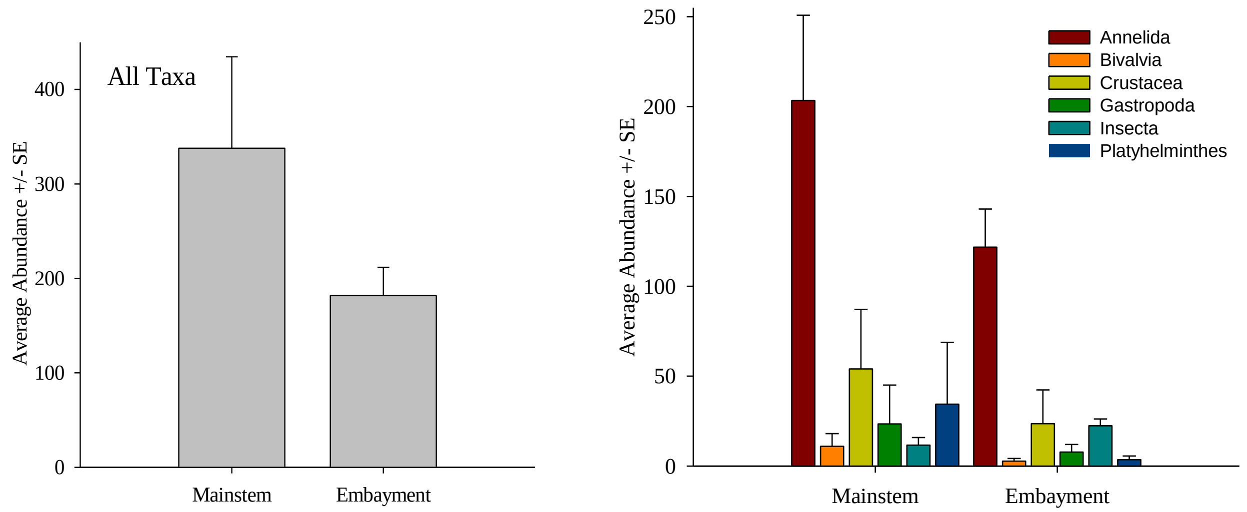

Figure C-3. Average abundance (± standard error) of benthic macroinvertebrate taxa in petite ponar samples collected in October 2017 separated by whether the site was in the Potomac mainstem (n=5) or in an embayment (n=12) (left) and by taxonomic group (right). There were no significant differences (p<0.05) in benthic macroinvertebrate abundances between mainstem and embayment sites.

