THE ONGOING AQUATIC MONITORING PROGRAM

FOR THE GUNSTON COVE AREA

OF THE TIDAL FRESHWATER POTOMAC RIVER

2015

DRAFT FINAL REPORT (revised)
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by

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INTRODUCTION

This section reports the results of the on-going aquatic monitoring program for Gunston Cove conducted by the Potomac Environmental Research and Education Center at George Mason University and Fairfax County's Environmental Monitoring Branch. This study is a continuation of work originated in 1984 at the request of the County's Environmental Quality Advisory Committee and the Department of Public Works. The original study design utilized 12 stations in Gunston Cove, the Potomac mainstem, and Dogue Creek. Due to budget limitations and data indicating that spatial heterogeneity was not severe, the study has evolved such that only two stations are sampled, but the sampling frequency has been maintained at semimonthly during the growing season. This sampling regime provides reliable data given the temporal variability of planktonic and other biological communities and is a better match to other biological sampling programs on the tidal Potomac including those conducted by the Maryland Department of Natural Resources and the District of Columbia. Starting in 2004, the sampling period was reduced to April through September and photosynthesis determinations were ended.

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 Shahran Moshsenin 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 Sammy Alexander, Beverly Bachman, Lauren Cross, Chelsea Gray, Larin Isdell, Peter Jacobs, Tabitha King, Casey Pehrson, Kali Rauhe, Kristen Reck, Chelsea Saber, C.J. Schlick, Amanda Sills, Esmael Vafamand, and Avery Wolfe. 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.

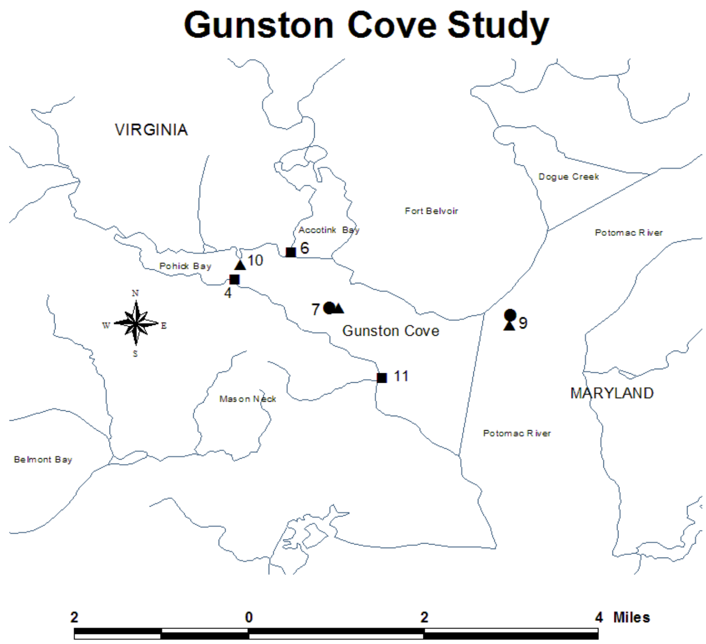


Figure 1a. Gunston Cove area of the Tidal Potomac River showing sampling stations. Circles (●) represent Plankton/Profile stations, triangles (▲) represent Fish Trawl stations, and squares (■) represent Fish Seine stations.

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

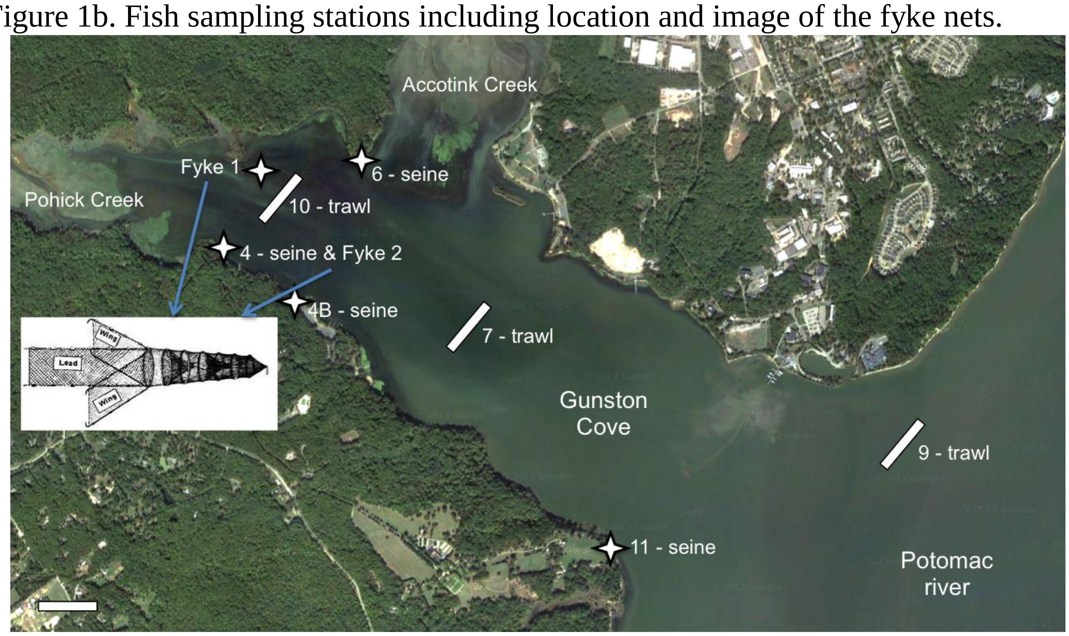


Table 1
Sampling Dates and Weather Data for 2015

	Type of Sampling					Avg Daily Temp (ºC)		Precipitation (cm)	
Date	G	F	T	S	Y	1-Day	3-Day	1-Day	3-Day
April 14			T	S	Y	16.1	16.3	1.63	1.63
April 29	G	F				18.3	15.6	0	T
May 4			T	S	Y	21.1	20.2	0	0
May 12	GB					27.2	25.7	0	0
May 19		F*				27.2	27.0	0	1.94
May 26	G	F	T	S	Y	26.1	23.9	0	0
June 3			T	S	Y	16.7	21.1	0.03	7.52
June 8	GB					25.0	23.9	1.65	1.65
June 17			T	S		26.1	28.9	0.46	0.66
June 23	G	F				30.0	29.8	2.13	2.21
July 1			T	S	Y	26.1	25.4	3.30	3.33
July 7	GB					28.3	27.6	0	0.06
July 15			T	S	Y	26.7	26.9	0.03	0.11
July 21	G	F				30.0	31.3	T	T
July 29		F*				29.4	29.6	0	2.39
August 5			T	S	Y	28.9	29.1	0	0.10
August 11	GB					27.8	26.5	0.86	1.24
August 19			T	S	Y	28.9	28.5	0	0
August 25	G	F,F*				25.0	25.4	0	1.04
Sept 8	GBD					27.8	26.7	0	0
Sept 9			T	S	Y	29.4	28.0	T	T
Sept 22	G	F				20.6	21.3	0	0.58

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) = $NV_s/(V_c V_f)$

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

Ichthyoplankton sample processing began with removal and sorting of larval fish speciments from the 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 4-fyke and 10-fyke (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, and August. Since this thick SAV cover is now annually recurring, we have adjusted our sampling regime in 2012 by adding fyke nets (Figure 1b).

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. Sampling with a fyke net near station 4 has been added since 2012 (Figure 1b).

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 in 2014. Fyke nets were now set in station 4-fyke and station 10-fyke 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 were 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).

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.

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

In 2015 air temperature was above average for most of the year including all of the months when sampling occurred (Table 2). July was the warmest month, over 1°C above normal as was August. April, May, and June were even more above normal, May being 4°C higher than the long term average. There were 41 days with maximum temperature above 32.2ºC (90ºF) during 2015 compared with 4 in 2004, 18 in 2005, 29 in 2006, 33 in 2007, 31 in 2008, 16 days in 2009, 62 in 2010, 42 in 2011, 42 in 2012, 27 in 2013, and 20 in 2014. Precipitation was below normal during May, but over three times normal in June. It was slightly above normal in July and well below normal in August and September. The largest daily rainfall totals were all in the very wet month of June: 6.32 cm (2.49 in) on June 1, 6.02 cm (2.37 in) on June 20 and 6.99 cm (2.75 in) on June 27.

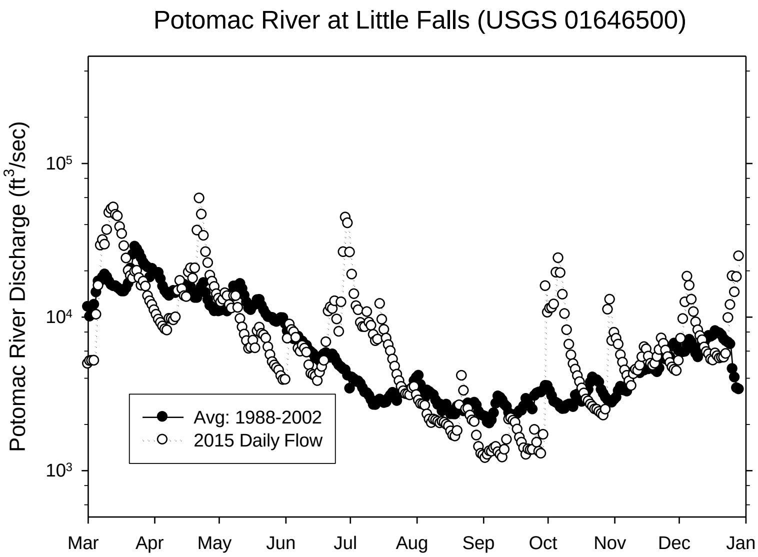
Table 2. Meteorological Data for 2015. National Airport. Monthly Summary.

MONTH	Air Temp (ºC)		Precipitation (cm)	
March	7.4	(8.1)	10.3	(9.1)
April	15.2	(13.4)	8.7	(7.0)
May	22.9	(18.7)	4.9	(9.7)
June	25.2	(23.6)	30.3	(8.0)
July	27.4	(26.2)	12.7	(9.3)
August	26.3	(25.2)	2.9	(8.7)
September	23.8	(21.4)	5.5	(9.6)
October	14.9	(14.9)	8.9	(8.2)
November	12.0	(9.3)	5.3	(7.7)
December	10.7	(4.2)	12.3	(7.8)

Note: 2015 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. (+) 2015 month > 2x Long Term Avg. (-) 2013 month < ½ Long Term Avg.

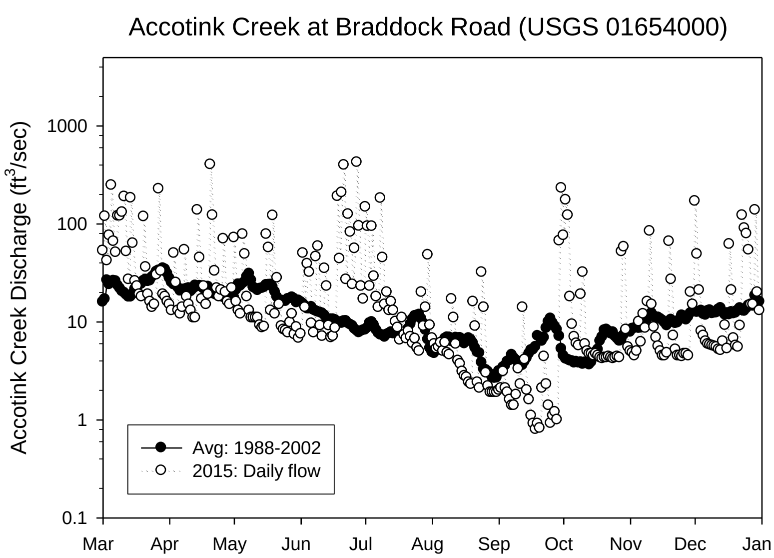
	Potomac River at Little Falls (cfs)		**Accotink Creek at Braddock Rd (cfs)**	
	2015	**Long Term Average**	**2015**	**Long Term Average**
March	23816	23600	70.5	42
April	18146	20400	42.7	36
May	8526	15000	24.0	34
June	10105	9030	69.4 (+)	28
July	8020	4820	29.4	22
August	2245 (-)	4550	6.2 (-)	22
September	1983 (-)	5040	12.0 (-)	27
October	7504	5930	21.6	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: Potomac River at Little Falls (USGS Data). Month tick is at the beginning of the month.

Potomac River discharge during 2015 was near normal in March and April, but well below normal in May (Table 2). June and July were above normal with August and September again low. An especially large and extended peak was found in late June and early July (Figure 2). Accotink Creek flows followed a similar pattern with exceptionally high flows in June and July and low flows in August (Figure 3). Throughout the year there were large, short lived flow peaks due to individual storms.



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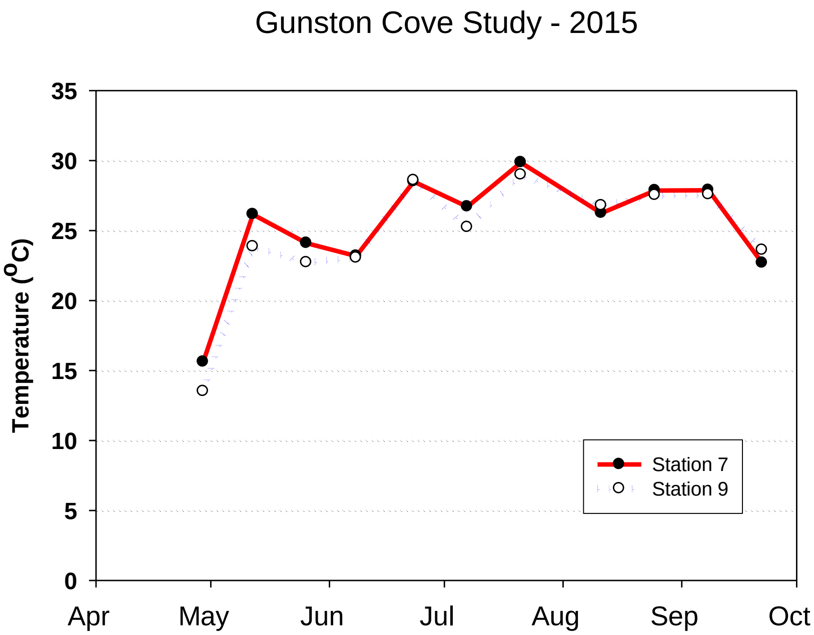
Figure 3. Mean Daily Discharge: Accotink Creek at Braddock Road (USGS Data).

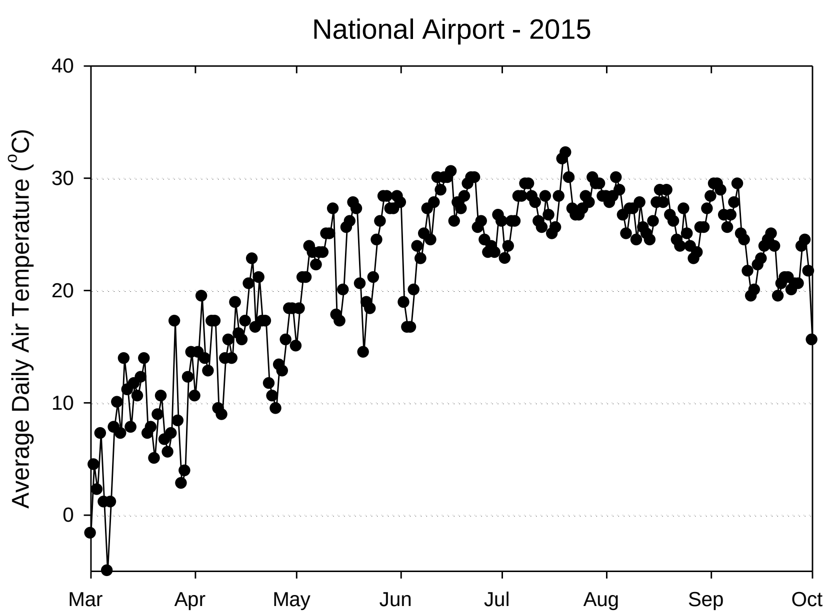
B. Physico-chemical Parameters – 2015



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

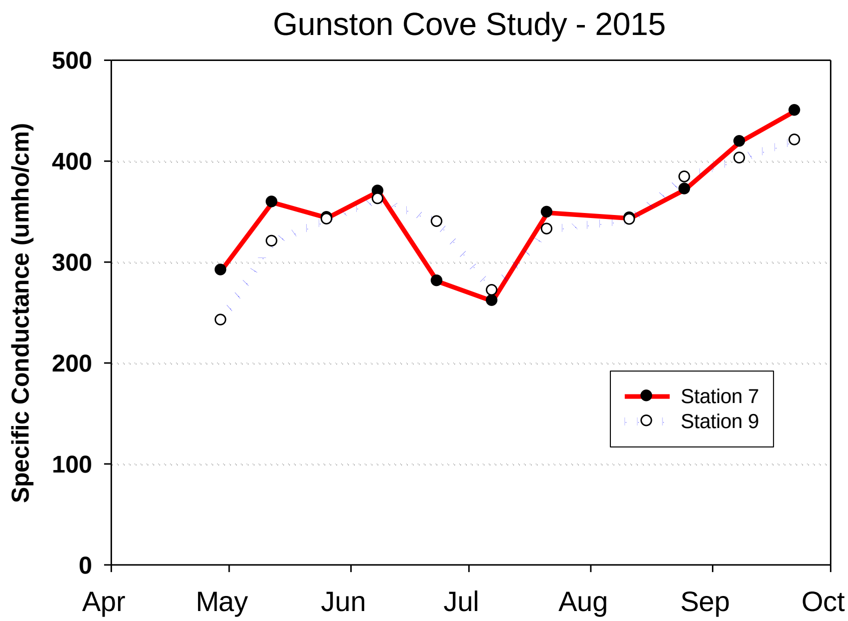
Figure 4. Water Temperature (°C). GMU Field Data. Month tick is at first day of month.

In 2015, water temperature followed the typical seasonal pattern at both sites (Figure 4). Both sites showed an early spring increase in keeping with the greatly above normal temperatures in May. Both sites neared 30°C in July, the warmest month for air temperature. For most of the summer, the two stations showed similar water temperatures between 25° and 30° C, Station 7 being consistently one degree or so higher. Water temperature declined in September.



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

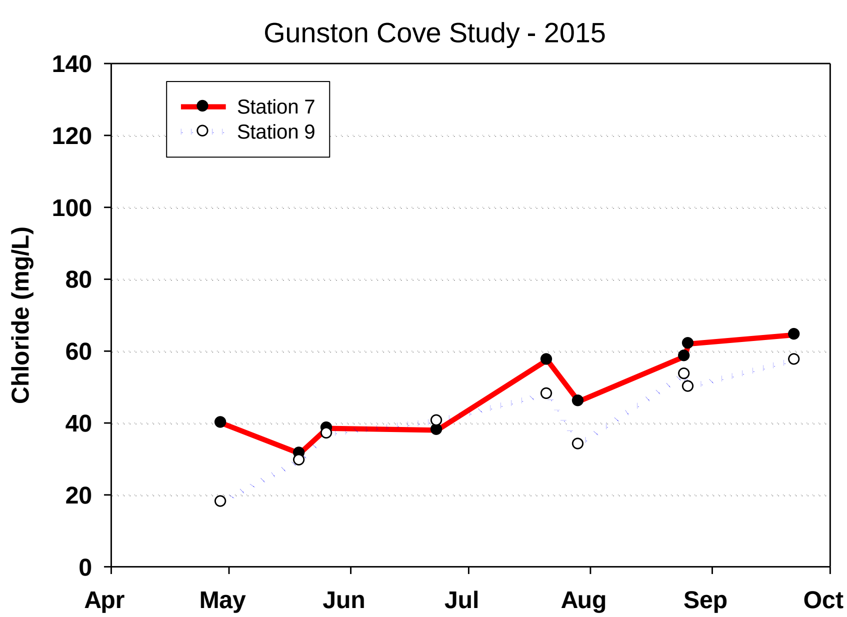
Figure 5. Average Daily Air Temperature (°C) at Reagan National Airport.



Specific conductance measures the capacity of the water to conduct electricity standardized to 25°C. 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.

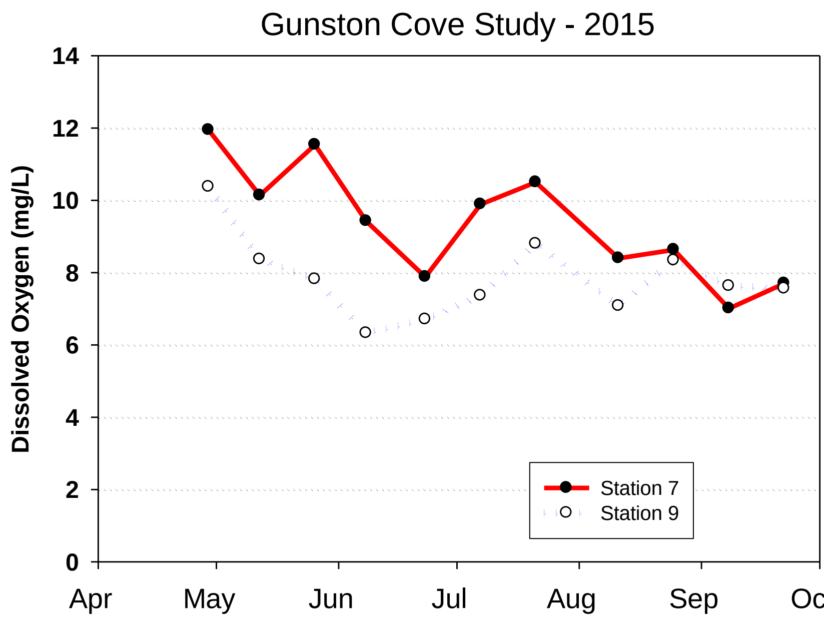
Figure 6. Specific Conductance (uS/cm). GMU Field Data. Month tick is at first day of month.