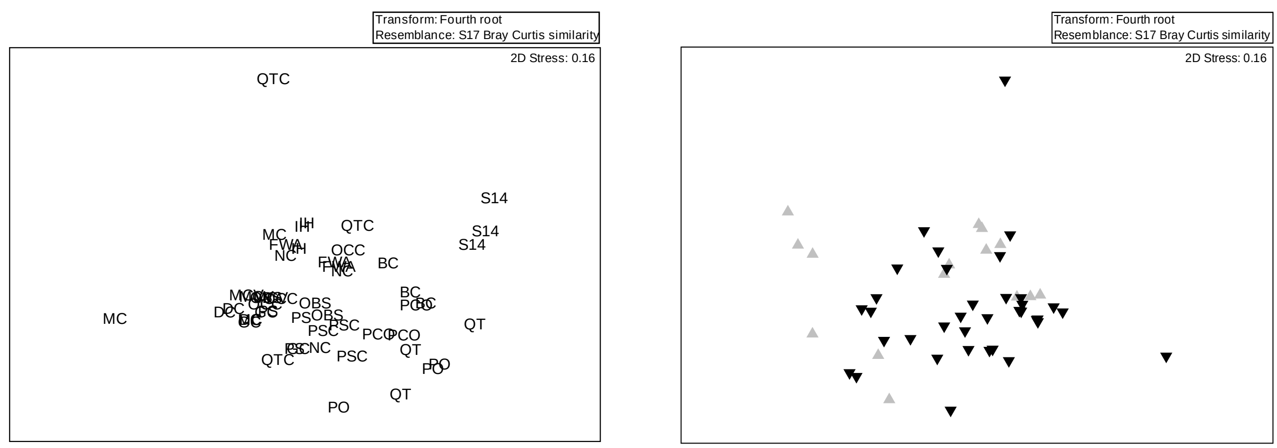

Figure C-4. Multidimensional scaling plot of abundances of benthic macroinvertebrate taxa in petite ponar samples sampled in the Potomac River during October 2017. Sites that are closer together have more similar communities in terms of both diversity and abundance. Left) At the site level (n=17; Global R=0.629, p=0.001). Right) Comparing mainstem (grey) to embayment (black) sites (Global R= 0.115, p=0.061).

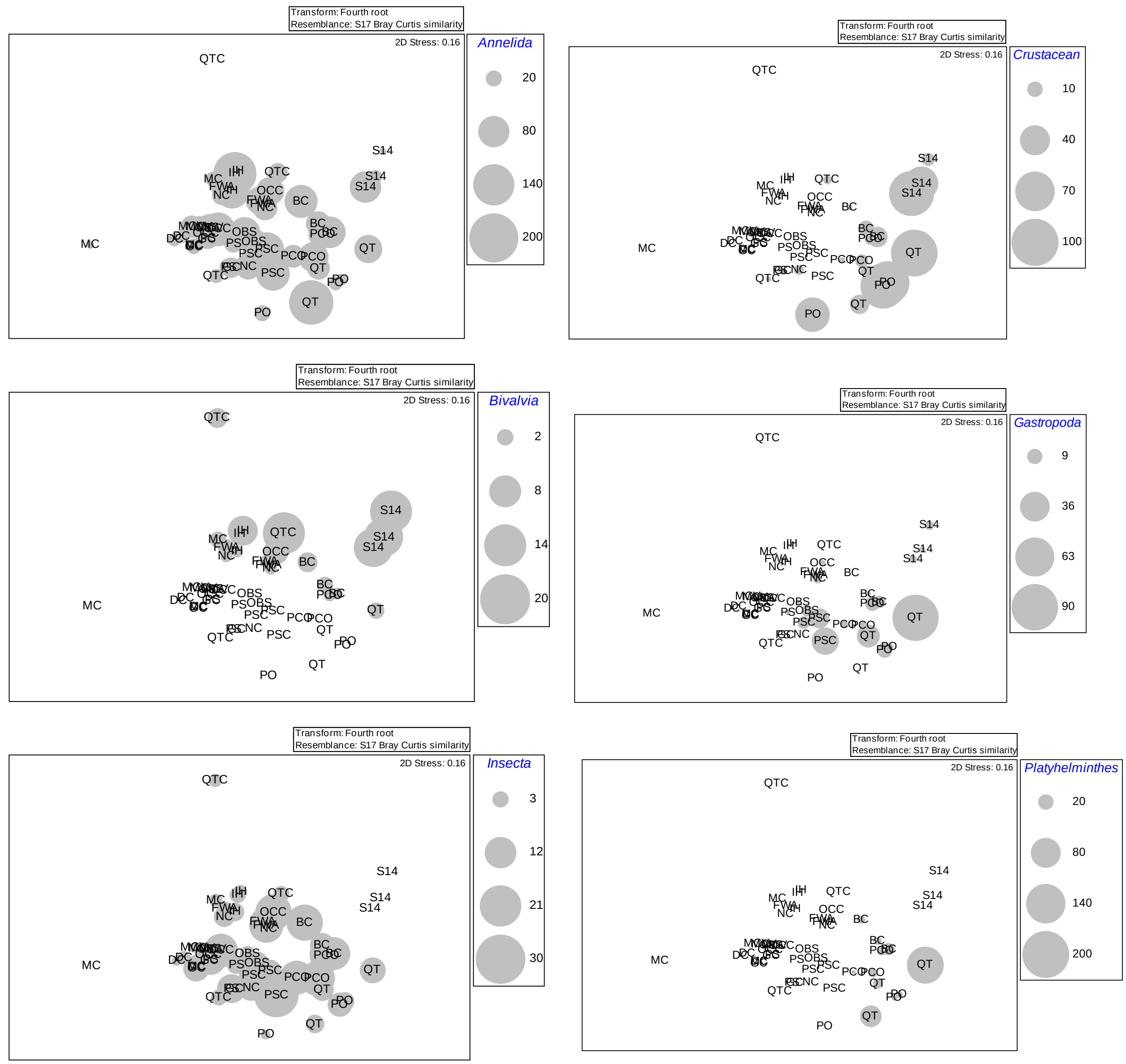

Figure C-5. Multidimensional scaling plot of abundances of benthic macroinvertebrate taxa in petite ponar samples sampled in the Potomac River during October 2017. Sites that are closer together have more similar communities in terms of both diversity and abundance. Data are presented by taxonomic group, and grey circles denote the relative abundance between taxonomic groups and sites. Note differences in abundances between taxonomic groups.

Goals for next year

The work that we completed this year has greatly expanded our knowledge and perspective on benthic communities in the tidal freshwater Potomac River. We recommend that this project be continued. Goals for next year would be:

- Completion of the taxa list
  - -Resample selected sites from 2017
  - -Identify and sample less impacted sites like those on the Rappahannock
- Develop and calibrate metrics
- Formulate and test the B-IBI

We expect to be able to accomplish many of these goals. As we work through them, we may find that further data must be collected to create a valid index. In that case our report next year will identify further work that must be done.

Appendix C-1. Benthic macroinvertebrate taxa (n=197) reported from the tidal freshwater Potomac River, along with their reported tolerance values (TV), trophic groups (TG), and habits. Habit abbreviations: BU = Burrower; SW = Swimmer; CN = Clinger; CB = Clinger Burrower; SP = Sprawler. Trophic group abbreviations: CG = Collector Gatherer; PR = Predator; SH = Shredder; CF = Collector Filterer; SC = Scraper Grazer; CL = Climber. Reference abbreviations: 1-Gunston Cove Study Reports (Jones et al. 2017 and previous). 2-Lippson et al. 1981. 3-Thorp et al. 1997. 4- Chesapeake Bay Program monitoring database (US EPA 2017).

Phylum	**Class**	**Order**	**Family**	**Taxon Name**	**TV**	**TG**	**Habit**	**Ref(s)**
Annelida	Clitellata	Haplotaxida	Enchytraeidae	Enchytraeidae	8	CG	BU	4
Annelida	Clitellata	Haplotaxida	Lumbricidae	Lumbricidae	8	CG	BU	4
Annelida	Clitellata	Haplotaxida	Naididae	*Arcteonais lomondi*	8	CG	BU	4
Annelida	Clitellata	Haplotaxida	Naididae	*Dero*	8	CG	BU	4
Annelida	Clitellata	Haplotaxida	Naididae	*Ilyodrilus templetoni*	8	CG	BU	4
Annelida	Clitellata	Haplotaxida	Naididae	*Limnodrilus cervix*	8	CG	BU	4
Annelida	Clitellata	Haplotaxida	Naididae	*Nais simplex*	8	CG	BU	4
Annelida	Clitellata	Haplotaxida	Naididae	*Ophidonais serpentina*	8	CG	BU	4
Annelida	Clitellata	Haplotaxida	Naididae	*Paranais litoralis*	8	CG	BU	4
Annelida	Clitellata	Haplotaxida	Naididae	*Stylaria lacustris*	8	CG	BU	4
Annelida	Clitellata	Haplotaxida	Naididae	*Tubificoides*	8	CG	BU	4
Annelida	Clitellata	Haplotaxida	Tubificidae	*Aulodrilus limnobius*	8	CG	BU	4
Annelida	Clitellata	Haplotaxida	Tubificidae	*Branchiura sowerbyi*	8	CG	BU	4
Annelida	Clitellata	Haplotaxida	Tubificidae	*Limnodrilus*	8	CG	BU	4
Annelida	Clitellata	Haplotaxida	Tubificidae	*Quistradrilus*	8	CG	BU	4