Specific conductance increased during spring, but exhibited a substantial decline in June which was exceptionally wet with lots of dilute spring inflow in 2015 (Figure 6). From July through September specific conductance increased steadily at both sites reaching a similar maximum in late September at both sites. Interestingly, chloride exhibited a gradual increase throughout the year without a decrease in June (Figure 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.

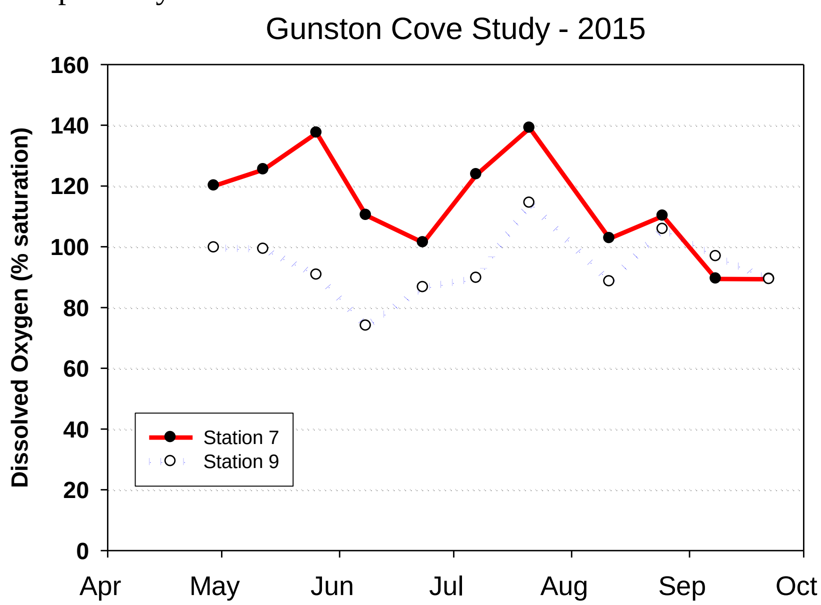
Figure 7. Chloride (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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.

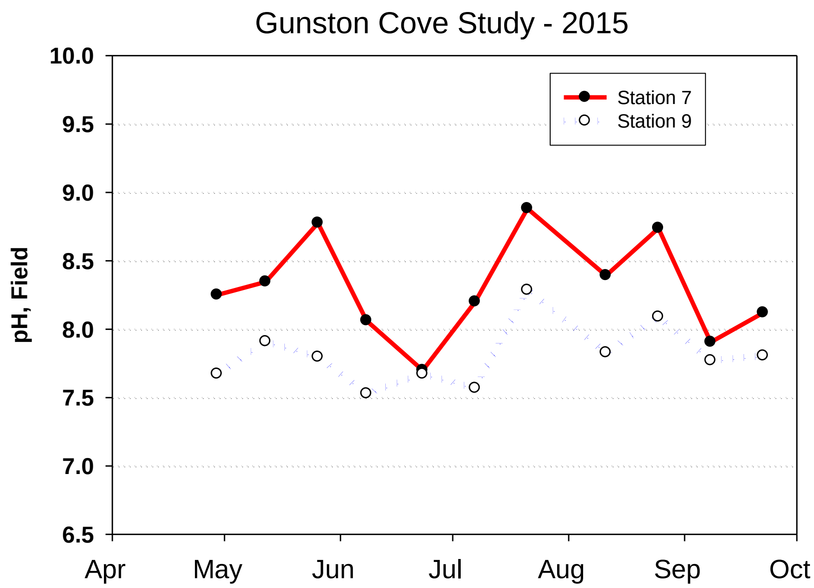
Figure 8. Dissolved Oxygen (mg/L). GMU Field Data. Month tick is at first day of month.

Dissolved oxygen showed substantial differences between the two stations for most of the year (Figure 8). From June through mid-August 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 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. A major peak in late May in the cove was probably attributable to phytoplankton while the peak in late July was 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.

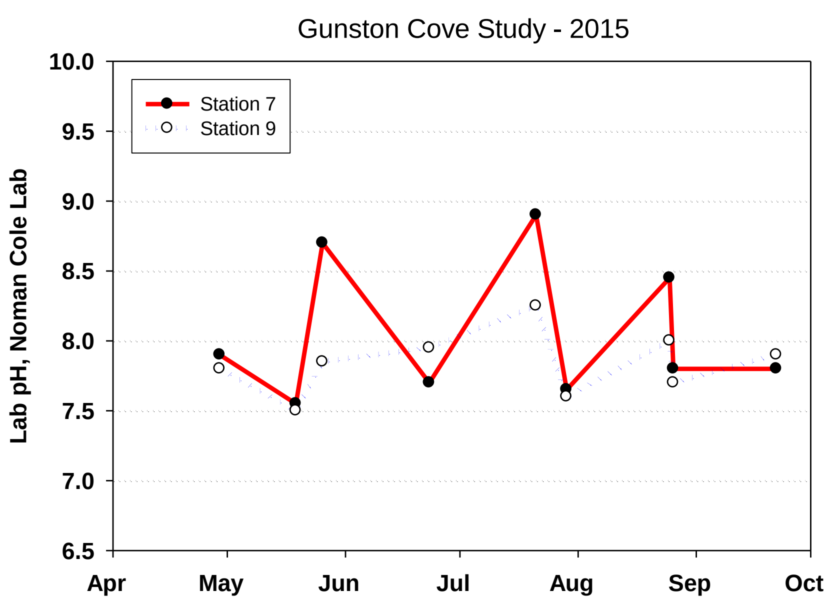
Figure 9. Dissolved Oxygen (% saturation). GMU Field Data. Month tick is at first day of month.



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.

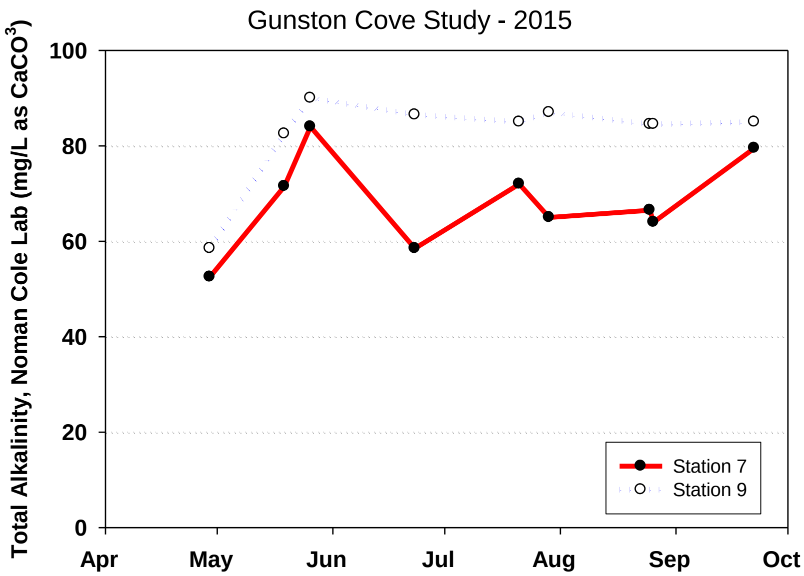
Figure 10. pH. GMU Field Data. Month tick is at first day of month.

Field pH was consistently greater in the cove than in the river again reflecting differences in photosynthetic activity (Figure 10). Times of pH peaks generally corresponded to those in dissolved oxygen Lab pH was collected less frequently, but generally showed similar patterns (Figure 11).



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.

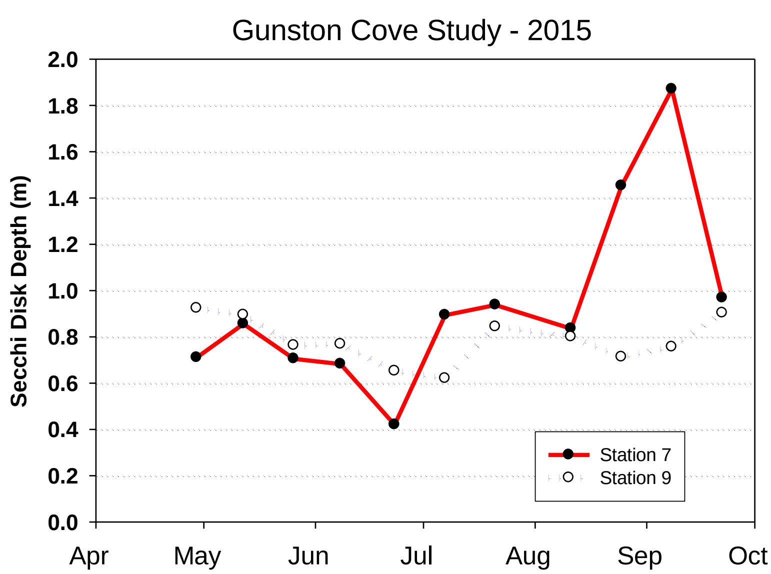
Figure 11. pH. Noman Cole Lab Data. Month tick is at first day of month.



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.

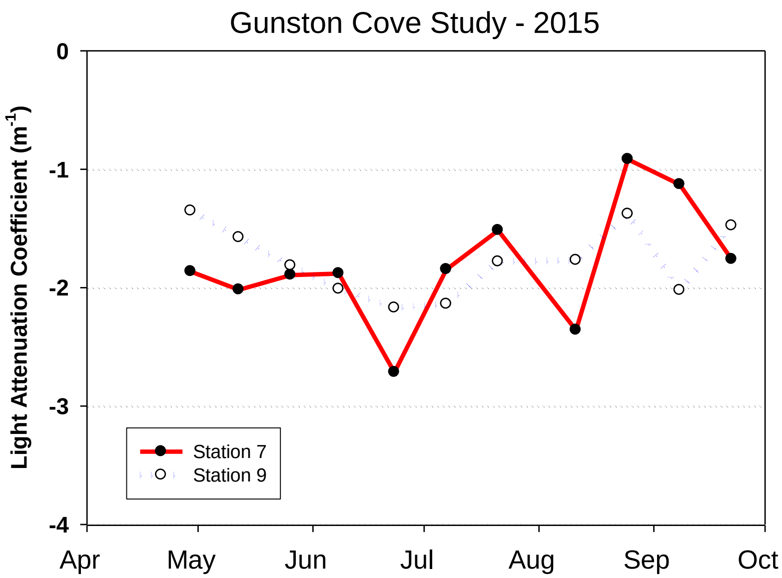
Figure 12. Total Alkalinity (mg/L as $CaCO_3$). Fairfax County Lab data. Month tick is at first day of month.

Total alkalinity was consistently higher in the river than in the cove (Figure 12). River values showed a more consistent pattern than was observed in the cove.
Water clarity as reflected by Secchi disk depth was generally similar at both sites, but in late August and early September it was much greater in the cove (Figure 13). On these two dates, summer Secchi exceeded 1 m consistently and in fact in early September set a new study record at nearly 2 m, a new record. The bottom of Gunston Cove was visible from the surface in several places.



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 determin-ing how far light is penetrating into the water column. Light is necessary for photosynthesis and thereby for growth of aquatic plants and algae.

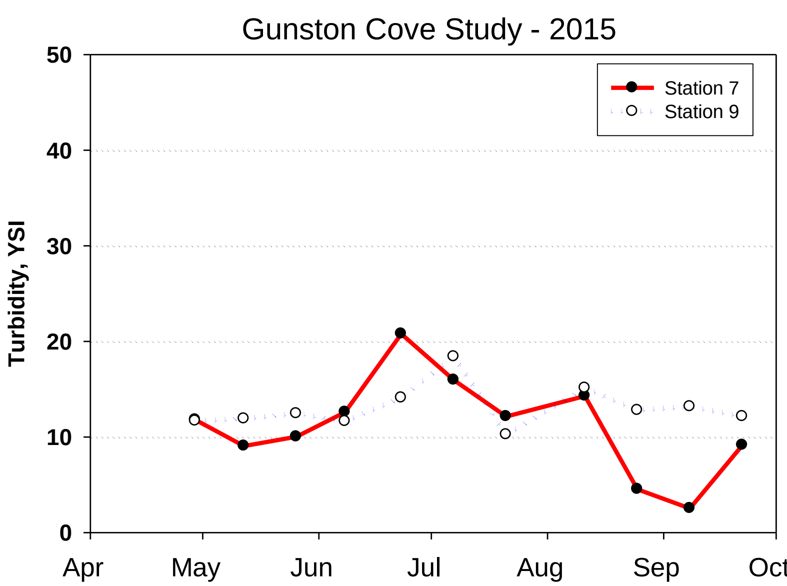
Figure 13. Secchi Disk Depth (m). GMU Field Data. Month tick is at first day of month.



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.

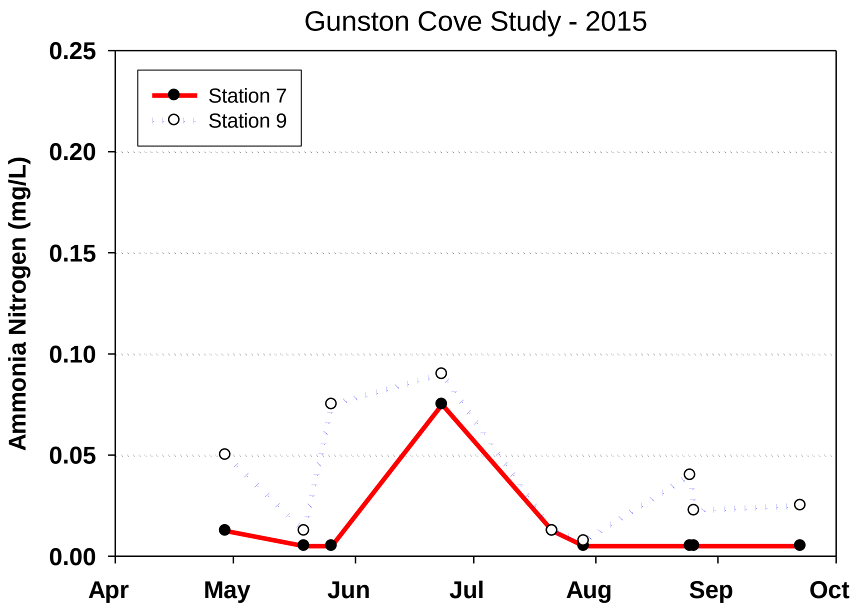
Figure 14. Light Attenuation Coefficient (m^{-1}). GMU Field Data. Month tick is at first day of month.

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. Light attenuation was less variable in the river than in the cove. The sharp drop in late June in was probably due to the large volume of runoff in the month. Turbidity showed a similar peak in late June and also a seasonal low in late August and September (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.

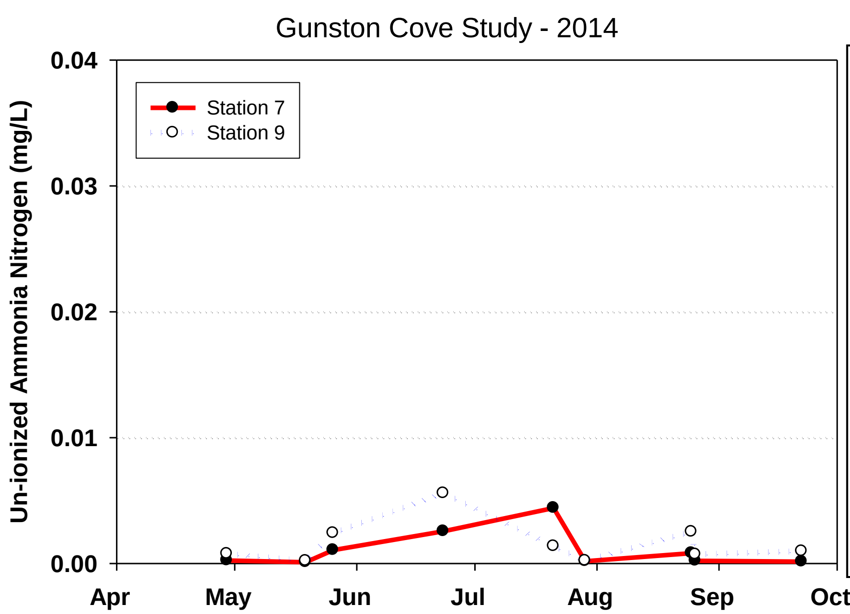
Figure 15. Turbidity (NTU). GMU Lab Data. Month tick is at first day of month.



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.

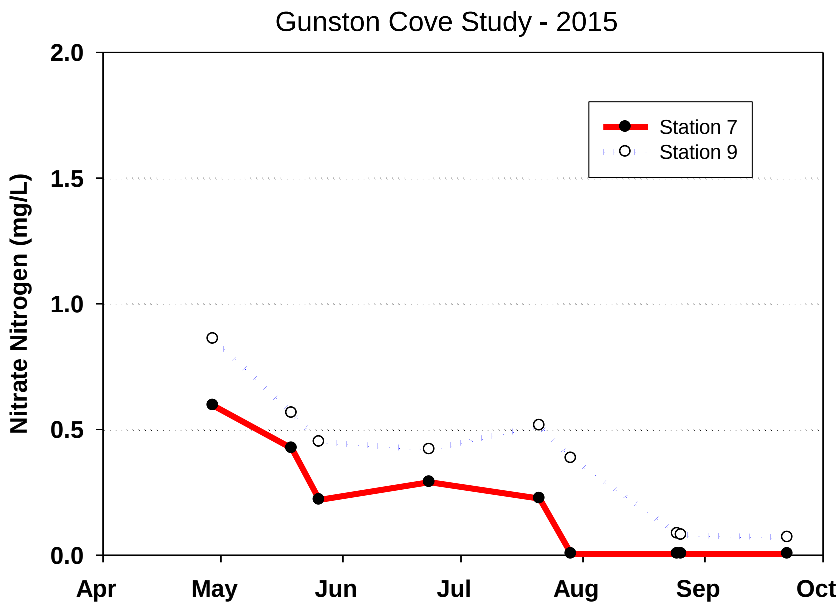
Figure 16. Ammonia Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month. (Limit of detection: 0.01 mg/L)

Ammonia nitrogen was consistently low (<0.08 mg/L) in the study area during 2015 (Figure 16). Values at both sites were highest in late May and June. Ammonia nitrogen at cove sites was consistently lower than in the river and except for late June was at or near detection limits. Un-ionized ammonia was very low at both stations through the entire year (Figure 17). Values were well below those causing toxicity problems.



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.

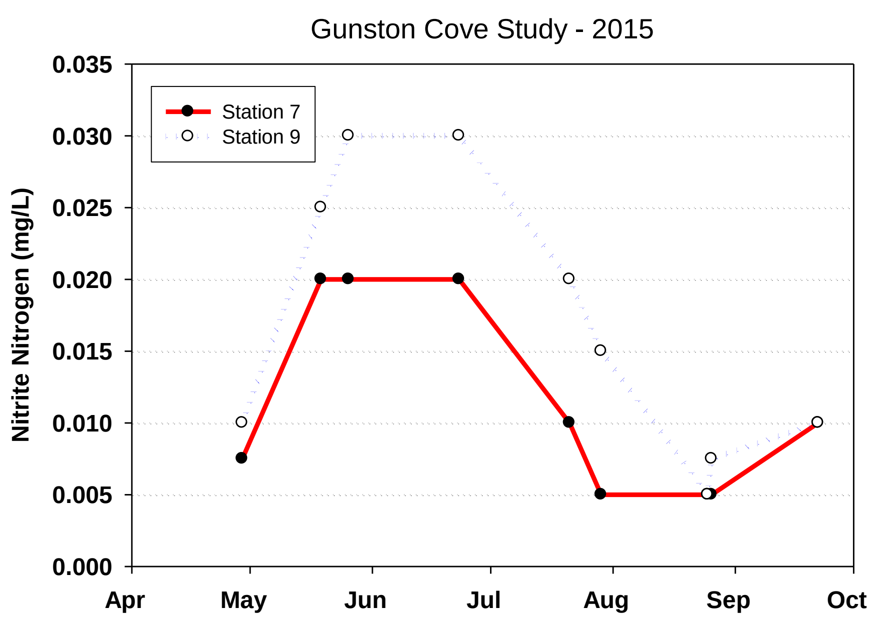
Figure 17. Un-ionized Ammonia Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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.

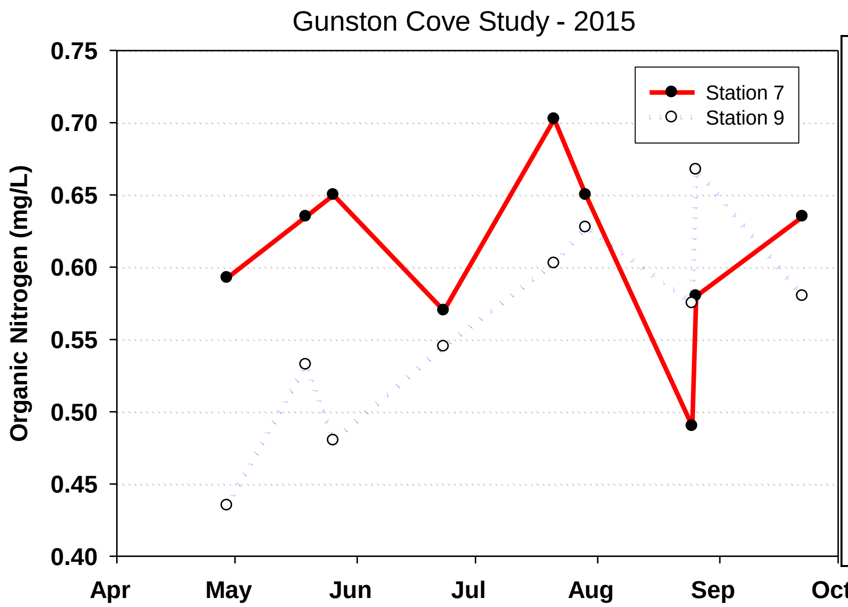
Figure 18. Nitrate Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month. (Limit of detection: 0.01 mg/L)

Nitrate nitrogen levels were highest at both sites in early spring and declined through the year (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. 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). Values at both sites were higher during the wetter period of late May and June.