				multisetosus				
Annelida	Clitellata	Haplotaxida	Tubificidae	Tubificidae	8	CG	BU	4
Annelida	Clitellata	Hirudinida	Glossiphoniidae	Glossiphoniidae	8	PR	SP, SW, CL	2,3
Annelida	Clitellata	Hirudinida	Piscicolidae	Piscicolidae	7	PR	SP, SW, CL	2
Annelida	Clitellata	Lumbriculida	Lumbriculidae	Lumbriculidae	8	CG	BU	4
Annelida	Clitellata	Oligochaeta	Aeolosomtidae	Aeolosomtidae	10	CG	BU	2
Annelida	Clitellata	Tubificida	Naididae	*Aulodrilus pigueti*	10	CG	BU	4
Annelida	Clitellata	Tubificida	Naididae	*Bothrioneurum vejdovskyanum*	10	CG	BU	4
Annelida	Clitellata	Tubificida	Naididae	*Isochaetides freyi*	10	CG	BU	4
Annelida	Clitellata	Tubificida	Naididae	*Limnodrilus hoffmeisteri*	10	CG	BU	4
Annelida	Clitellata	Tubificida	Naididae	*Piguetiella michiganensis*	10	CG	BU	4
Annelida	Clitellata	Tubificida	Naididae	*Stephensoniana trivandrana*	10	CG	BU	4
Annelida	Polychaeta	Phyllodocida	Nereididae	*Neanthes succinea*		CG	BU	4
Annelida	Polychaeta	Spionida	Spionidae	*Boccardiella ligerica*		CG	BU	4
Annelida	Polychaeta	Spionida	Spionidae	*Marenzelleria viridis*		CG	BU	4
Annelida	Polychaeta	Spionida	Spionidae	*Polydora cornuta*		CG	BU	4
Annelida	Polychaeta	Spionida	Spionidae	*Streblospio benedicti*		CG	BU	4
Arthropoda	Arachnida	Trombidiformes	Hydrachnidae	Hydrachnidae	6	PR	CL, SW	1,3
Arthropoda	Entognatha	Collembola	Bourletiellidae	*Bourletiella*				4
Arthropoda	Entognatha	Symphypleona	Sminthuridae	Sminthuridae				4
Arthropoda	Hexanauplia	Sessilia	Balanidae	*Balanus improvisus*				4
Arthropoda	Insecta	Anisoptera	Aeshnidae	Aeshnidae	3	PR	CL	4
Arthropoda	Insecta	Anisoptera	Aeshnidae	*Boyeria*	5	PR	CL	4
Arthropoda	Insecta	Anisoptera	Cordulegastridae	Cordulegastridae	3	PR	BU	4
Arthropoda	Insecta	Anisoptera	Corduliidae	Corduliidae	5	PR	CL	4
Arthropoda	Insecta	Anisoptera	Gomphidae	Gomphidae	3	PR	BU	4
Arthropoda	Insecta	Coleoptera	Dytiscidae	Dytiscidae	5	PR	SW	4
Arthropoda	Insecta	Coleoptera	Elmidae	*Dubiraphia*	6	CG	CN	4
Arthropoda	Insecta	Coleoptera	Elmidae	Elmidae	4	SC; CG	CN	1,4