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.

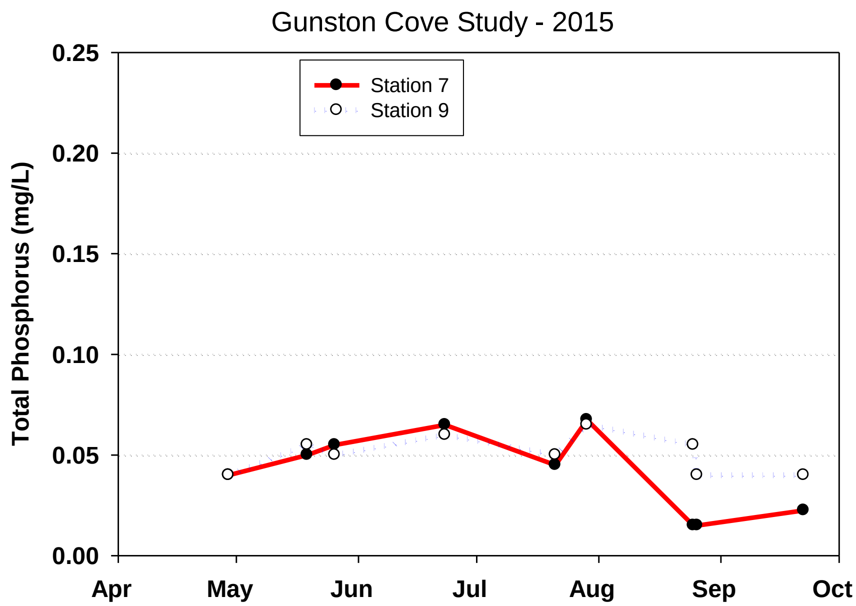
Figure 19. Nitrite Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month. (limit of detection = 0.02 mg/L).



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.

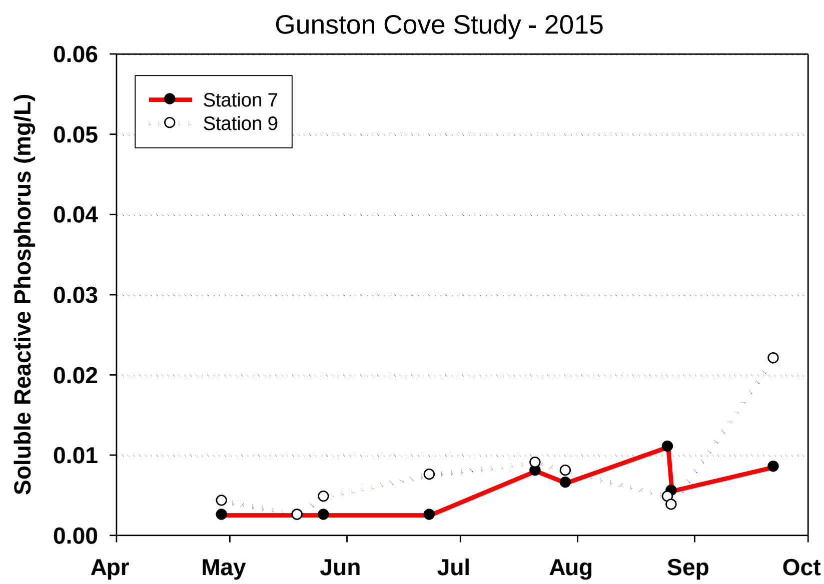
Organic nitrogen was highest in the cove in the spring and similar at both sites from late June through August (Figure 20). There was a general upward pattern through time in the river. The cove was quite variable in late summer.



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.

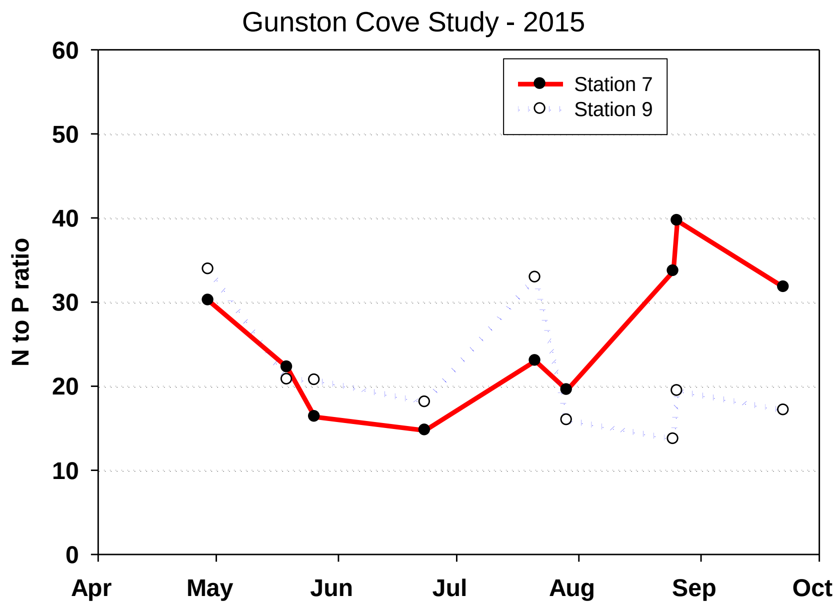
Figure 21. Total Phosphorus (mg/L). Fairfax County Lab Data. Month tick is at first day of month. (Limit of detection: 0.03 mg/L)

Total phosphorus was similar at both sites on almost all dates and did not show much seasonal variation (Figure 21). Cove values did markedly drop in late August and September. Soluble reactive phosphorus was similar at both sites being less than 0.01 mg/L in almost all 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.

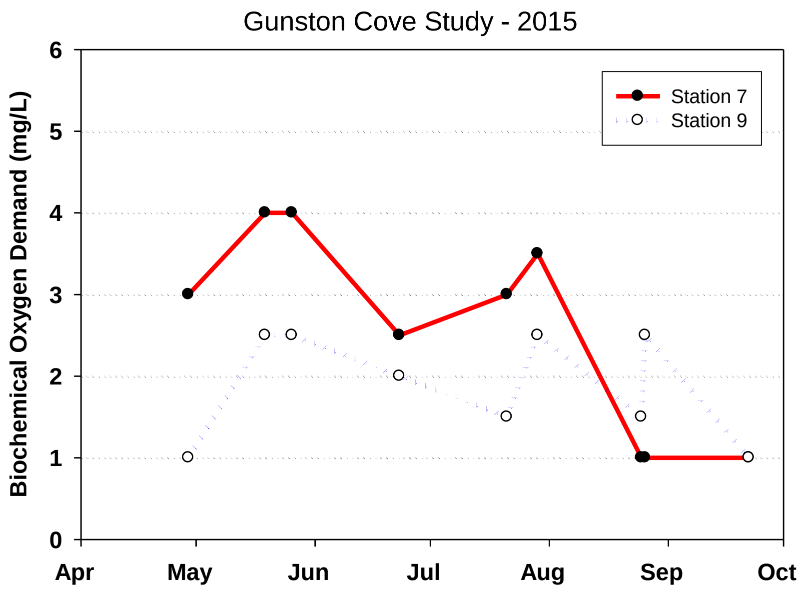
Figure 22. Soluble Reactive Phosphorus (mg/L). Fairfax County Lab Data. Month tick is at first day of month. (Limit of detection = 0.005 mg/L)



N:P ratio is determined by summing all of the compon-ents 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.

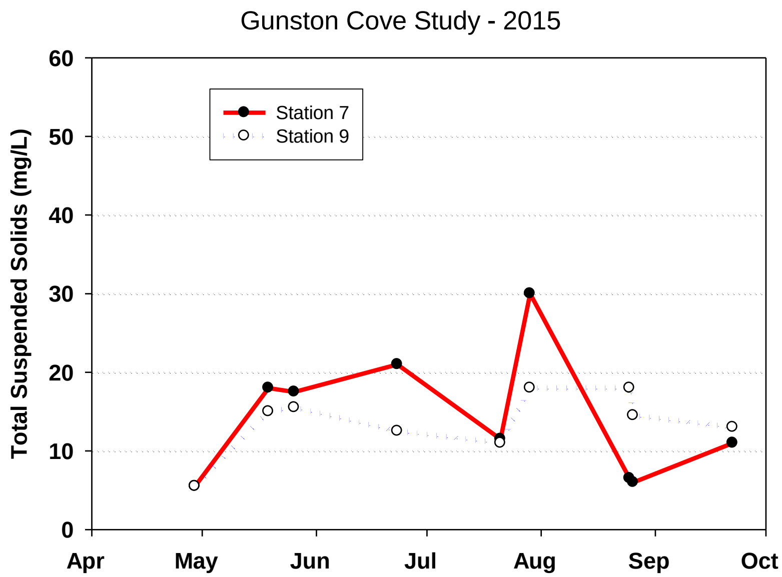
Figure 23. N/P Ratio (by mass). Fairfax County Lab Data. Month tick is at first day of month.

N/P ratio were generally in the range 15-40 at both sites, indicative of P limitation of primary production by algae and SAV (Figure 23). Lowest values in the cover were in late June and in the river in late August. Biochemical oxygen demand (BOD) was consistently higher in the cove than in the river (Figure 24). Values in the cove were highest in late May and lowest in late August and September.



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 number 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 of measurement.

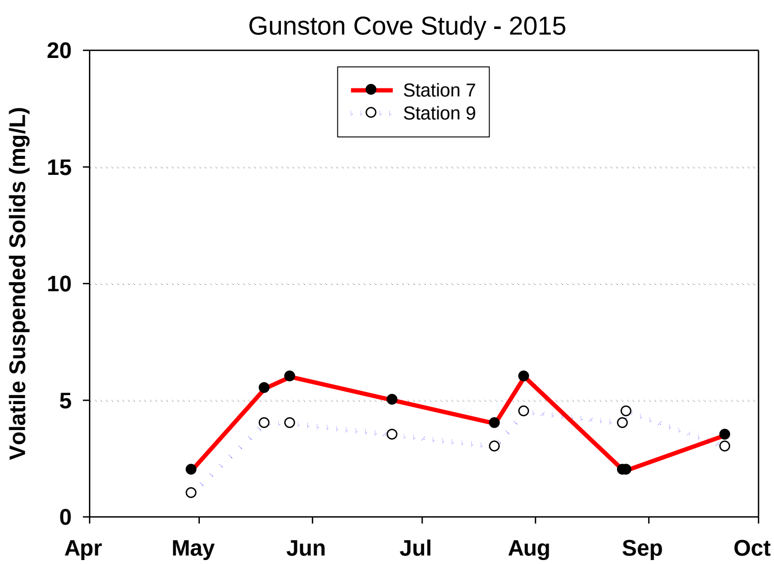
Figure 24. Biochemical Oxygen Demand (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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.

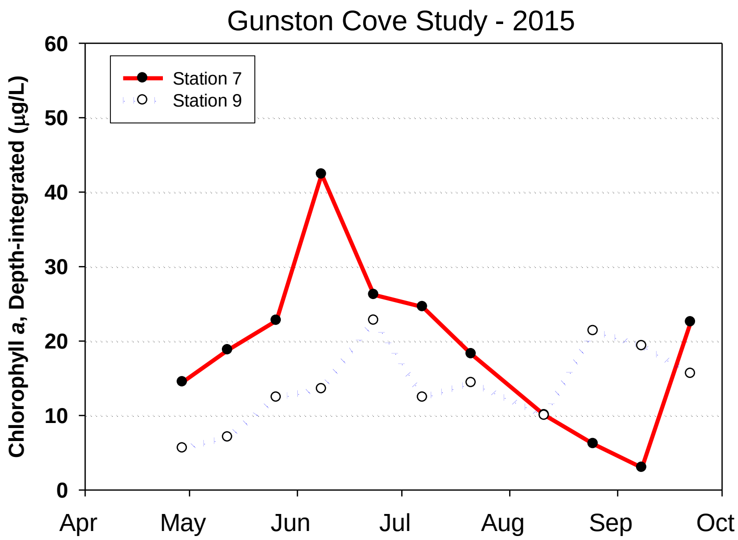
Total suspended solids was generally in the range 10-20 mg/L at both stations (Figure 25). There was little seasonal pattern, but cove values did spike in late July. Volatile suspended solids was very similar at the two sites with little seasonal pattern (Figure 26).



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 Lab Data. Month tick is at first day of month.

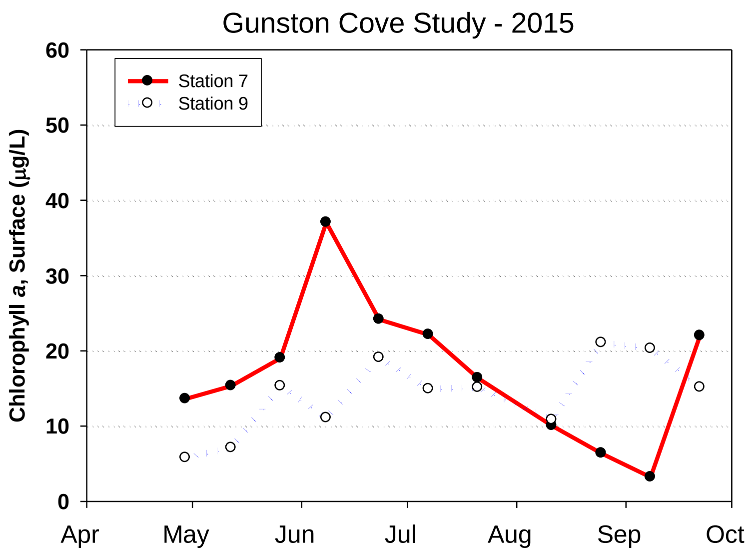
C. Phytoplankton -2015



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.

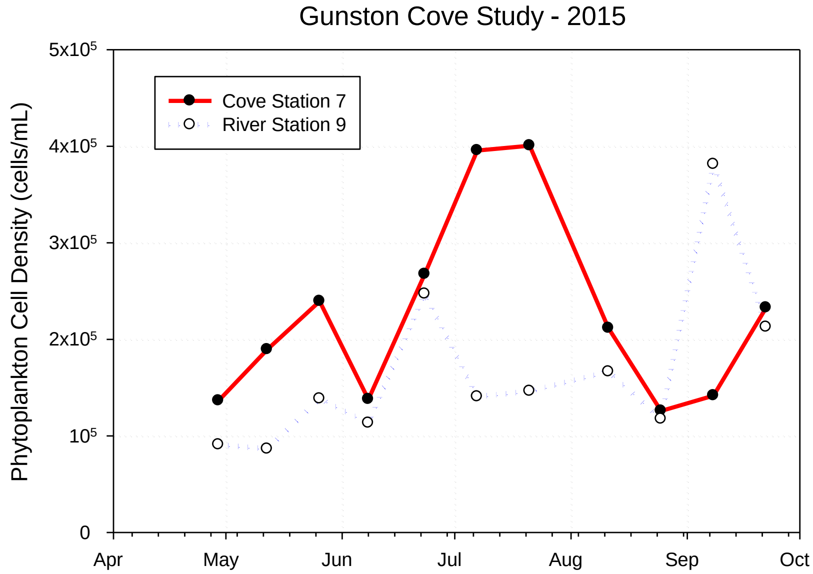
Figure 27. Chlorophyll *a* (ug/L). Depth-integrated. GMU Lab Data. Month tick is at the first day of month.

Chlorophyll *a* in the cove displayed a distinct seasonal pattern in 2015 (Figure 27). A marked increase was observed from late April through early June. This period was very favorable for algal growth with low water input to the cove, high than normal temperatures and plenty of light. However during the month of June there were periods of high flushing from water runoff which decreased phytoplankton and by late July SAV was building up into the water column and depleting light to the phytoplankton which decreased for the rest of the summer. In the river chlorophyll values were lower and not as variable seasonally. 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 exhibited a peak in late May and a higher peak in July (Figure 29). In the river there was an increase from April through the end of July and a higher peak in early September. Seasonal patterns in total biovolume in the cove were similar to those in cell density with maxima in late May and July/August. In the river a July maximum was observed (Figure 30).

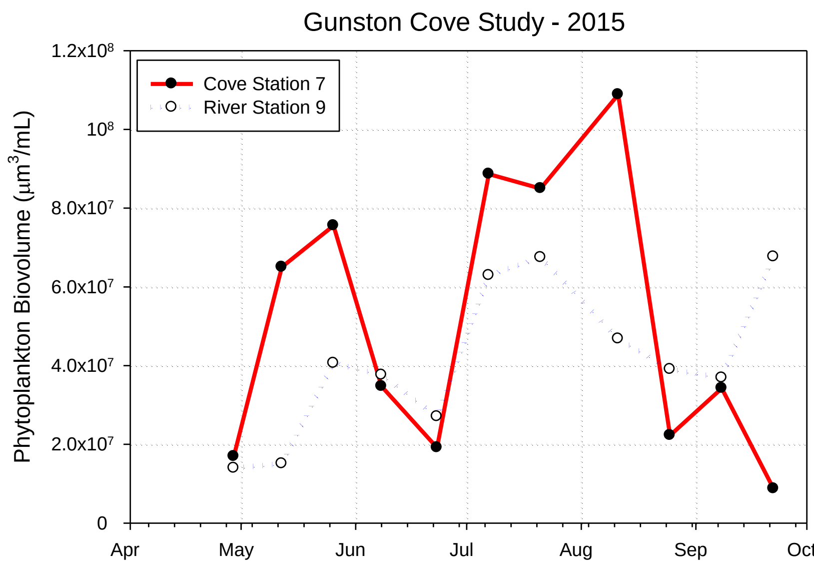
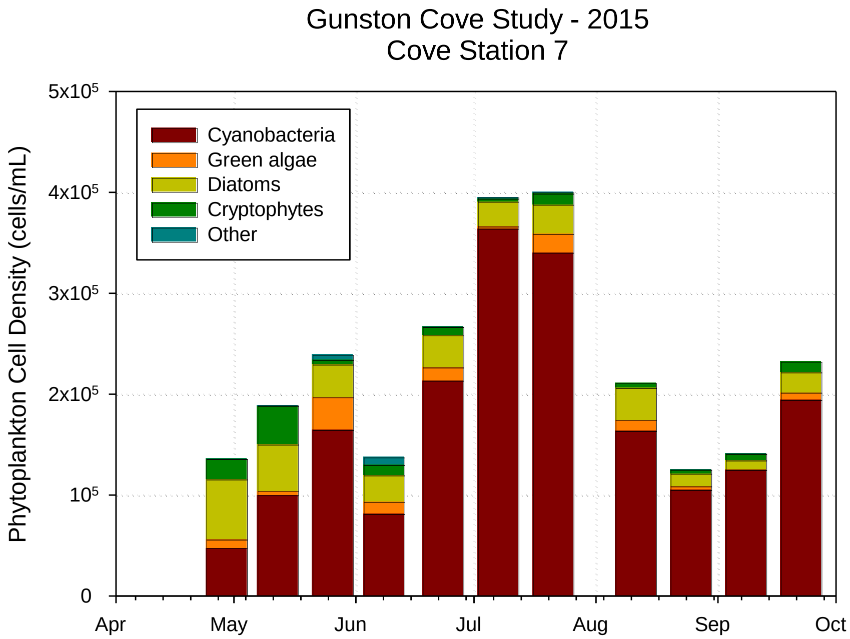


Figure 30. Phytoplankton Biovolume (um^3/mL).