Arthropoda	Insecta	Coleoptera	Elmidae	*Macronychus*	0	CG	CN	4
Arthropoda	Insecta	Coleoptera	Elmidae	*Microcylloepus*	2	SC	CN	4
Arthropoda	Insecta	Coleoptera	Elmidae	*Optioservus*	4	SC	CN	4
Arthropoda	Insecta	Coleoptera	Elmidae	*Oulimnius*	5	SC	CN	4
Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis*	5	SC	CN	4
Arthropoda	Insecta	Coleoptera	Psephenidae	Psephenidae	4	SC	CN	4
Arthropoda	Insecta	Coleoptera	Ptilodactylidae	*Anchytarsus*	4	SH	CN	4
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogonidae	6	PR	SP	1,4
Arthropoda	Insecta	Diptera	Ceratopogonidae	*Dasyhelea*	6	CG	SP	4
Arthropoda	Insecta	Diptera	Ceratopogonidae	*Probezzia*	6	PR	BU	4
Arthropoda	Insecta	Diptera	Chaoboridae	*Chaoborus punctipennis*	8	PR	SP	1,4
Arthropoda	Insecta	Diptera	Chironomidae	*Ablabesmyia mallochi*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Chironominae*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Chironomini*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Chironomus*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Coelotanypus*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Cricotopus (isocladius)*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Cryptochironom us*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Cryptotendipes*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Diamesinae*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Dicrotendipes*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Dicrotendipes neomodestus*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Dicrotendipes nervosus*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Glyptotendipes*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Harnischia*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Microchironomu s*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Micropsectra*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Nanocladius*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Nanocladius crassicornus*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Orthocladiinae*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Parachironomus*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Parachironomus monochromus*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Paracladopelma*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Polypedilum*	6	CG	BU	4

				halterale				
Arthropoda	Insecta	Diptera	Chironomidae	*Procladius*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Rheotanytarsus*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Stictochironomus caffarius*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Tanytarsini*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Chironomidae	*Tanytarsus*	6	CG	BU	4
Arthropoda	Insecta	Diptera	Empididae	*Chelifera*	6	PR	SP	4
Arthropoda	Insecta	Diptera	Empididae	Empididae	6	PR	SP	4
Arthropoda	Insecta	Diptera	Empididae	*Hemerodromia*	6	PR	SP	4
Arthropoda	Insecta	Diptera	Ephydridae	*Ephydridae*	7	CG	BU	1,4
Arthropoda	Insecta	Diptera	Limoniidae	*Antocha*				4
Arthropoda	Insecta	Diptera	Phoridae	Phoridae	0			4
Arthropoda	Insecta	Diptera	Ptychopteridae	Ptychopteridae	8	CG		4
Arthropoda	Insecta	Diptera	Simuliidae	*Prosimulium*	4	CF	CN	4
Arthropoda	Insecta	Diptera	Simuliidae	Simuliidae	6	CF	CN	1,4
Arthropoda	Insecta	Diptera	Tabanidae	Tabanidae	6	PR	SP	4
Arthropoda	Insecta	Diptera	Tipulidae	*Antocha sp.*	4	SH	BU	1
Arthropoda	Insecta	Diptera	Tipulidae	*Tipula*	6	SH	BU	4
Arthropoda	Insecta	Diptera	Tipulidae	Tipulidae	3	SH	BU	1,4
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Acentrella*	5	CG	SW	4
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Acerpenna*	5	CG	SW	4
Arthropoda	Insecta	Ephemeroptera	Baetidae	Baetidae	4	CG, SC	SW; CN	1,3,4
Arthropoda	Insecta	Ephemeroptera	Caenidae	*Caenis*	6	CG	SP	3,4
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	*Ephemerella*	1	CG	CN	4
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Ephemerellidae	3	CG; SC	CN	4
Arthropoda	Insecta	Ephemeroptera	Ephemeridae	Ephemeridae	4	CG	BU	3,4
Arthropoda	Insecta	Ephemeroptera	Ephemeridae	*Hexagenia*	6	CG	BU	4
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Heptageniidae	4	SC	CN	4
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	*Stenonema*	3	SC	CN	4
Arthropoda	Insecta	Ephemeroptera	Isonychiidae	*Isonychia*	4	CF	SW	4
Arthropoda	Insecta	Ephemeroptera	Isonychiidae	Isonychiidae		CF	SW	4
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	*Habrophlebia*	4	O	SW	4
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Leptophlebiidae	2	CG	SW	4
Arthropoda	Insecta	Hemiptera	Corixidae	Corixidae	5	PR	SW	4
Arthropoda	Insecta	Lepidoptera	Noctuidae	Noctuidae				4
Arthropoda	Insecta	Megaloptera	Corydalidae	Corydalidae	5	PR	CN	4
Arthropoda	Insecta	Megaloptera	Corydalidae	*Nigronia*	5	PR	CN	4

Arthropoda	Insecta	Megaloptera	Sialidae	Sialidae	4	PR	BU	4
Arthropoda	Insecta	Megaloptera	Sialidae	*Sialis*	6	PR	BU	4
Arthropoda	Insecta	Plecoptera	Chloroperlidae	Chloroperlidae	1	PR	CN	4
Arthropoda	Insecta	Plecoptera	Nemouridae	*Amphinemura*	3	SH	SP	4
Arthropoda	Insecta	Plecoptera	Nemouridae	Nemouridae	2	SH	SP	4
Arthropoda	Insecta	Plecoptera	Nemouridae	*Shipsa*				4
Arthropoda	Insecta	Plecoptera	Perlidae	*Perlesta*	4	PR	CN	4
Arthropoda	Insecta	Plecoptera	Perlidae	Perlidae	1	PR	CN	4
Arthropoda	Insecta	Plecoptera	Perlodidae	*Clioperla*	1	PR	CN	4
Arthropoda	Insecta	Plecoptera	Perlodidae	Perlodidae	2	PR	CN	4
Arthropoda	Insecta	Trichoptera	Glossosomatidae	*Glossosoma*	1	SC	CN	4
Arthropoda	Insecta	Trichoptera	Glossosomatidae	Glossosomatidae	0	SC	CN	4
Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	6	CF	CN	4
Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Diplectrona*	4	CF	CN	4
Arthropoda	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	5	CF	CN	1,4
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Hydropsychidae	5	CF	CN	4
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilidae	4	PH	CL	1,3
Arthropoda	Insecta	Trichoptera	Leptoceridae	Leptoceridae	4	CG	CL	1,3
Arthropoda	Insecta	Trichoptera	Philopotamidae	*Dolophilodes*	1	CF	CN	1,4
Arthropoda	Insecta	Trichoptera	Philopotamidae	Philopotamidae	3	CF	CN	4
Arthropoda	Insecta	Trichoptera	Polycentropodidae	Polycentropodidae	6	CF	CN	4
Arthropoda	Insecta	Trichoptera	Psychomyiidae	Psychomyiidae	2	CG		4
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	*Rhyacophila*	3	PR	CN	4
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Rhyacophilidae	3	PR	CN	4
Arthropoda	Insecta	Trichoptera	Uenoidae	Uenoidae	4	SC		4
Arthropoda	Insecta	Zygoptera	Calopterygidae	*Calopteryx*	6	PR	CL	1,4
Arthropoda	Insecta	Zygoptera	Coenagrionidae	*Amphiagrion*	5	PR	CL	1
Arthropoda	Insecta	Zygoptera	Coenagrionidae	*Argia*	6	PR	CN	1,3,4
Arthropoda	Insecta	Zygoptera	Coenagrionidae	Coenagrionidae	9	PR	CL	4
Arthropoda	Insecta	Zygoptera	Coenagrionidae	*Enallagma*	8	PR	CL	4
Arthropoda	Malacostraca	Amphipoda	Corophiidae	*Apocorophium lacustre*				4
Arthropoda	Malacostraca	Amphipoda	Corophiidae	*Leptocheirus plumulosus*				4
Arthropoda	Malacostraca	Amphipoda	Crangonyctidae	Crangonyctidae	4	CF; CG	SP; SW	4
Arthropoda	Malacostraca	Amphipoda	Crangonyctidae	*Stygobromus*	5	PR	SP	1
Arthropoda	Malacostraca	Amphipoda	Crangonyx	*Crangonyx*	6	CG	SP; SW	4
Arthropoda	Malacostraca	Amphipoda	Gammaridae	*Gammarus*	6	O	SP; SW	1,2,4
Arthropoda	Malacostraca	Amphipoda	Gammaridae	*Gammarus daiberi*	6	O	SP; SW	4