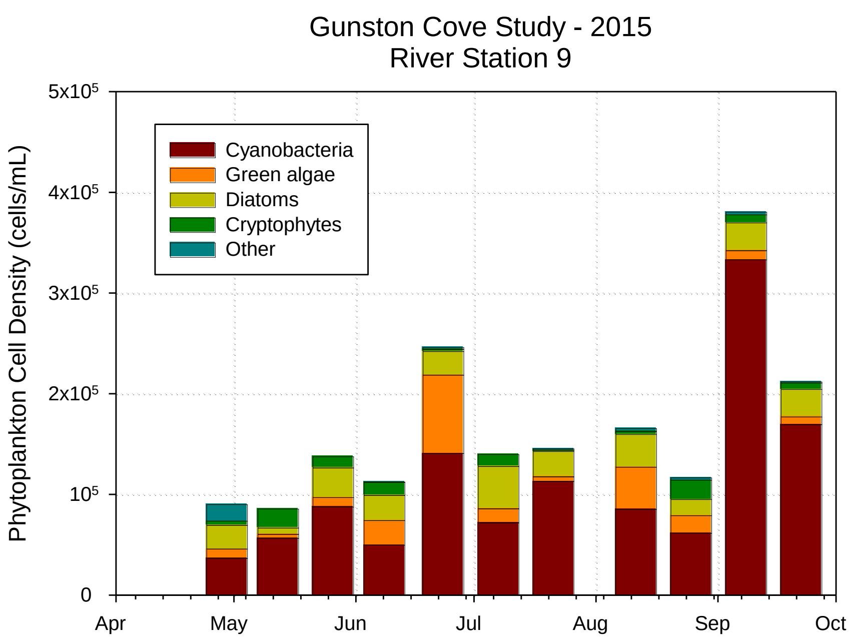
The volume of individual cells of each species is determined by approximating the cells of each species to an appropriate geometric shape (e.g. sphere, cylinder, cone, etc.) and then making the measurements of the appropriate dimensions under the microscope. Total phytoplankton biovolume (shown here)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



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

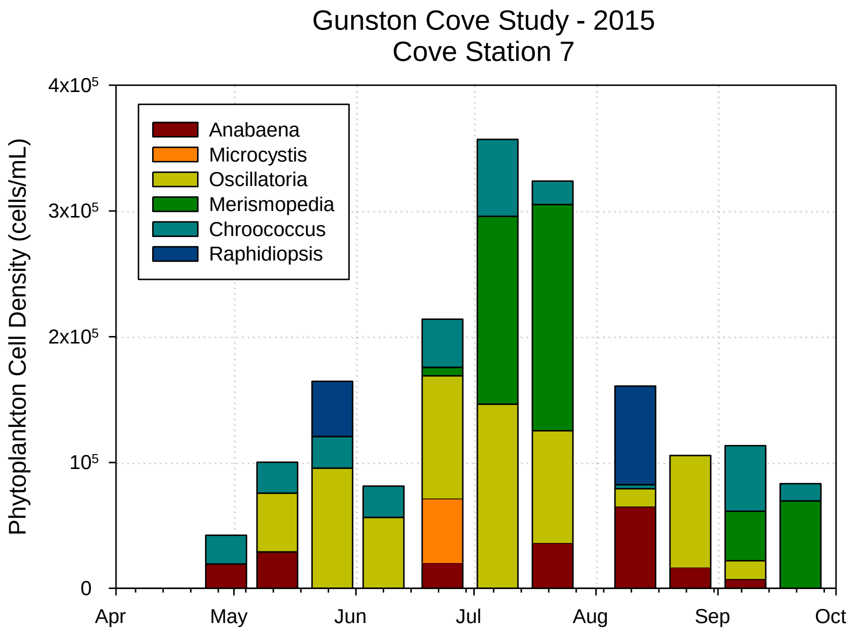
Figure 31. Phytoplankton Density by Major Group (cells/mL). Gunston Cove.

Phytoplankton density in the cove was dominated by cyanobacteria throughout the year (Figure 31). Diatoms were important in the spring. In the river cyanobacteria were clearly most numerous on most dates (Figure 32). Due to their small size, cyanobacteria usually are the most abundant group, but do not necessarily represent the greatest biomass.



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.

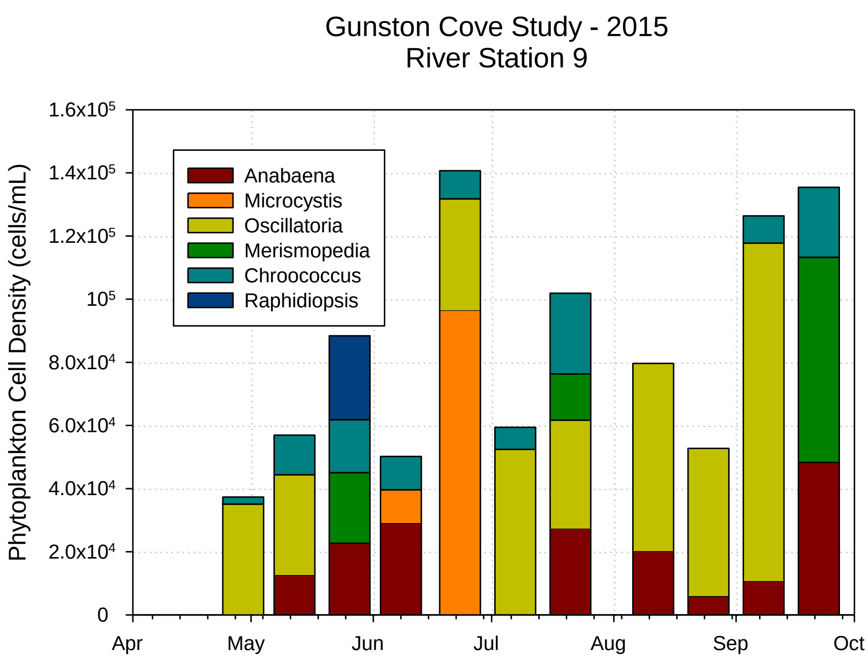


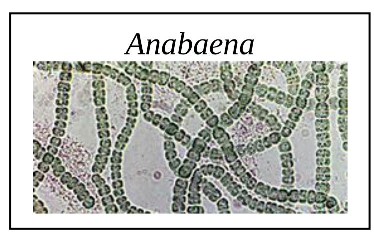
The dominant cyanobacteria on a numerical basis were:

- *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 and Merismopedia were the most abundant cyanobacteria on most dates (Figure 33). *Anabaena* was co-dominant with *Raphidiopsis* in early August. *Microcystis* was dominant on one date in late August. In the river *Oscillatoria* and *Anabaena* were co-dominant on many dates. *Microcystis* was numerically most important in a single sample in late June in the river (Figure 34).





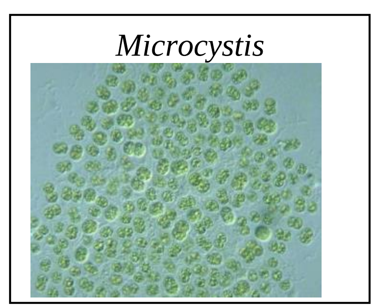
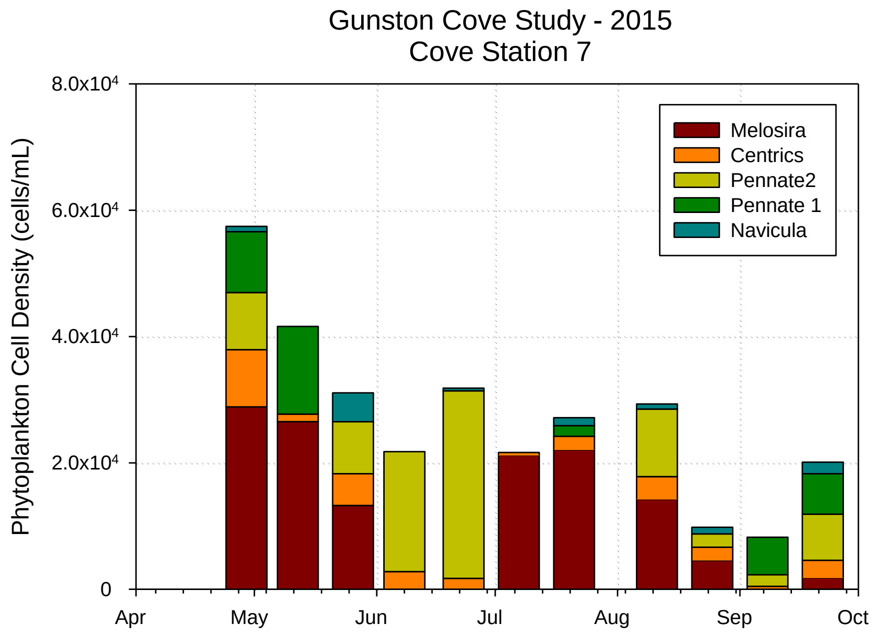


Figure 34. Phytoplankton Density by Dominant Cyanobacteria (cells/mL). River.



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
Navicula – a small pennate diatom

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

Diatom cell density was dominated by *Melosira* in most cove samples (Figure 35). Pennate 2 was dominant in June. Other diatom taxa were generally of minor importance. In the river *Melosira* and Pennate 2 generally shared dominance (Figure 36).

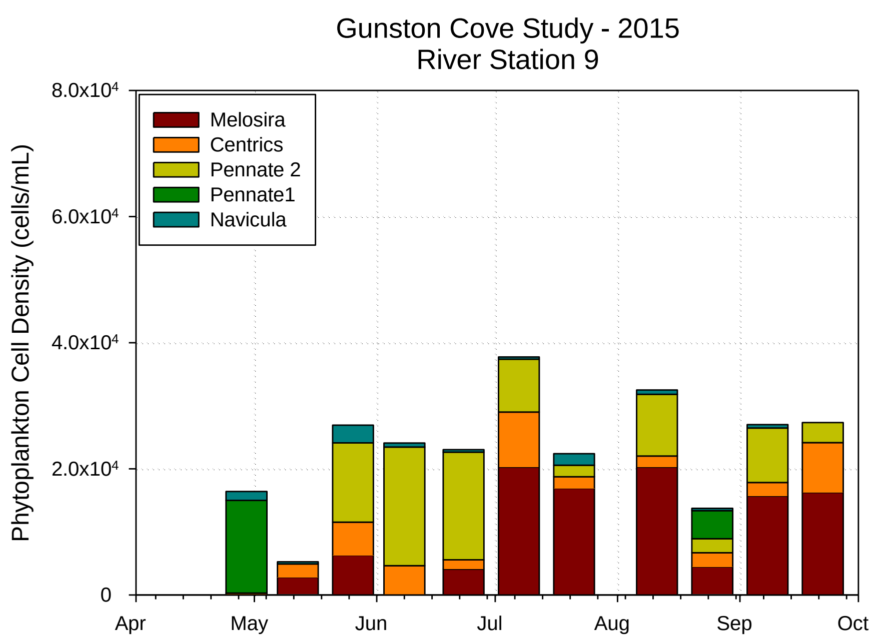
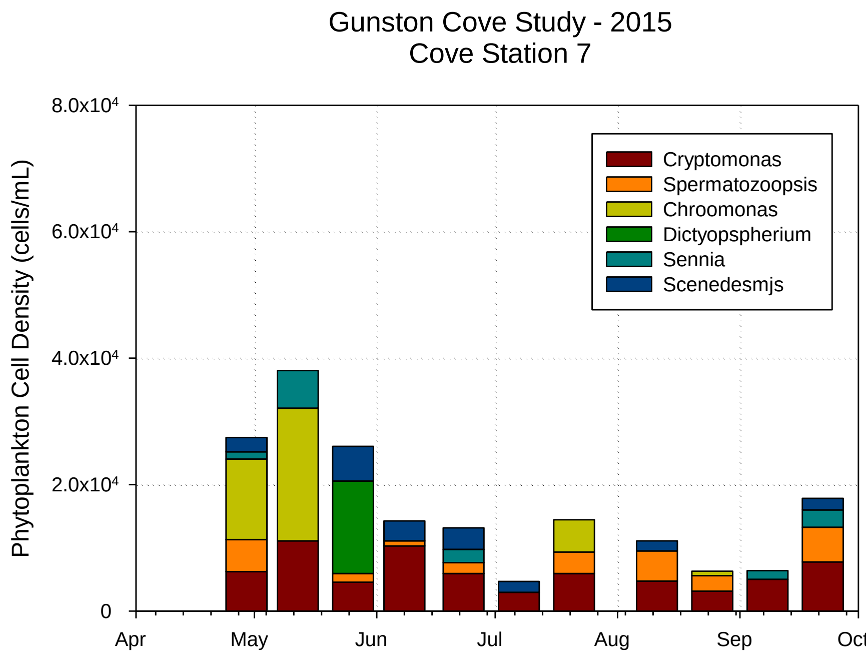


Figure 36. Phytoplankton Density by Dominant Diatoms (cells/mL). River.

Melosira

Discoid Centrics

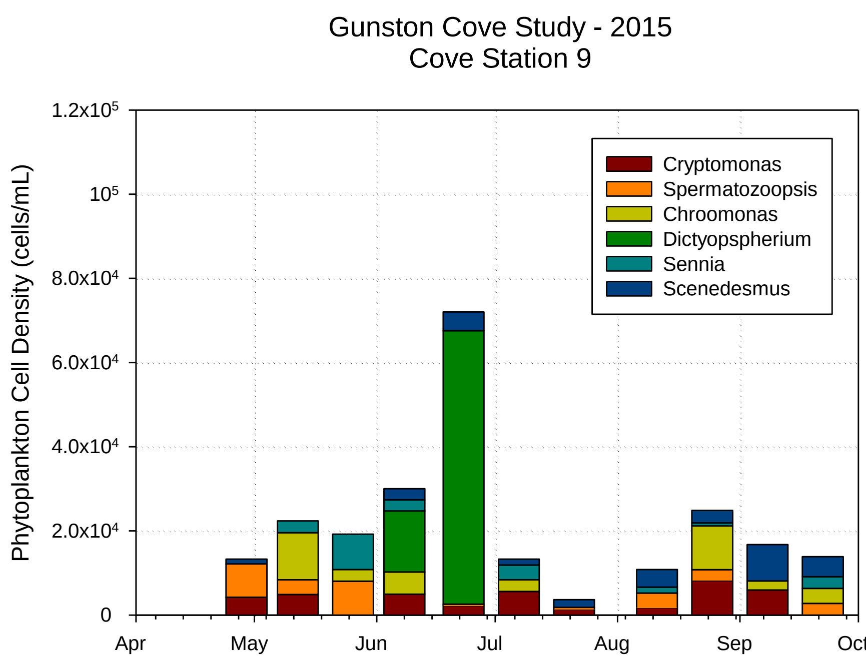


The most numerous phytoplankton among the cryptophytes, green algae and others were:

Cryptomonas – an ellipsoidal, flagellated unicell
Spermatozoopsis – flagellated green unicell
Chroomonas – a flagellated cryptomonad unicell
Dictyosphaerium – colony of small green unicells
Sennia - a small cryptophyte
Scenedesmus – green alga typically growing in colonies of 4 cells each

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

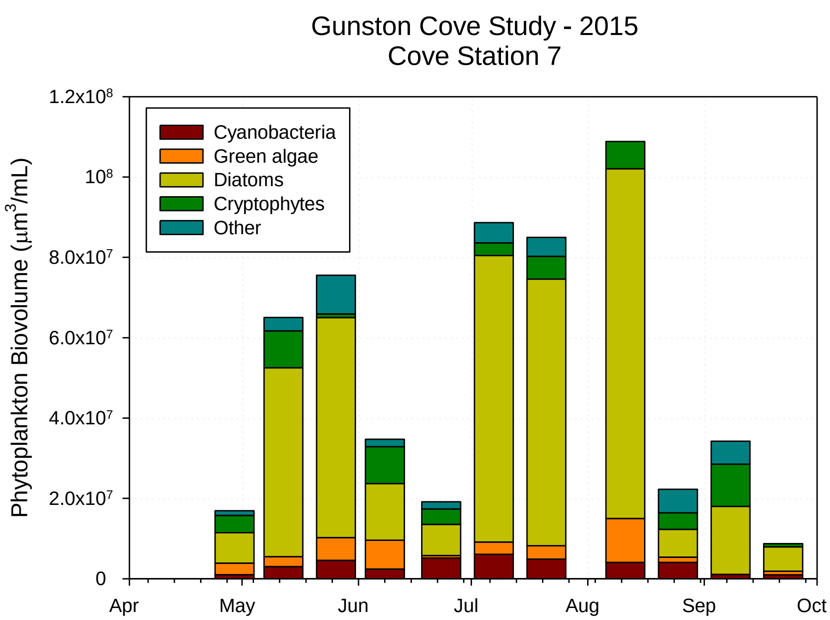
In the cove numerous other taxa were important and there was a lot of variation between dates (Figure 37). *Cryptomonas*, *Spermatozoopsis*, and *Chroomonas* were generally the most abundant other taxa with a large number of *Dictyospherium* in late May. In the river a similar assemblage was normally found with a greater contribution also from *Dictyospherium* and *Scenedesmus* (Figure 38).




Cryptomonas


Scenedesmus

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

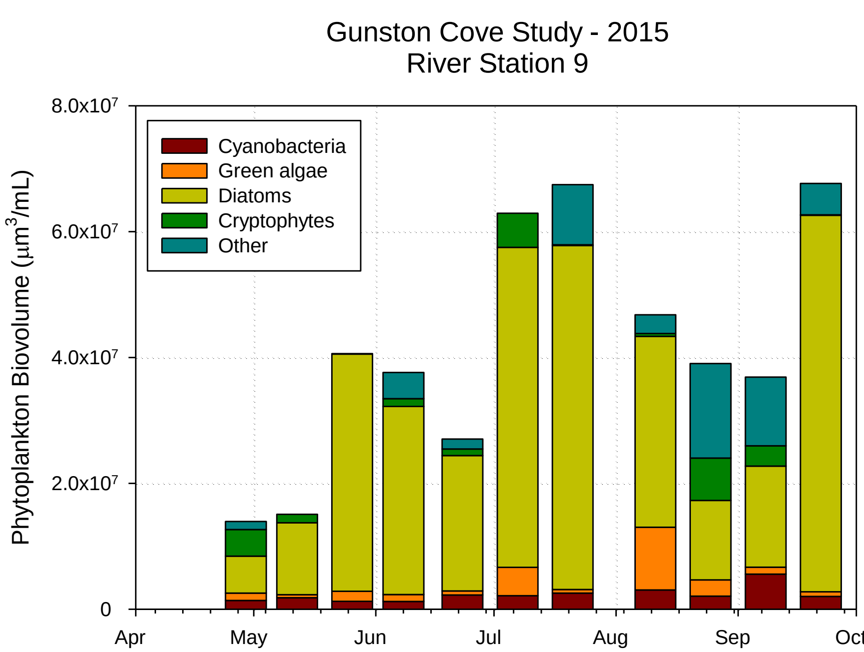


Total phytoplankton biovolume can be broken down into groups:

- **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 diatoms were dominant in biovolume throughout the year (Figure 39). Despite their greater numbers, cyanobacteria were much lower in terms of biovolume due to their much smaller size. Green algae and cryptophytes were of importance on a few dates. In the river, diatoms were strongly dominant in biovolume for most of the year. Other algae were important in mid to late summer (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.

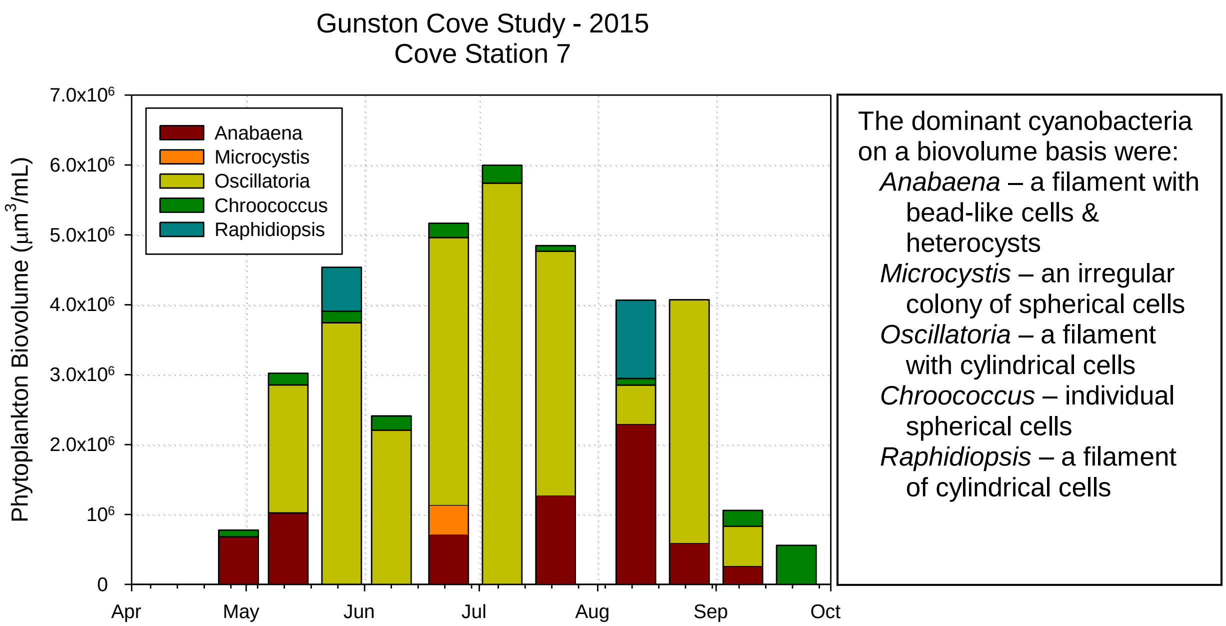


Figure 41. Phytoplankton Biovolume (um^3/mL) by Cyanobacteria Taxa. Gunston Cove.

In the cove *Oscillatoria* and *Anabaena* accounted for almost all of the cyanobacterial biovolume for the entire year (Figure 41). *Raphiopsis* and *Chroococcus* were of importance on certain dates. A similar pattern of dominance was observed in the river (Figure 42).