Arthropoda	Malacostraca	Amphipoda	Gammaridae	*Gammarus fasciatus*	6	O	SP; SW	4
Arthropoda	Malacostraca	Amphipoda	Hyallelidae	*Hyalella*	8	CG	SP; SW	1,2
Arthropoda	Malacostraca	Amphipoda	Oedicerotidae	*Monoculodes*				2
Arthropoda	Malacostraca	Amphipoda	Talitridae	Talitridae	8	CG	SP; SW	1
Arthropoda	Malacostraca	Decapoda	Cambaridae	Cambaridae	5	CG; SH	BU, CL, SW	4
Arthropoda	Malacostraca	Isopoda	Anthuridae	*Cyathura polita*				1,4
Arthropoda	Malacostraca	Isopoda	Asellidae	*Asellus*	8	CG	SP	1,2
Arthropoda	Malacostraca	Isopoda	Chaetiliidae	*Chiridotea almyra*				2,4
Arthropoda	Malacostraca	Isopoda	Sphaeromatidae	*Cassidinidea ovalis*				4
Entoprocta	NA	NA	Pedicellinidae	Pedicellinidae				2
Entoprocta	Phylactolaemata	Plumatellida	Lophopodidae	Lophopodidae				2
Mollusca	Gastropoda	Basommatophora	Ancylidae	*Ferrissia rivularis*	6	SC	BU, CN	1,2,4
Mollusca	Gastropoda	Caenogastropoda	Viviparidae	*Campeloma decisum*	3	SC	BU, CN	4
Mollusca	Gastropoda	Cerithioidea	Pleuroceridae	Pleuroceridae	4	SC	BU, CN	1,4
Mollusca	Gastropoda	Littorinimorpha	Amnicolidae	*Amnicola*		SC	BU, CN	2,4
Mollusca	Gastropoda	Lymnaeoidea	Lymnaeidae	Lymnaeidae	7	SC	BU, CN	1,2,4
Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae	*Amnicola limosa*	3	SC	BU, CN	4
Mollusca	Gastropoda	Neotaenioglossa	Pleuroceridae	*Goniobasis virginica*	4	SC	BU, CN	4
Mollusca	Gastropoda	Planorboidea	Physidae	*Physa*	8	SC	BU, CN	1,2,4
Mollusca	Gastropoda	Planorboidea	Physidae	*Physella*	8	SC	BU, CN	4
Mollusca	Gastropoda	Planorboidea	Planorbidae	*Gyraulus*	7	SC	BU, CN	4
Mollusca	Gastropoda	Planorboidea	Planorbidae	*Laevapex fuscus*	7	SC	BU, CN	4
Mollusca	Gastropoda	Planorboidea	Planorbidae	*Menetus*	7	SC	BU, CN	1,2,4
Mollusca	Gastropoda	Rissooidea	Hydrobiidae	Hydrobiidae	3	SC	BU, CN	1,3
Mollusca	Gastropoda	Rissooidea	Hydrobiidae	*Littoridinops tenuipes*	3	SC	BU, CN	4
Mollusca	Gastropoda	Valvatoidea	Valvatidae	*Valvata sincera*	8	SC	BU, CN	1,4