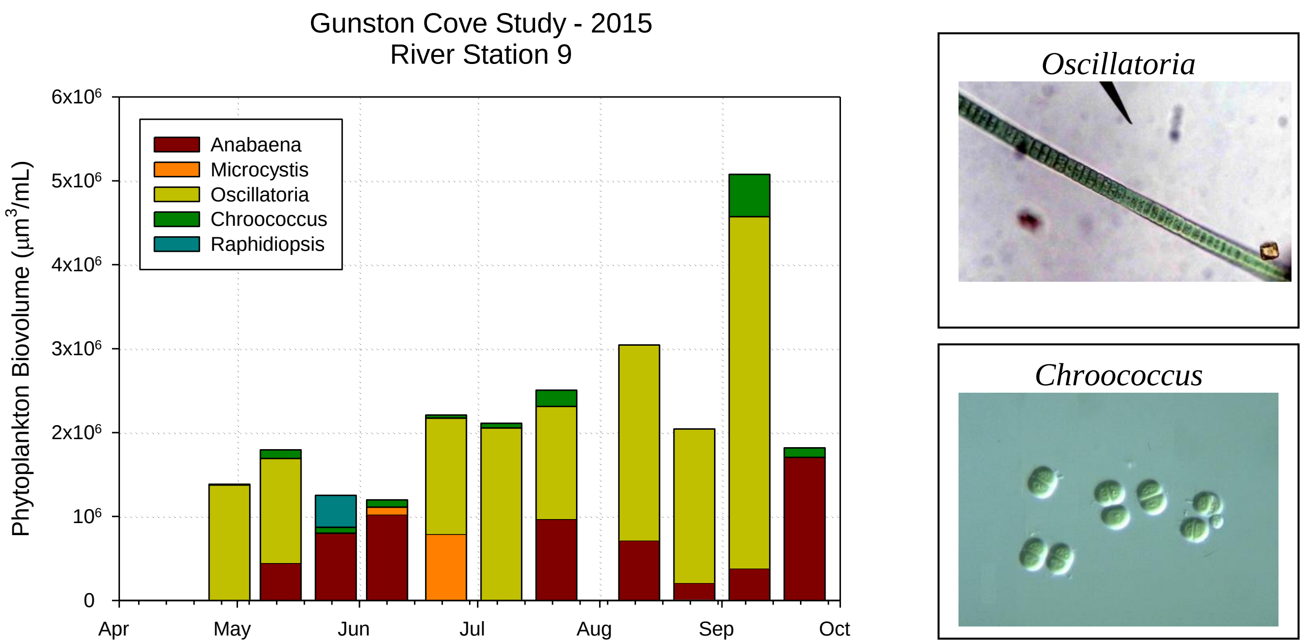
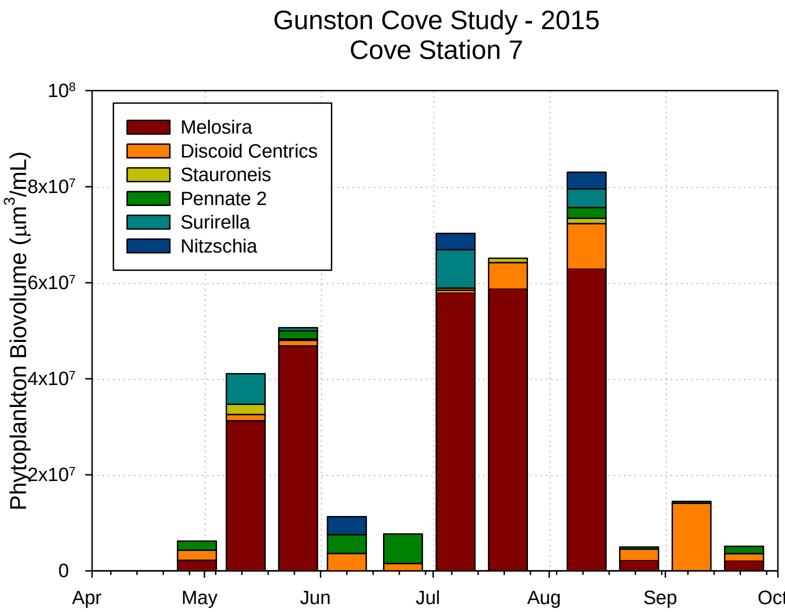


Figure 42. Phytoplankton Biovolume (um^3/mL) by Cyanobacterial Taxa. River.

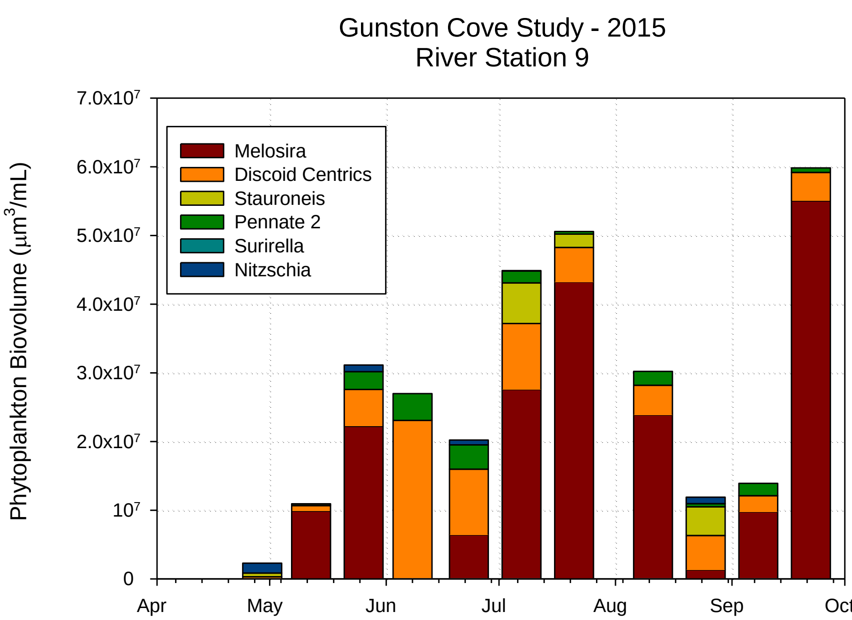


The most numerous diatoms in the phytoplankton were:

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

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

As with cell density, *Melosira* heavily dominated diatom biovolume in the cove (Figure 43). In June diatoms were greatly depressed in the aftermath of the strong water inflows, but *Melosira* rebounded in July. *Melosira* decreased strongly in late August. In the river *Melosira* was dominant on many dates, but in June centric diatoms were dominant and were important on other dates (Figure 44).



Melosira

Surirella

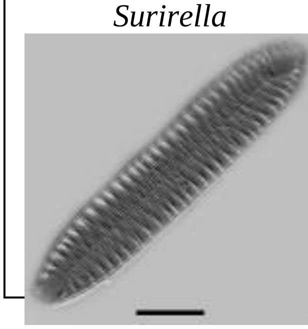
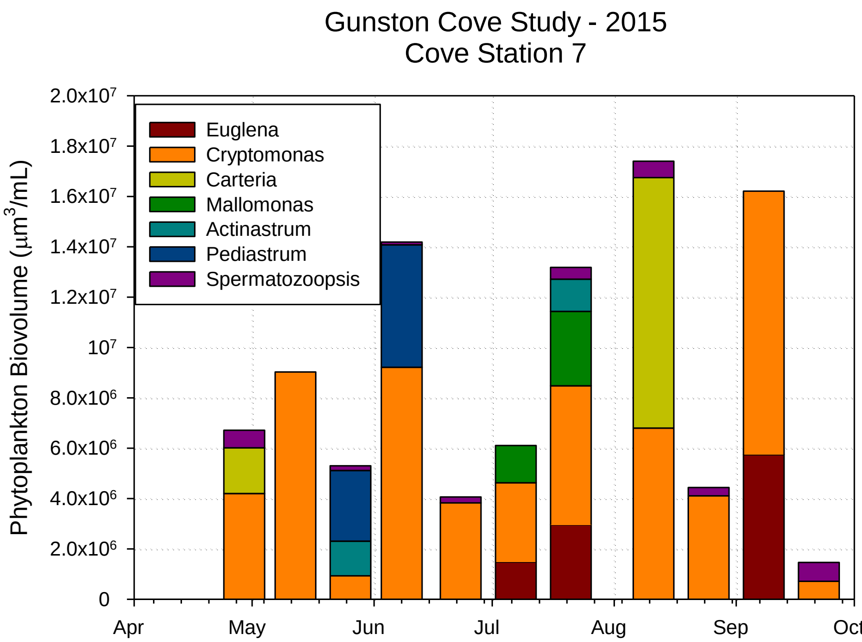


Figure 44. Phytoplankton Biovolume (um^3/mL) by Diatom Taxa. River.

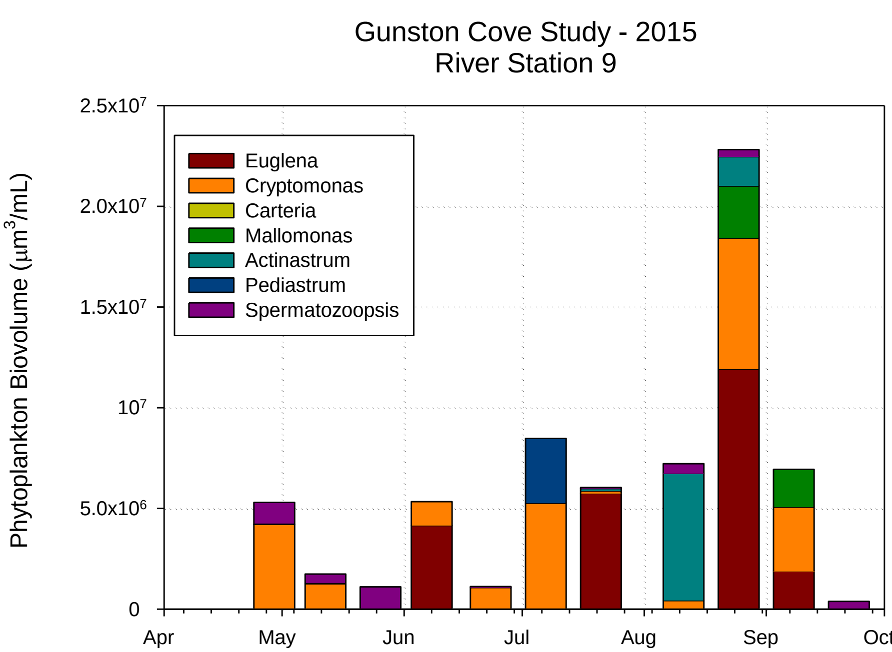


The most numerous phyto-plankton among the cryptophytes, green algae and others were:

- *Euglena* – large euglenoid flagellate
- *Cryptomonas* – an ellipsoidal, flagellated unicell
- *Carteria* – flagellated green unicell
- *Mallomonas* – unicellular scaled flagellate
- *Actinastrum* – stellate colonies of spindle-shaped unicells
- *Pediastrum* – flat colony of green algae
- *Spermatozoopsis* – flagellated green unicell

Figure 45. Phytoplankton Biovolume (um^3/mL) by Dominant Other Taxa. Gunston Cove.

A number of other taxa were present at Station 7 (Figure 45). *Cryptomonas* was consistently dominant were consistently important in the cove. *Carteria*, *Pediastrum*, and *Euglena* were also important on some dates. In the river, other phytoplankton taxa occurred more sporadically (Figure 46).

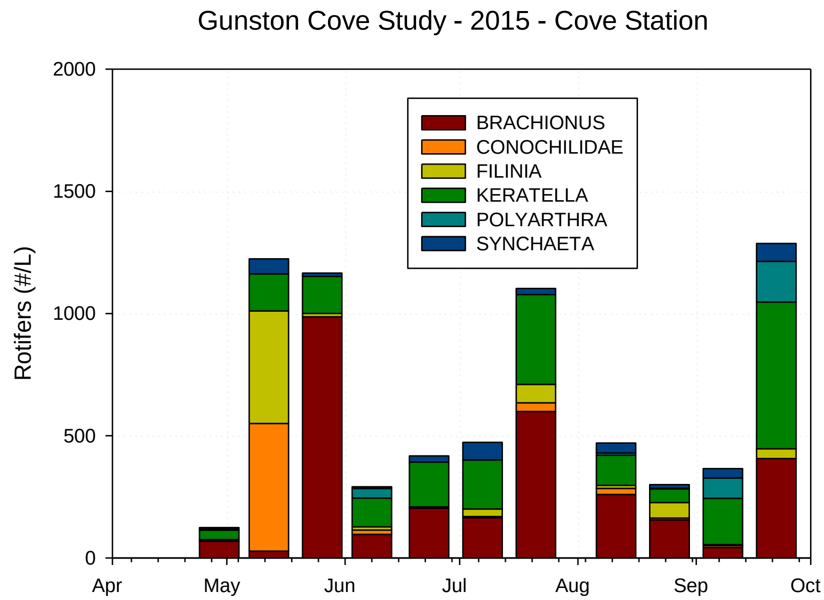


Cryptomonas

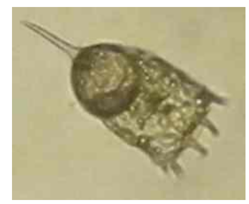
Euglena

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

D. Zooplankton – 2015



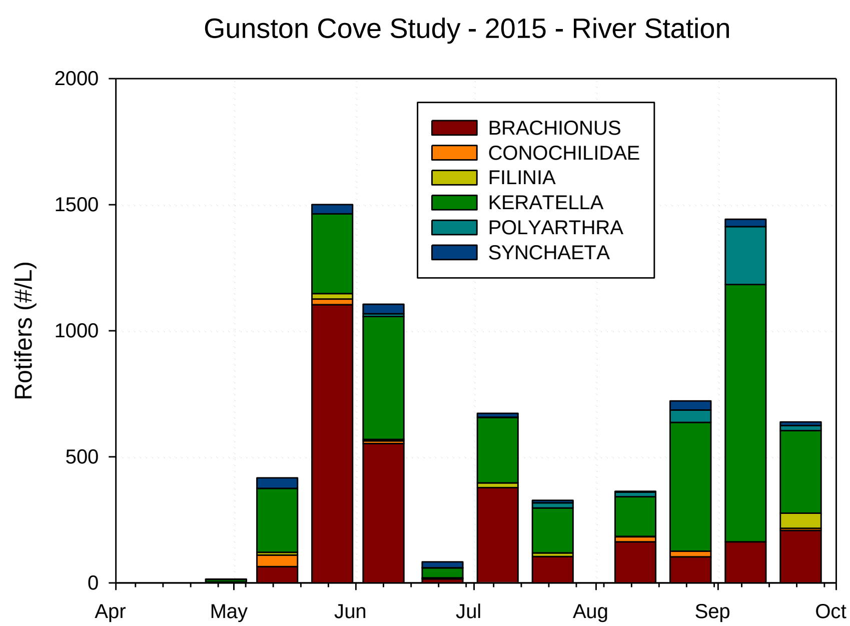
Brachionus (Sta 7, RCJ)



Keratella (Sta 7, RCJ)

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

In the cove, rotifers increased strongly in May and then declined in June (Figure 47). They increased again in June and July, declined and then peaked again in late September. *Brachionus* was usually the most numerous rotifer, but Cononchilidae and *Filinia* were dominant in early May and *Keratella* was important at other times. In the river there was also a late May peak and a September peak (Figure 48). *Keratella* was very important on all dates and sometimes dominant over *Brachionus*.



Brachionus (c. 50 um)

Conochilidae

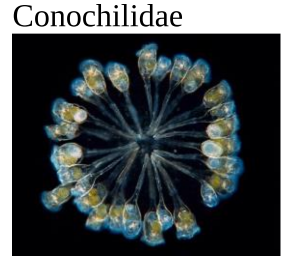
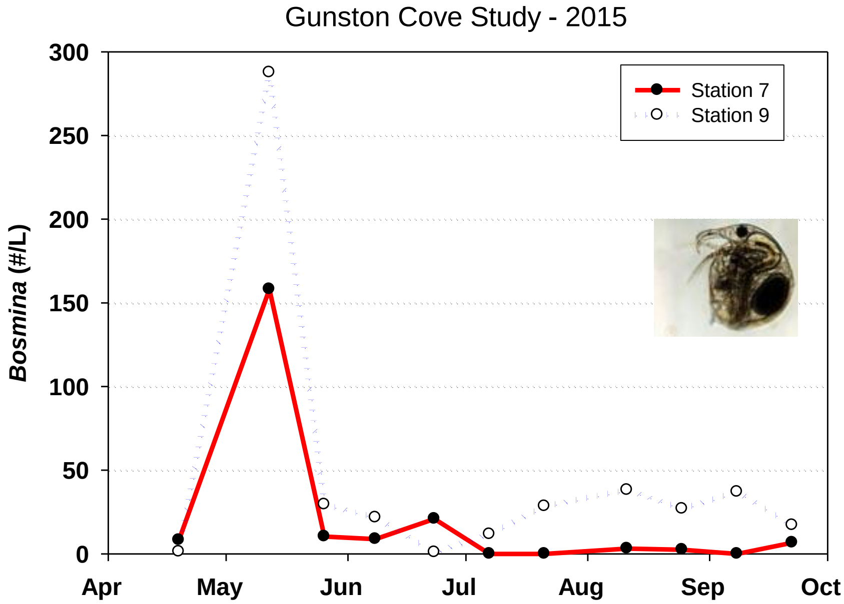


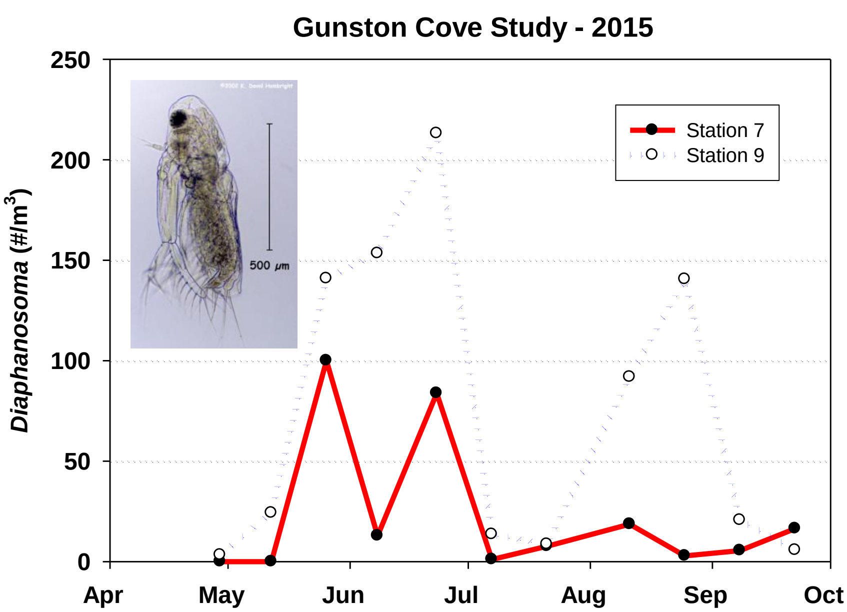
Figure 48. Rotifer Density by Dominant Taxa (#/L). River.



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.

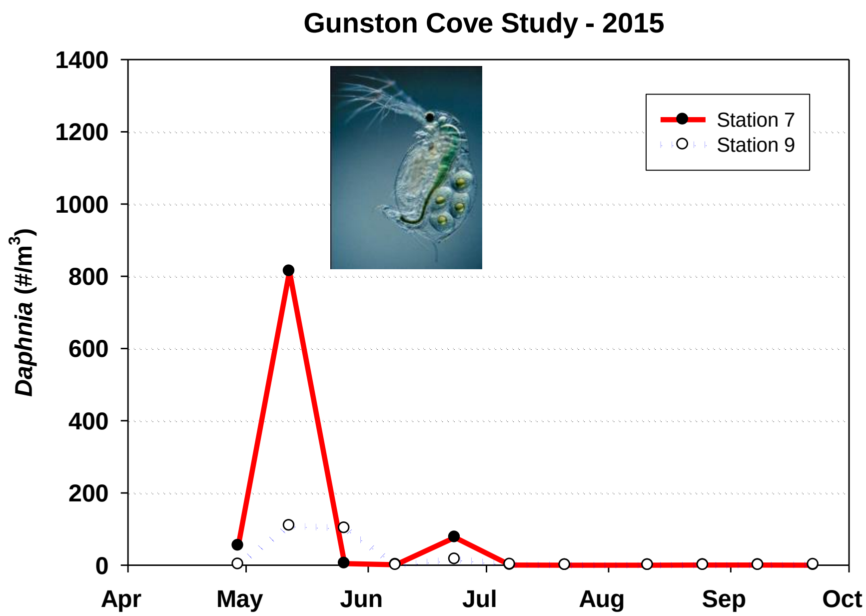
Figure 49. *Bosmina* Density by Station (#/L).

In 2015 the small cladoceran *Bosmina* was most abundant in spring reaching a maximum in early May at both sites (Figure 49). In the cove levels remained low for the rest of the year. *Diaphanosoma*, typically the most abundant larger cladoceran in Gunston Cove, attained much lower than normal levels in 2015, reaching a maximum of about 100/m^3 in June (Figure 50). A somewhat higher peak of about 200/m^3 was observed in late June in the river with a second smaller peak in late August.



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.

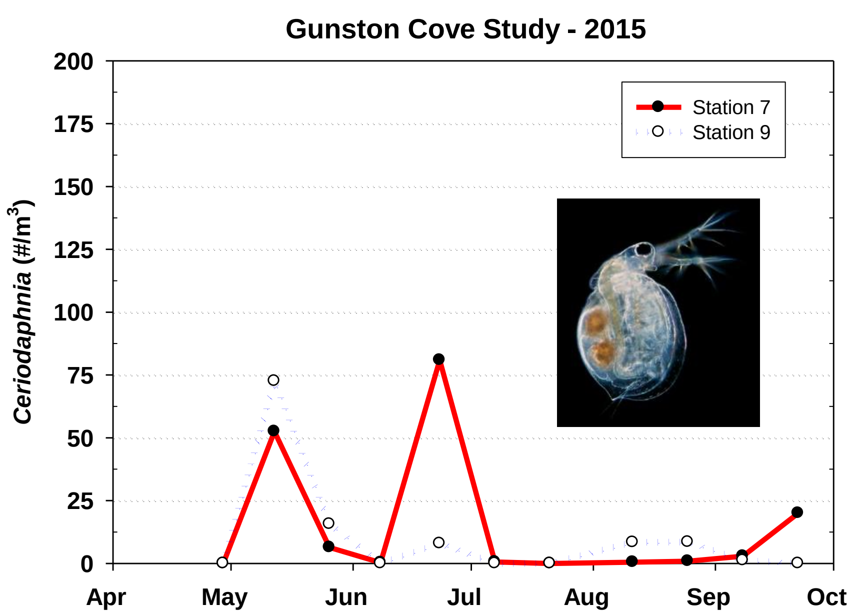
Figure 50. *Diaphanosoma* Density by Station (#/m^3).



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.

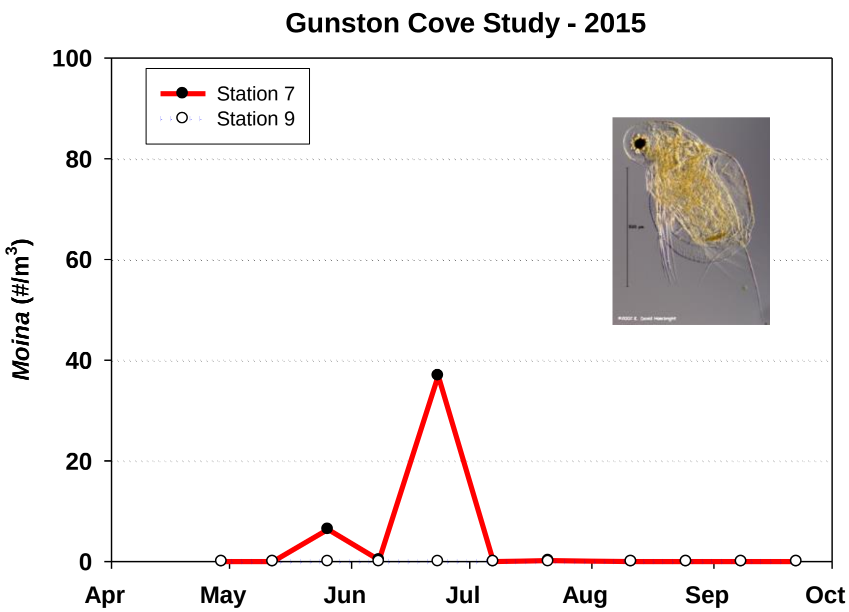
Figure 51. *Daphnia* Density by Station (#/m^3).

In 2015 *Daphnia* was very common in early May attaining 800/m^3, but declined rapidly thereafter (Figure 51). In the river, *Daphina* abundance was very limited. *Ceriodaphnia* was present in modest levels in early May at both sites and again in late June at the river reaching peaks of 50-75/m^3 in both areas (Figure 52).



Ceriodaphnia, another common large-bodied cladoceran, is usually present in numbers similar to *Daphnia*. Like all waterfleas, the juveniles look like miniature adults and grow through a series of molts to a larger size and finally reach reproductive maturity. Most reproduction is asexual except during stressful environmental conditions.

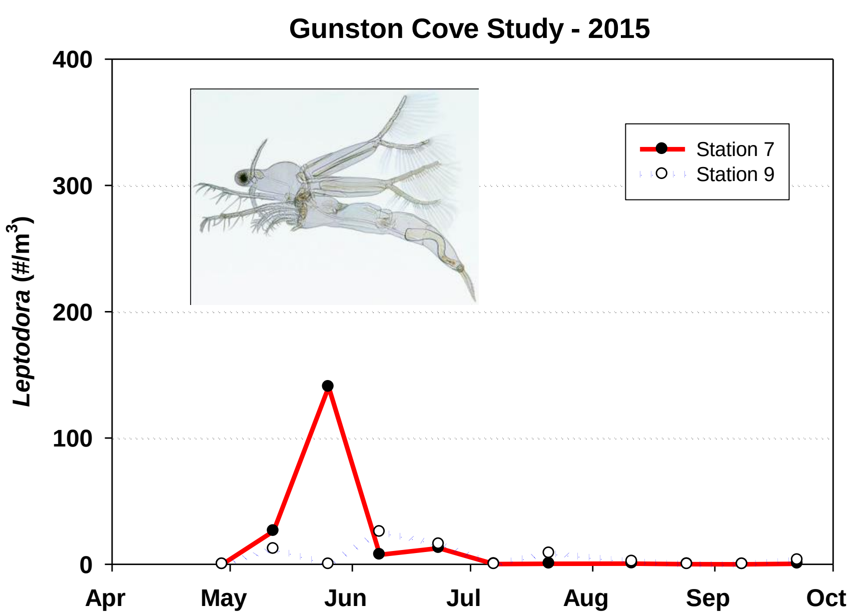
Figure 52. *Ceriodaphnia* Density by Station (#/m^3).



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

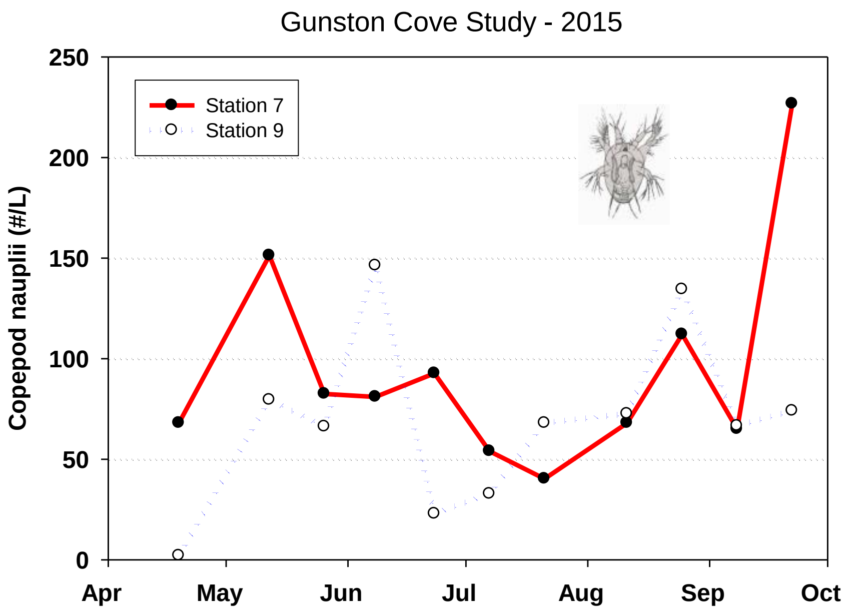
Figure 53. *Moina* Density by Station (#/m^3).

Moina found only in the cove in 2015 with a modest peak of about 40/ m^3 (Figure 53). *Leptodora*, the large cladoceran predator, was mostly present in late May in the cove (Figure 54).



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.

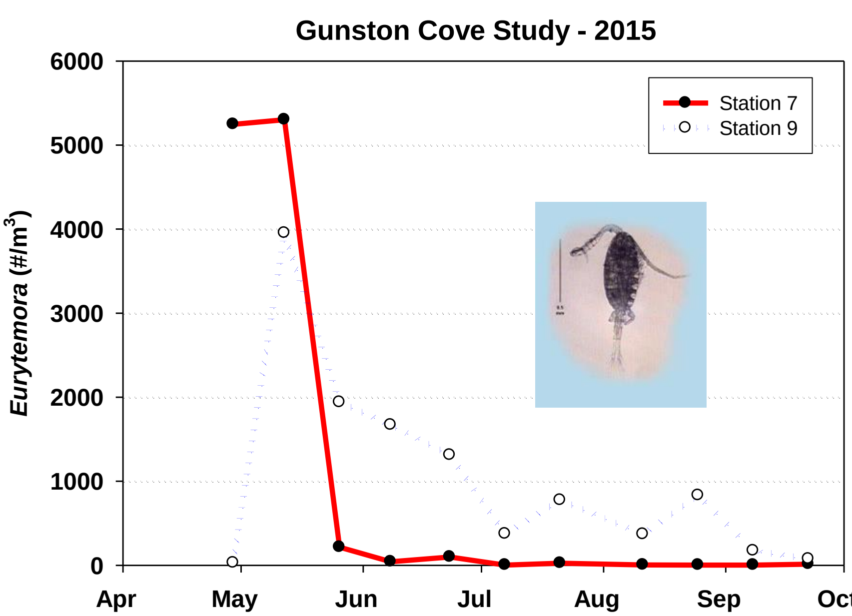
Figure 54. *Leptodora* Density by Station (#/m^3).



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.

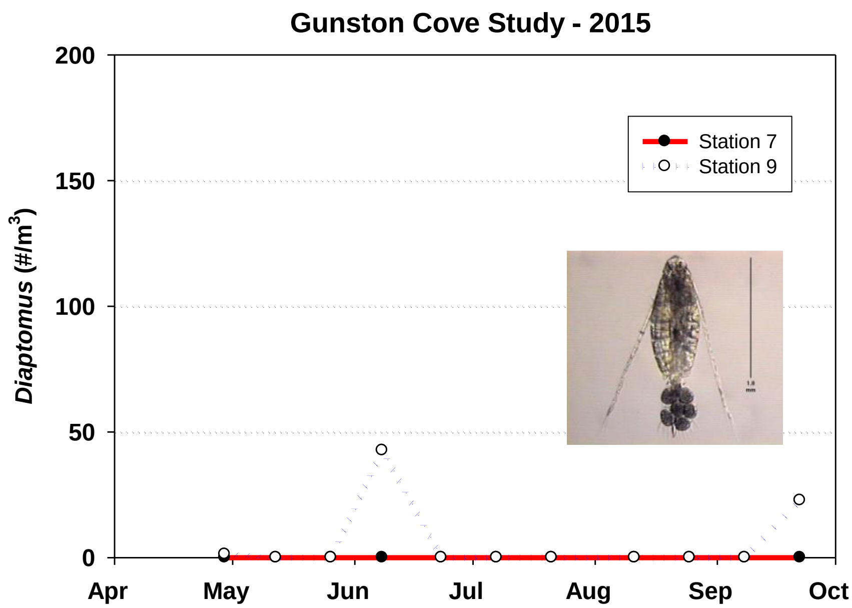
Figure 55. Copepod Nauplii Density by Station (#/L).

In the cove copepod nauplii showed a late May peak and a maximum in late September (Figure 55). In the river, nauplii exhibited early June and late August peaks. *Eurytemora* exhibited highest densities in the cove in late April and early May attaining substantial densities of over 5000/m^3 (Figure 56). Thereafter *Eurytemora* declined strongly in the cove. In the river *Eurytemora* peaked in early May at about 4000/m^3. It declined slowly in the river over then ensuing months.



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*.

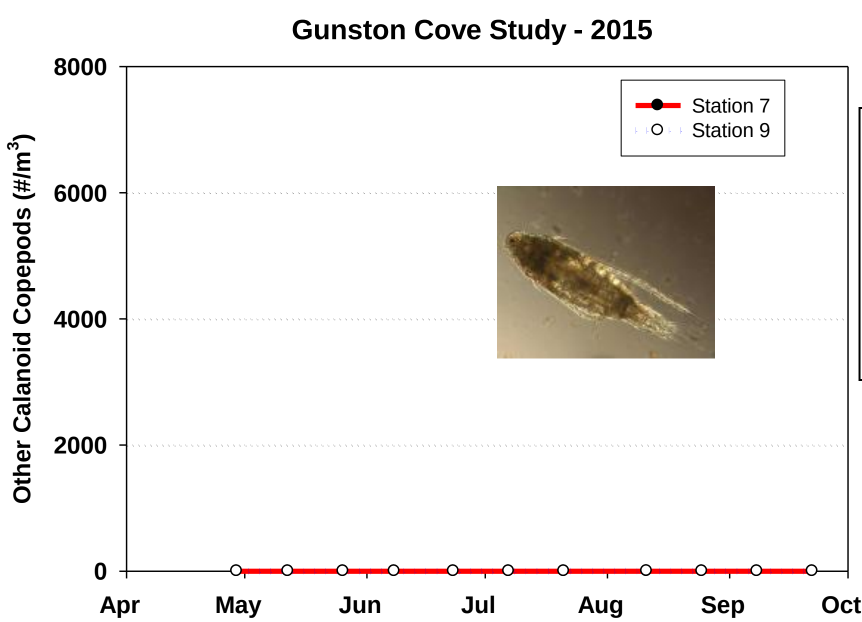
Figure 56. *Eurytemora* Density by Station (#/m^3).



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*.

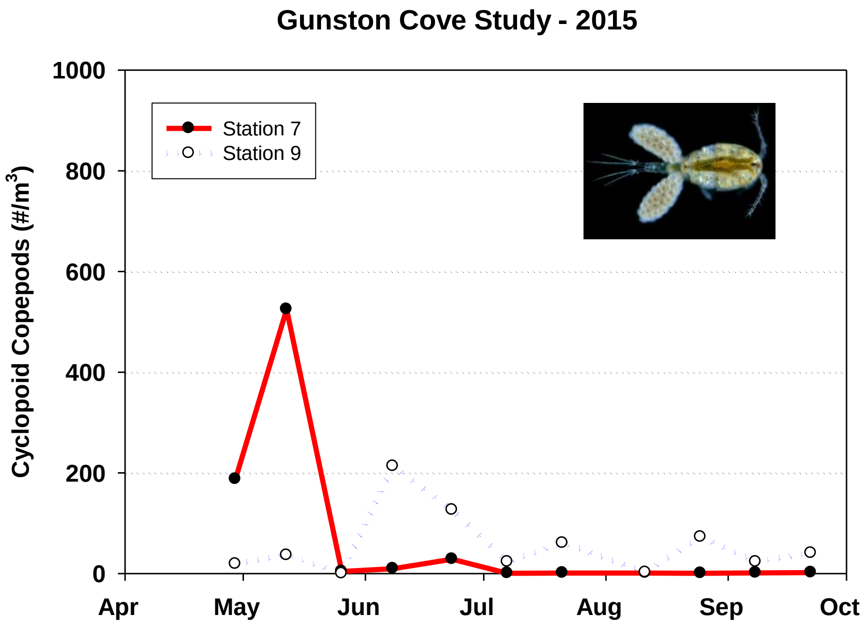
Figure 57. *Diaptomus* Density by Station (#/m^3).

Diaptomus was not found in the cove in 2015 and was only present at 25-50/m^3 in two samples from the river (Figure 57). Other calanoid copepods were not found in 2015 (Figure 58).



Some adult and copepodid copepods are difficult to identify to the genus or species level. These have been lumped into the category of "other copepods".

Figure 58. Other Calanoids Density by Station (#/m^3).



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

Cyclopoid copepods were present in the cove in early spring in 2015 at moderate levels (Figure 55).In the In the river they were somewhat less abundant, but were present for most of the year.

E. Ichthyoplankton – 2015

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 2015, we collected 14 samples (7 at Station 7 and 7 at Station 9) during the months April through July and obtained a total of 1294 larvae (Table 4). The fish larvae are sometimes too damaged to distinguish at the species level, thus some of the counts are only to the genus level. Much progress has been made in the identification of alosa larvae, but due to the damage to the larvae, presumably during collection, the dominant taxa is still Clupeidae (which includes the different *Alosa* species.). Clupeidae were dominant with 54.56% of the catch. Since clupeids actually include all *Alosa*'s and *Dorosoma*'s, our taxon Clupeidae indicates all larvae that could not be identified further than Family. All clupeids therefore, constituted 88.17% of the catch. The most common clupeids were Gizzard Shad at 13.99%, this includes larvae that were only identified to the genus Dorosoma, but Threadfin Shad (another *Dorosoma* than Gizzard Shad) is unlikely to be found this high up in the watershed, and we have not yet positively identified it. Other abundant clupeids were Alewife at 9.35%, Blueback Herring at 8.5%, Hickory Shad at 1.31% and American Shad at 0.46%. Another species abundantly represented in the ichthyoplankton samples was Inland Silverside at 10.43%. Unlike last year, *Morone* sp. (White Perch or Striped Bass) were less common, comprising 0.78% of the catch.

Table 4. The larval fishes collected in Gunston Cove and the Potomac River in 2015

Taxon	Common Name	Station 7	Station 9	Total	% of Total
Alosa aestivalis	Blueback Herring	41	69	110	8.50
Alosa mediocris	Hickory Shad	6	11	17	1.31
Alosa pseudoharengus	Alewife	71	50	121	9.35
Alosa sapidissima	American Shad	4	2	6	0.46
Centrarchidae sp.	Unk. Centrarchid	1	0	1	0.08
Clupeidae	Herring or Shad	310	396	706	54.56
Dorosoma cepedianum	Gizzard Shad	34	0	34	2.63
Dorosoma sp.	Gizzard (or Threadfin) Shad	25	122	147	11.36
Eggs	Unk. Fish eggs	4	1	5	0.39
Lepomis sp.	Unk. Sunfish	1	0	1	0.08
Menidia beryllina	Inland Silverside	12	123	135	10.43
Morone americana	White Perch	5	4	9	0.70
Morone sp.	White Perch or Striped Bass	0	1	1	0.08
unidentified	unidentified	1	0	1	0.08
	TOTAL	**515**	**779**	**1294**	

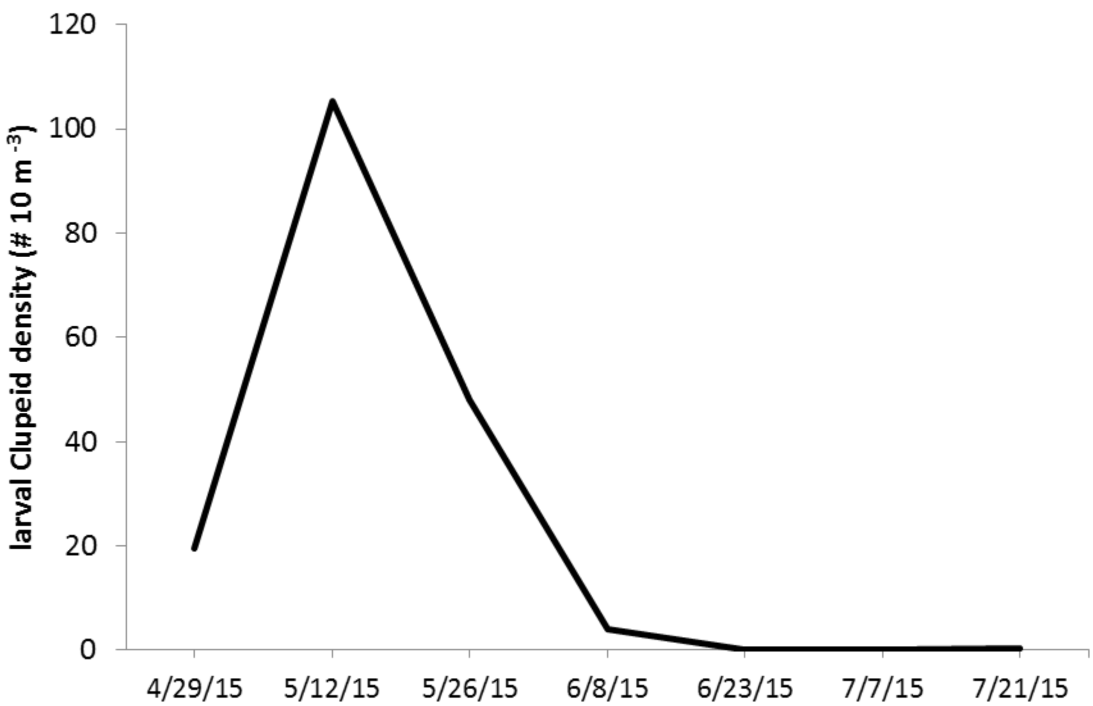


Figure 60. Clupeid larvae, mean density (abundance per $10m^3$).

Clupeid larvae in Figure 60 include Blueback Herring, Hickory Shad, Alewife, American shad, Gizzard Shad, and potentially Threadfin Shad. These have similar spawning patterns so they are lumped into one group for this analysis. Clupeids increased in the study areas in early spring attaining a maximum in mid-May (Figure 60). This is earlier than last year, when the spawning was likely delayed due to the late snow we experienced in 2014, but similar to earlier years By early June the numbers dropped to close to zero, displaying a distinct spawning season from late April to to mid-June. The abundance of other larvae was lower, and had one distinct peak in late May (Figure 61). The other larvae included the taxa Centrarchids (sunfish or bass), *Lepomis* (sunfish), Inland Silverside, White Perch and *Morone* sp. (White Perch or Striped Bass).

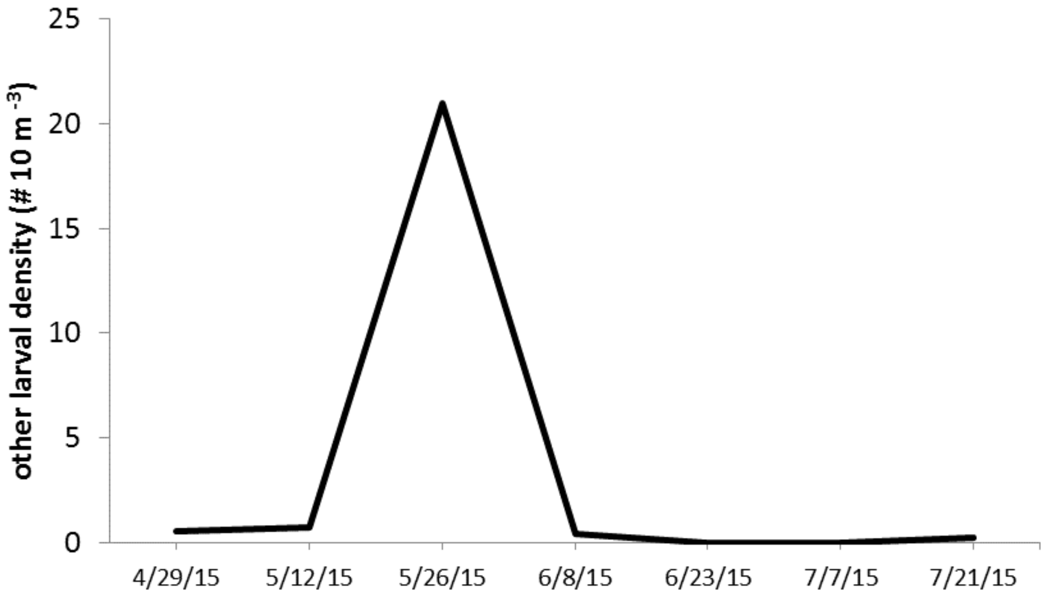


Figure 61. All other larvae, mean density (abundance per $10m^3$).