Mollusca	Gastropoda	Viviparoidea	Viviparidae	Viviparidae	3	SC	BU, CN	1,4
Mollusca	Pelecypoda	Imparidentia	Mactridae	*Rangia cuneata*		CF	BU	2,4
Mollusca	Pelecypoda	Unionoida	Unionidae	*Elliptio complanata*	4	CF	BU	4
Mollusca	Pelecypoda	Unionoida	Unionidae	Unionidae	4	CF	BU	2,4
Mollusca	Pelecypoda	Veneroida	Cyrenidae	*Corbicula fluminea*	6	CF	BU	1,4
Mollusca	Pelecypoda	Veneroida	Pisidiidae	Pisidiidae	8	CF	BU	4
Mollusca	Pelecypoda	Veneroida	Pisidiidae	*Pisidium*	8	CF	BU	4
Mollusca	Pelecypoda	Veneroida	Sphaeriidae	*Musculium*	8	CF	BU	1,4
Mollusca	Pelecypoda	Veneroida	Sphaeriidae	*Musculium transversum*	8	CF	BU	1,4
Nematoida	Gordioda	Gordea	Gordiidae	Gordiidae				4
Platyhelminthes	Catenulida		Stenostomidae	Stenostomidae	4	CG		2
Platyhelminthes	Rhabditophora	Rhabdocoela		*Rhabdocoela*	4	CG		4
Platyhelminthes	Rhabditophora	Tricladida	Dugesiidae	*Dugesia*	4	CG		1,2,4
Platyhelminthes	Rhabditophora		Macrostomidae	Macrostomidae	4	CG		2
Platyhelminthes	Rhabditophora		Microstomidae	*Microstomum*	4	CG		2
Platyhelminthes	Turbellaria	Tricladida	Planariidae	*Dugesia tigrina*	4	CG		4
Platyhelminthes	Turbellaria			*Turbellaria*	4	CG		4

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Status and Diversity of Native Freshwater Mussels In the Tidal Freshwater Potomac River 2017

Draft Final Report
June 2018

By

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To

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In the 2016 report we presented a complete list of river mussel species know or expected to occur in the tidal freshwater Potomac River. However, we noted that our current ponar grab method for benthic sampling, which works well for overall assessment of the benthic community, is not very effective for the sparsely populated river mussel populations. In the 2017-18 proposal we proposed to conduct field trials of new techniques for sampling that specifically targeted freshwater mussels.

Specifically, we built and used a brail sampler, which has been mentioned in recent research papers and recommended by experts in the field as an effective device to sample mussel populations in deeper waters (US EPA 2013). We constructed an approximately 6 foot long bar that was equipped with 50 chains hanging from it. Each of the pieces of chain had four gauge wire hooks attached. The idea is that as the brail is pulled downstream, the wire hooks drag along the sediment, hold the bar off the bottom, and serve as irritants to any mussels that come in contact with the wire. The mussel will close its valves on the wire, and as the brail continues to be pulled, the mussel is pulled from the substrate.

We used our newly constructed brail sampler to sample 5 different locations in the Potomac River mainstem on October 16, 2017, in locations where we have collected mussels before using our petit ponar grab. In each trial, we dragged the brail sampler behind the boat for approximately 5 minutes at depths between 10 and 20 feet. Unfortunately, we did not capture any mussels using this method.

Upon talking with Dr. Art Bogan, the research curator for molluscs at the North Carolina Museum of Natural Sciences and an international expert on freshwater mussels, we realized that this brail method is usually only effective at sampling mussel populations when densities are relatively high. Dr. Bogan suggested that, if we wanted to specifically target mussels in further sampling, we employ scientific divers to scour the bottom in defined, linear tracks using a randomized transect and quadrat approach. However, owing to the murky water transparency and the hazards of deep diving in areas of poor visibility and tidal currents, this is not practical in the tidal Potomac River. We continue to collect mussels (<5 per year across 20-30 samples) in our petit ponar samples, we recommend that we continue with our established monitoring program and continue to count any freshwater mussels encountered in our abundance and diversity measures. Major changes in mussel occurance and abundance should be detected with the ponar method. We recently discovered a nearshore site along Mason Neck that has an abundance of mussel shells and will be sampled to determine if there are any new taxa there.

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