F. Adult and juvenile fishes – 2015

Trawls

Trawl sampling was conducted between April 14 and May 26 at station 10, and between April 14 and September 9 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 earlier in the season each year. The site has been double sampled with a fyke net since 2012, which may become the only method of sampling in that area in years to come. A total of 3870 fishes comprising 23 species were collected (Table 5). The most dominant species of the fish collected was White Perch (58.3%, 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. Other abundant species included Spottail Shiner (21.7%), Blueback Herring (8.8%), and Alewife (3.6%). Other species were observed sporadically and at low abundances (Tables 5 and 6). Total catch was back up after low abundance in the trawls last years, which is likely attributable to normal inter-annual variability. The sampling period in station 10 was even shorter than previous years, and contributed minimally to total abundance (Table 7).

Table 5. Adult and Juvenile Fish Collected by Trawling. Gunston Cove Study - 2015

Scientific Name	**Common Name**	**Abundance**
Morone americana	White Perch	2256
Notropis hudsonius	Spottail Shiner	839
Alosa aestivalis	Blueback Herring	341
Alosa pseudoharengus	Alewife	140
Alosa sapidissima	American Shad	74
Morone saxatilis	Striped Bass	35
Ictalurus furcatus	Blue Catfish	32
Fundulus diaphanus	Banded Killifish	27
Lepomis microlophus	Redear Sunfish	24
Etheostoma olmstedi	Tessellated Darter	20
Lepomis gibbosus	Pumpkinseed	14
Lepomis macrochirus	Bluegill	14
Lepomis auritus	Redbreast Sunfish	11
Perca flavescens	Yellow Perch	9
Menidia beryllina	Inland Silverside	7
Anchoa mitchilli	Bay Anchovy	6
Alosa sp. Unidentified	Herring or shad	5
Hybognathus regius	Eastern Silvery Minnow	4
Ameiurus nebulosus	Brown Bullhead	3
Dorosoma cepedianum	Gizzard Shad	3
Pomoxis nigromaculatus	Black Crappie	3
Ictalurus punctatus	Channel Catfish	2
Ictalurus sp. Unidentified	Catfish	1
	TOTAL	3870

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 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 6. Adult and Juvenile Fish Collected by Trawling. Gunston Cove Study - 2015

Scientific Name	Common Name	14-Apr	4-May	26-May	3-Jun	17-Jun	1-Jul	15-Jul	5-Aug	19-Aug	9-Sep
Alosa aestivalis	Blueback Herring	0	0	0	0	1	21	62	6	251	0
Alosa pseudoharengus	Alewife	0	0	8	92	3	16	3	6	12	0
Alosa sapidissima	American Shad	0	0	8	20		4	31	2	9	0
Alosa sp. Unidentified	Herring or shad	0	0	0	2	0	0	0	0	3	0
Ameiurus nebulosus	Brown Bullhead	1	0	0	0	0	1	1	0	0	0
Anchoa mitchilli	Bay Anchovy	0	0	0	1	1	0	0	4	0	0
Dorosoma cepedianum	Gizzard Shad	0	0	0	0	0	0	2	0	1	0
Etheostoma olmstedi	Tessellated Darter	10	1	0	0	0	8	1	0	0	0
Fundulus diaphanus	Banded Killifish	15	0	1	0	0	1	2	0	0	8
Hybognathus regius	E. Silvery Minnow	1	0	0	0	0	2	0	1	0	0
Ictalurus furcatus	Blue Catfish	7	1	0	0	5	6	11	1	0	1
Ictalurus punctatus	Channel Catfish	0	0	0	0	0	2	0	0	0	0
Ictalurus sp.	Catfish	0	0	0	0	0	1	0	0	0	0
Lepomis auritus	Redbreast Sunfish	0	9	0	0	0	0	0	0	0	2
Lepomis gibbosus	Pumpkinseed	4	1	2	0	3	2	1	0	1	0
Lepomis macrochirus	Bluegill	4	0	1	1	0	1	3	3	1	0
Lepomis microlophus	Redear Sunfish	8	0	3	3	4	1	0	0	1	4
Menidia beryllina	Inland Silverside	0	0	3	4	0	0	0	0	0	0
Morone americana	White Perch	10	5	36	828	838	125	330	38	45	1
Morone saxatillis	Striped Bass	0	0		0	1	29	3	2	0	0
Notropis hudsonius	Spottail Shiner	89	0	11	33	294	60	191	6	149	6
Perca flavescens	Yellow Perch	1	0	1	0	5	1	1	0	0	0
Pomoxis nigromaculatus	Black Crappie	0	0	0	0	2	0	0	1	0	0
	TOTAL	150	17	74	984	1157	281	642	70	473	22

The dominant migratory species, White Perch, was ubiquitous occurring at all stations on every sampling. In the spring adult White Perch were primarily caught in the nets while later in the summer juveniles dominated.

In total numbers and species richness of fish, station 7 dominated the other stations by far with 3600 individuals from 20 species (Table 7, Figure 62a). Stations 9 and 10 had 175 individuals from 12 species and 95 individuals from 7 species, respectively (Table 7). Station 10 had less units of effort (sampling dates) than station 7 and 9 due to SAV cover, which was the reason the least number of fishes were caught there. A high number of juvenile blueback herring were collected in the Cove (station 7) in late summer (Table 6), which coincides with a large adult spawning population estimated for Pohick Creek earlier in the season (see the Anadromous report). Once spawned in the creeks, the larvae drift down into Gunston Cove, which they then subsequently use as a nursery during the juvenile life stage.

Table 7. Adult and Juvenile Fish Collected by Trawling. Gunston Cove Study – 2015

Scientific Name	Common Name	7	9	10
Alosa aestivalis	Blueback Herring	339	2	0
Alosa pseudoharengus	Alewife	54	86	0
Alosa sapidissima	American Shad	51	23	0
Alosa sp. Unidentified	Herring or shad	3	2	0
Ameiurus nebulosus	Brown Bullhead	1	2	0
Anchoa mitchilli	Bay Anchovy	1	5	0
Dorosoma cepedianum	Gizzard Shad	3	0	0
Etheostoma olmstedi	Tessellated Darter	11	0	9
Fundulus diaphanus	Banded Killifish	12	0	15
Hybognathus regius	Eastern Silvery Minnow	4	0	0
Ictalurus furcatus	Blue Catfish	0	32	0
Ictalurus punctatus	Channel Catfish	0	2	0
Ictalurus sp.	Catfish	0	1	0
Lepomis auritus	Redbreast Sunfish	11	0	0
Lepomis gibbosus	Pumpkinseed	13	0	1
Lepomis macrochirus	Bluegill	11	0	3
Lepomis microlophus	Redear Sunfish	16	0	8
Menidia beryllina	Inland Silverside	5	2	0
Morone americana	White Perch	2234	16	6
Morone saxatillis	Striped Bass	35	0	0
Notropis hudsonius	Spottail Shiner	784	2	53
Perca flavescens	Yellow Perch	9	0	0
Pomoxis nigromaculatus	Black Crappie	3	0	0
	TOTAL	3600	175	95

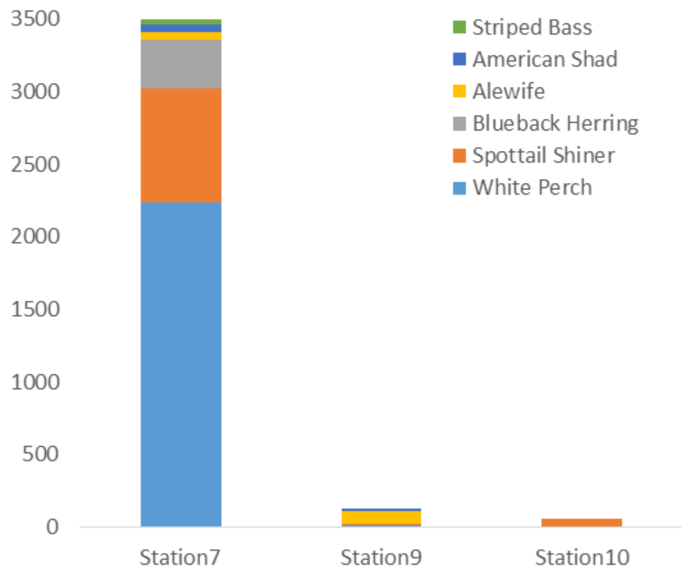


Figure 62a. Adult and Juvenile Fishes Collected by Trawling in 2015. Dominant Species by Station.

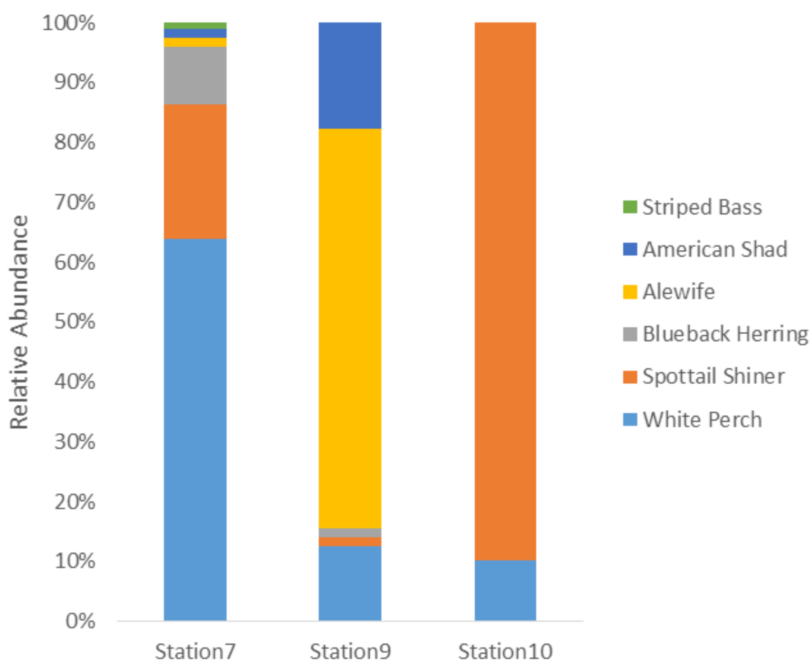


Figure 62b. Relative abundance of Adult and Juvenile Fishes Collected by Trawling in 2015.

The six most abundant species varied in representation across stations (Figure 62b). 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 58a). We were able to identify a few (35) juvenile striped bass among the representatives of the *Morone* genus (the rest were white perch); which shows (as in a few instances in previous years) that the juveniles of striped bass can be found in the fresh upper reaches of the Potomac River. Station 10 showed a high proportion of Spottail Shiner, which was caught in high abundance at station 7 as well. Alosines (herring or shad) were a dominant group at station 7 and 9, with representation from Blueback Herring, Alewife and American Shad. These species of concern had a highly productive year , with high juvenile catches in the cove, as well as high abundances of adults and larvae in the creeks draining into Gunston Cove (see Anadromous report). Blue Catfish (not shown in figure) are primarily a mainstem species and have not been featured prominently at stations within the cove (32 collected at station 9 this year, while 0 at station 7 or 10). Station 7 was overall the most productive site, with a total abundance an order of magnitude higher than the other two stations.

When looking at the seasonal trend in the same data it is clear that White Perch was the most common species, and was present throughout the season (Figure 63a and b). The relative abundance of Spottail Shiner was even throughout the season. American Shad and Alewife were most abundant in June and July with high relative abundance throughout September. These all constitute juveniles that were spawned in spring (March-May) and remain in Gunston Cove, which serves as a nursery to these species. Just as in previous years, the most productive month was June, 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 (Gizzard Shad), and on benthos, fishes, and detritus.

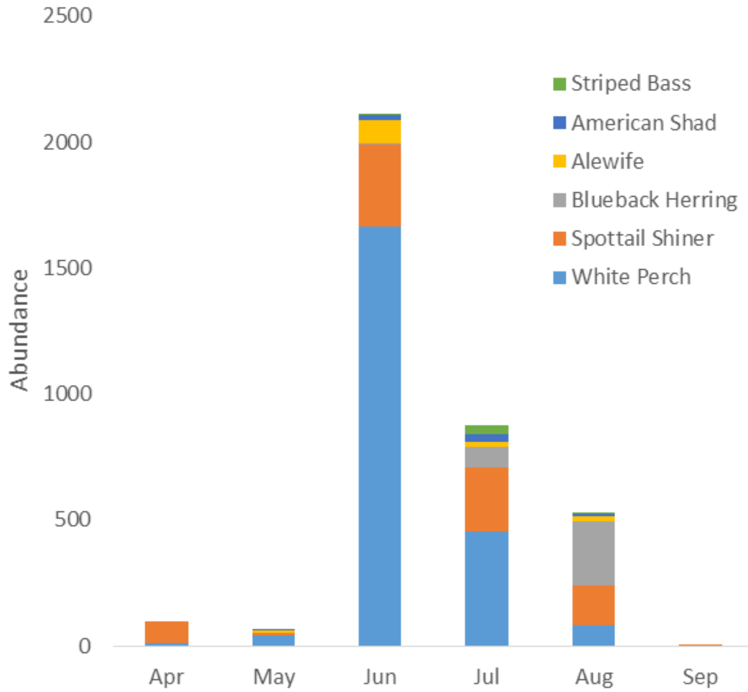


Figure 63a. Adult and Juvenile Fishes Collected by Trawling in 2015. Dominant Species by Month.

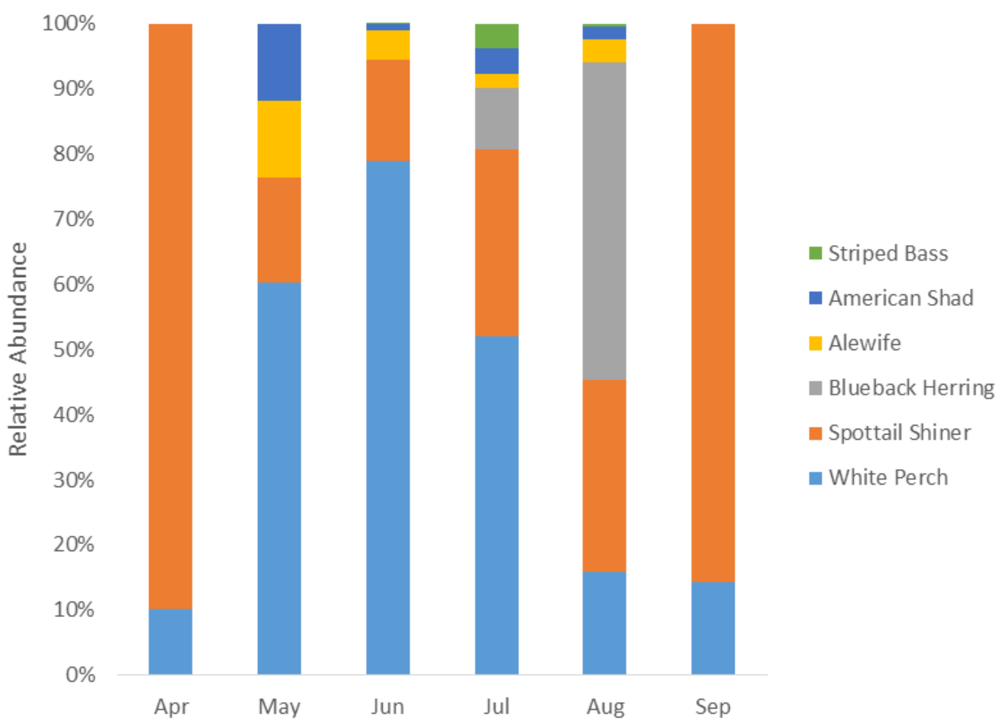


Figure 63b. Relative Abundance for Adult and Juvenile Fishes Collected by Trawling in 2015.

Seines

Seine sampling was conducted approximately semi-monthly at 4 stations between April 14 and September 9. As planned, only one sampling trip per month was performed in April and September. We stopped seining at station 4 on June 17 (last seine sample was on June 17) 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 5992 fishes of 29 species (Table 8). This is comparable to 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 44.4%. The evenness is increased as compared to last year, where 71.6% of the catch was Banded Killifish, while the total catch was slightly higher. Other dominant species (with >5% of relative abundance) were White Perch (19.3%) followed by Gizzard Shad (11.4%), and American Shad (7.7%). Other species that had over 100 individuals include Spottail Shiner (3.0%), Inland Silverside (2.7%), Golden Shiner (2.3%), *Alosa* sp. (1.7%), and Tessellated Darter (1.7%). 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 early summer than late summer (Table 9, Figure 64). While the highest abundance of Banded Killifish occurred in May, the highest total abundance was in June due to large numbers of juvenile clupeids (particularly gizzard shad). The high abundance in July constituted a pulse of White Perch juveniles that recruited to shallow habitats accessible by the seine.

The highest abundance of Banded Killifish was found in station 4 this year. Highest total abundance was at station 11 due to the large catch of juvenile white perch in July, and sizeable catches of American Shad and Banded Killifish (Table 10, Figure 65). Abundance varied from n=2153 fish at station 11 to n=1025 at station 6 (Table 10). Species richness varied from 20 species in station 4 to 23 species in station 6 and 4B.

Table 8. Adult and Juvenile Fish Collected by Seining. Gunston Cove Study - 2015

Scientific Name	Common Name	Abundance
Fundulus diaphanus	Banded Killifish	2663
Morone americana	White Perch	1157
Dorosoma cepedianum	Gizzard Shad	682
Alosa sapidissima	American Shad	461
Notropis hudsonius	Spottail Shiner	181
Menidia beryllina	Inland Silverside	164
Notemigonus crysoleucas	Golden Shiner	138
Alosa sp. Unidentified	Herring or shad	102
Etheostoma olmstedi	Tessellated Darter	101
Carpiodes cyprinus	Quillback	92
Fundulus heteroclitus	Mummichog	66
Hybognathus regius	Eastern Silvery Minnow	24
Strongylura marina	Atlantic Needlefish	24
Lepomis macrochirus	Bluegill	22
Morone saxatillis	Striped Bass	19
Alosa aestivalis	Blueback Herring	17
Enneacanthus gloriosus	Bluespotted Sunfish	16
Alosa pseudoharengus	Alewife	15
Lepomis auritus	Redbreast Sunfish	9
Carassius auratus	Goldfish	7
Perca flavescens	Yellow Perch	7
Lepomis gibbosus	Pumpkinseed	5
Lepomis microlophus	Redear Sunfish	5
Micropterus salmoides	Large-mouth Bass	5
Alosa mediocris	Hickory Shad	3
Gambusia holbrooki	Mosquitofish	3
Anchoa mitchilli	Bay Anchovy	2
Lepisosteus osseus	Longnose Gar	1
Lepomis cyanellus	Green Sunfish	1
	TOTAL	5992

Banded Killifish (*Fundulus diaphanus*) is a small fish, but the most abundant species in shoreline areas of the cove. Individuals become sexually mature at about 5 cm in length and may grow to over 8 cm long. Spawning occurs throughout the warmer months over vegetation and shells. They feed on benthic invertebrates, vegetation, and very small fishes.

White Perch (*Morone americana*), which was discussed earlier in the trawl section, is also a common shoreline fish as juveniles collected in seines. Abundances of White Perch in the seine collections are decreasing as the Banded Killifish catches increase, which indicates a change in community structure in the littoral zone.

Seining is conducted in shallow water adjacent to the shoreline. Some fish minimize predation by congregating along the shoreline rather than disperse through the open water. While seines and trawls tend to collect about the same number of indi-viduals per effort, seines sample a smaller volume of water emphasizing the higher densities of fish along the shoreline.

Table 9. Adult and Juvenile Fish Collected by Seining. Gunston Cove Study - 2015

Scientific Name	Common Name	14-Apr	4-May	26-May	3-Jun	17-Jun	1-Jul	15-Jul	5-Aug	19-Aug	9-Sep
Alosa aestivalis	Blueback Herring	0	0	0	0	1	5	2	2	6	1
Alosa mediocris	Hickory Shad	0	0	0	2	0	1	0	0	0	0
Alosa pseudoharengus	Alewife	0	0	10	1	2	1	0	0	1	0
Alosa sapidissima	American Shad	0	0	10	168	46	70	92	18	41	16
Alosa sp. Unidentified	Herring or shad	0	0	1	99	0	1	0	0	1	0
Anchoa mitchilli	Bay Anchovy	0	0	2	0	0	0	0	0	0	0
Carassius auratus	Goldfish	0	0	0	0	5	1	0	1	0	0
Carpiodes cyprinus	Quillback	0	0	0	5	38	12	33	2	1	1
Dorosoma cepedianum	Gizzard Shad	0	0	0	668	0	11	2	0	1	0
Enneacanthus gloriosus	Bluespotted Sunfish	0	0	0		1	0	0	0	0	15
Etheostoma olmstedi	Tessellated Darter	21	27	28	2	8	3	2	0	0	10
Fundulus diaphanus	Banded Killifish	302	367	856	232	580	31	40	39	76	140
Fundulus heteroclitus	Mummichog	6	6	26	2	1	2	20	0	2	1
Gambusia holbrooki	Mosquitofish	0	0	0	0	0	0	0	1	0	2
Hybognathus regius	Eastern Silvery Minnow	8	0	0	0	0	5	6	5	0	0
Lepisosteus osseus	Longnose Gar	0	0	0	0	0	0	1	0	0	0
Lepomis auritus	Redbreast Sunfish	0	0	1	2	0	0	1	0	1	4
Lepomis cyanellus	Green Sunfish	0	0	0	0	0	0	0	1	0	0
Lepomis gibbosus	Pumpkinseed	0	0	0	0	4	0	0	0	0	1
Lepomis macrochirus	Bluegill	6	0	0	2	0	2	1	3	0	8
Lepomis microlophus	Redear Sunfish	2	0	1	0	1	0	0	0	0	1
Menidia beryllina	Inland Silverside	6	48	10	81	6	5	3	4	0	1
Micropterus salmoides	Large-mouth Bass	0	0	0	0	0	2	2	0	0	1
Morone americana	White Perch	0	1	3	4	146	701	146	16	3	137
Morone saxatillis	Striped Bass	0	0	0	1	0	13	4	0	0	1
Notemigonus crysoleucas	Golden Shiner	122	2	6	6	0	0	1	1	0	0
Notropis hudsonius	Spottail Shiner	93	33	20	2	8	11	13	0	0	1
Perca flavescens	Yellow Perch	2	0	1	2	1	0	0	1	0	0
Strongylura marina	Atlantic Needlefish	0	0	18	6	0	0	0	0	0	0
	TOTAL	568	484	993	1285	848	877	369	94	133	341

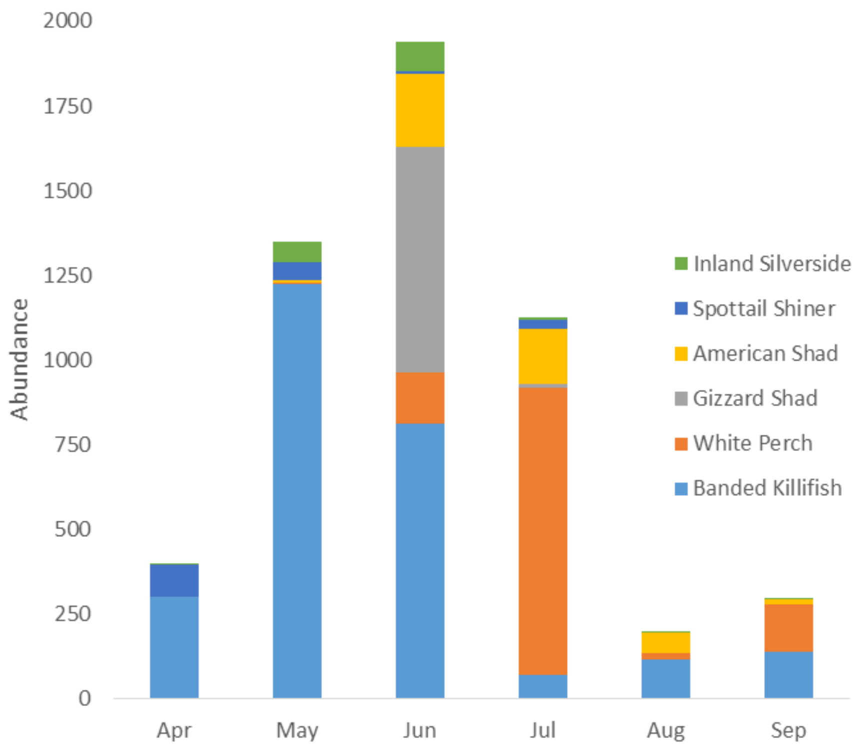


Figure 64. Adult and Juvenile Fish Collected by Seining in 2015. Dominant Species by Month.

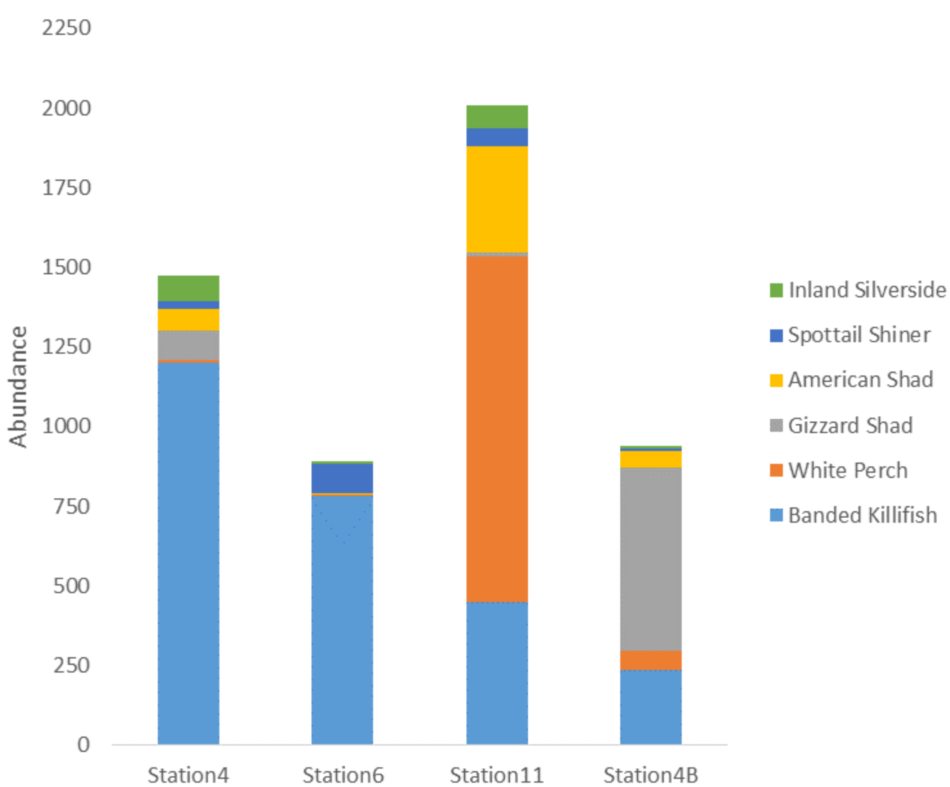


Figure 65. Adult and Juvenile Fishes Collected by Seining in 2015. Dominant Species by Station.

Table 10. Adult and Juvenile Fish Collected by Seining in 2015 per station in Gunston Cove.

Scientific Name	Common Name	4	6	11	4B
Alosa aestivalis	Blueback Herring	1	0	16	0
Alosa mediocris	Hickory Shad	1	0	1	1
Alosa pseudoharengus	Alewife	3	2	4	6
Alosa sapidissima	American Shad	71	4	332	54
Alosa sp. Unidentified	Herring or shad	99	2	1	0
Anchoa mitchilli	Bay Anchovy	0	0	0	2
Carassius auratus	Goldfish	5	2	0	0
Carpiodes cyprinus	Quillback	0	3	69	20
Dorosoma cepedianum	Gizzard Shad	92	0	14	576
Enneacanthus gloriosus	Bluespotted Sunfish	1	14	0	1
Etheostoma olmstedi	Tessellated Darter	9	14	8	70
Fundulus diaphanus	Banded Killifish	1199	781	447	236
Fundulus heteroclitus	Mummichog	16	44	4	2
Gambusia holbrooki	Mosquitofish	0	2	0	1
Hybognathus regius	Eastern Silvery Minnow	0	8	16	0
Lepisosteus osseus	Longnose Gar	0	0	0	1
Lepomis auritus	Redbreast Sunfish	0	7	0	2
Lepomis cyanellus	Green Sunfish	0	1	0	0
Lepomis gibbosus	Pumpkinseed	4	0	1	0
Lepomis macrochirus	Bluegill	1	18	1	2
Lepomis microlophus	Redear Sunfish	1	2	1	1
Menidia beryllina	Inland Silverside	79	6	72	7
Micropterus salmoides	Largemouth Bass	0	4	0	1
Morone americana	White Perch	9	5	1085	58
Morone saxatillis	Striped Bass	1	2	11	5
Notemigonus crysoleucas	Golden Shiner	80	7	5	46
Notropis hudsonius	Spottail Shiner	22	93	60	6
Perca flavescens	Yellow Perch	0	3	2	2
Strongylura marina	Atlantic Needlefish	16	1	3	4
	TOTAL	1710	1025	2153	1104

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 653 (1210) specimens of 17 species in the two fyke nets (Station Fyke 1 and Station Fyke 2; Figure 1b; Table 11), which is about half of what we caught in 2014 (but more than 2013). While Banded Killifish is highly dominant here as well (69% 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. Species contributing to more than 1% of the catch include White Perch (6.9%), Pumpkinseed (6.6%), Bluegill (4.6%), Redear Sunfish (4.1%), Inland Silverside (2.7%), Eastern Silvery Minnow (1.7%), and Redbreast Sunfish (1.5%). This emphasizes the value of sampling with different gear types when striving to represent the community present in Gunston Cove. We did not collect any bullheads or native catfishes in the fyke nets this year, but we will continue to monitor the native bullhead and catfish catches in the fyke nets, as relative high catches in the fyke nets of these species 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 (mainly in the Potomac mainstem).

Table 11. Adult and Juvenile Fish Collected by Fyke Nets. Gunston Cove Study - 2015

Scientific Name	**Common Name**	**Abundance**
Fundulus diaphanus	Banded Killifish	453
Morone americana	White Perch	45
Lepomis gibbosus	Pumpkinseed	43
Lepomis macrochirus	Bluegill	30
Lepomis microlophus	Redear Sunfish	27
Menidia beryllina	Inland Silverside	18
Hybognathus regius	Eastern Silvery Minnow	11
Lepomis auritus	Redbreast Sunfish	10
Carassius auratus	Goldfish	6
Enneacanthus gloriosus	Bluespotted Sunfish	3
Alosa sapidissima	American Shad	1
Alosa sp. Unidentified	Herring or Shad	1
Etheostoma olmstedi	Tessellated Darter	1
Lepomis sp. Unidentified	Sunfish	1
Notropis hudsonius	Spottail Shiner	1
Perca flavescens	Yellow Perch	1
Pomoxis nigromaculatus	Black Crappie	1
	TOTAL	653

Table 12. Adult and Juvenile Fish Collected by Fyke Nets. Gunston Cove Study - 2015

Scientific Name	Common Name	14-Apr	4-May	26-May	3-Jun	1-Jul	15-Jul	5-Aug	19-Aug	9-Sep
Alosa sapidissima	American Shad	0	0	0	0	0	0	0	1	0
Alosa sp. Unidentified	Herring or Shad	0	0	1	0	0	0	0	0	0
Carassius auratus	Goldfish	0	0	0	0	0	4	1	1	0
Enneacanthus gloriosus	Bluespotted Sunfish	1	0	0	0	0	0	0	0	2
Etheostoma olmstedi	Tessellated Darter	0	1	0	0	0	0	0	0	0
Fundulus diaphanus	Banded Killifish	0	0	7	7	222	130	61	14	12
Hybognathus regius	Eastern Silvery Minnow	0	0	0	0	3	8	0	0	0
Lepomis auritus	Redbreast Sunfish	0	0	0	0	0	0	0	0	10
Lepomis gibbosus	Pumpkinseed	0	0	0	2	3	28	4	5	1
Lepomis macrochirus	Bluegill	6	0	5	1	2	6	3	6	1
Lepomis microlophus	Redear Sunfish	0	0	4	0	11	7	1	0	4
Lepomis sp. Unidentified	Sunfish	0	0	0	0	1	0	0	0	0
Menidia beryllina	Inland Silverside	0	5	7	0	0	5	1	0	0
Morone americana	White Perch	2	7	0	0	30	2	4	0	0
Notropis hudsonius	Spottail Shiner	0	0	0	0	0	1	0	0	0
Perca flavescens	Yellow Perch	0	0	0	1	0	0	0	0	0
Pomoxis nigromaculatus	Black Crappie	0	0	1	0	0	0	0	0	0
	TOTAL	9	13	25	11	272	191	75	27	30

SAV coverage was extensive and dense even earlier in the season this year than in previous years (June). Highest abundances were collected in July just like last year, mostly caused by a high abundance of Banded Killifish (Table 12).

Fyke 1 had a higher total catch (469 fishes; Table 13), while in both nets the same species were caught with a similar relative contribution to the catch (Table 13). Abundance of dominant species by month (Figure 66) reveals that Banded Killifish and total catch reached the highest abundance in July. Abundance in Fyke 1 was higher than Fyke 2 just like last year, due to the high abundance of Banded Killifish collected in Fyke 1 (Figure 67). The community structure collected with the two fyke nets is very similar.

Table 13. Adult and Juvenile Fish Collected by Fyke Nets. Gunston Cove Study - 2015

Scientific Name	Common Name	Fyke 1	Fyke 2
Alosa sapidissima	American Shad	0	1
Alosa sp. Unidentified	Herring or Shad	0	1
Carassius auratus	Goldfish	3	3
Enneacanthus gloriosus	Bluespotted Sunfish	1	2
Etheostoma olmstedi	Tessellated Darter	0	1
Fundulus diaphanus	Banded Killifish	372	81
Hybognathus regius	Eastern Silvery Minnow	1	10
Lepomis auritus	Redbreast Sunfish	5	5
Lepomis gibbosus	Pumpkinseed	31	12
Lepomis macrochirus	Bluegill	10	20
Lepomis microlophus	Redear Sunfish	19	8
Lepomis sp. Unidentified	Sunfish	0	1
Menidia beryllina	Inland Silverside	9	9
Morone americana	White Perch	17	28
Notropis hudsonius	Spottail Shiner	1	0
Perca flavescens	Yellow Perch	0	1
Pomoxis nigromaculatus	Black Crappie	0	1
	TOTAL	469	184

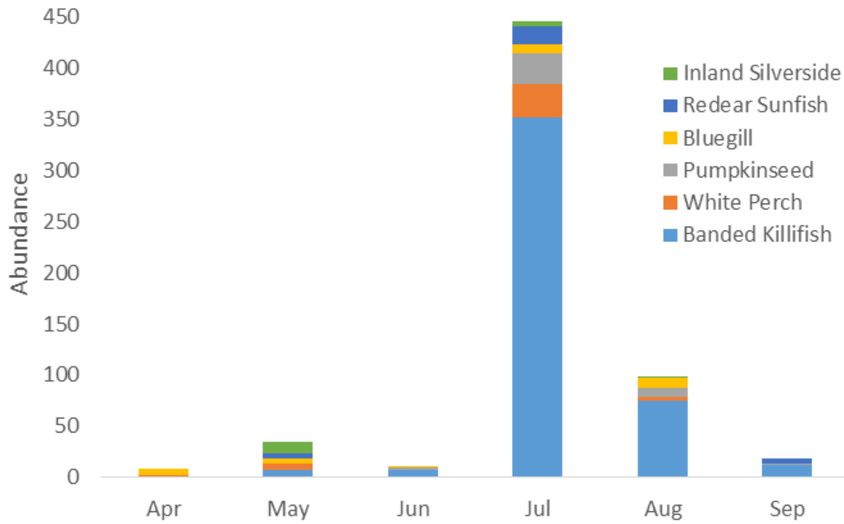


Figure 66. Adult and Juvenile Fish Collected by Fyke Nets. Dominant Species by Month. 2015.

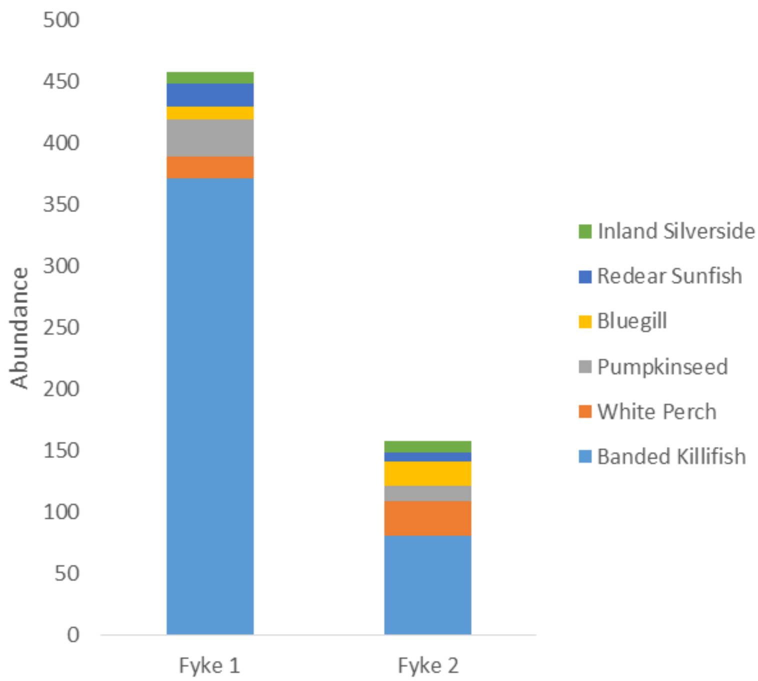


Figure 67. Adult and Juvenile Fishes Collected by Fyke Nets. Dominant Species by Station. 2015.

G. Submersed Aquatic Vegetation – 2015

The map below (Figure 68) depicts the area covered by SAV as determined by the Virginia Institute of Marine Science utilizing aerial imagery for 2015. This map indicates that SAV coverage in 2015 was more extensive than in 2013 and 2014 and was one of the greatest years on record covering almost all of the inner cove up to about Station 7 which was just outside the SAV area.

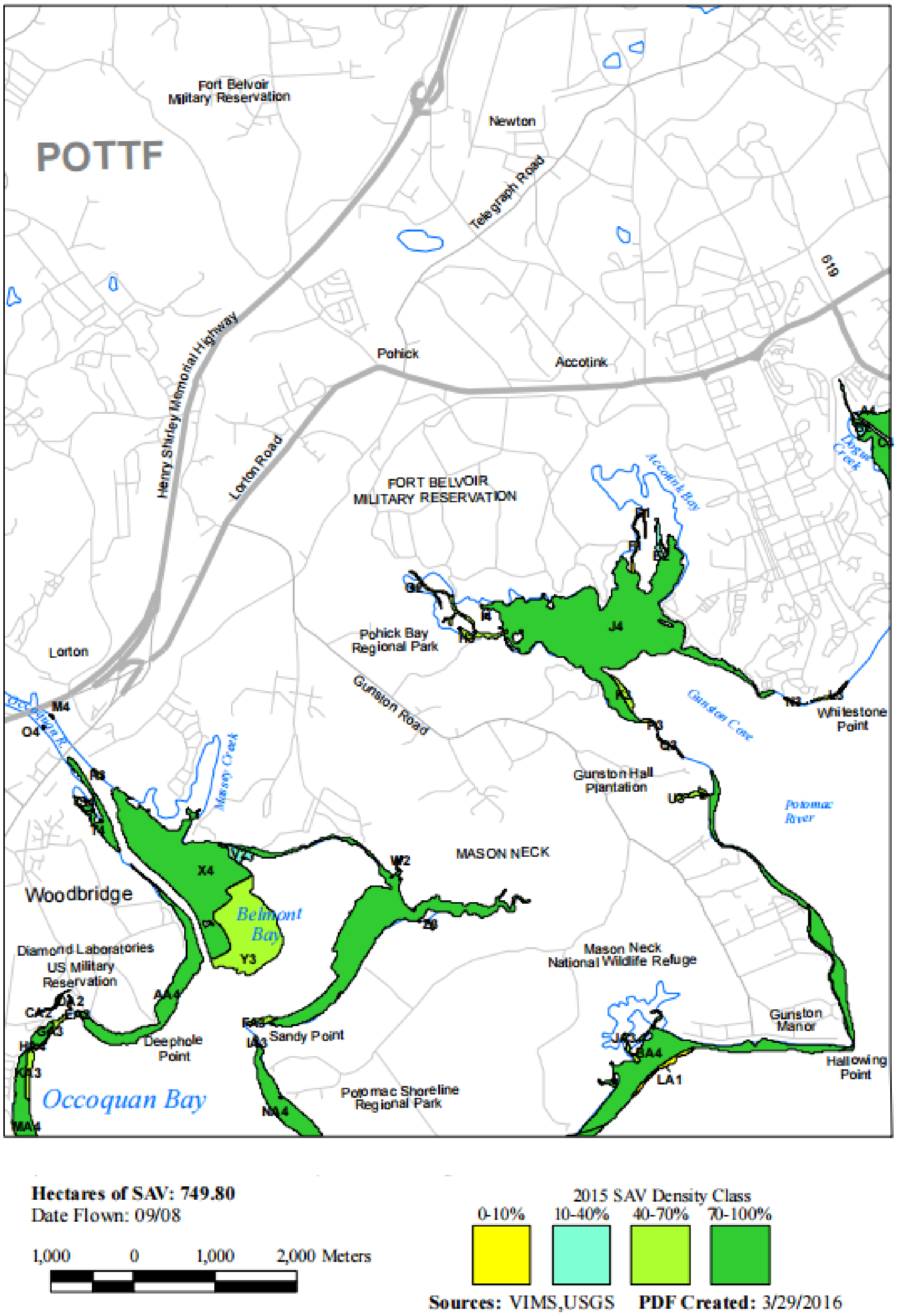


Figure 68. Distribution and density of Submersed Aquatic Vegetation (SAV) in the Gunston Cove area in 2015. VIMS (http://www.vims.edu/bio/sav/index.html).

H. Benthic Macroinvertebrates - 2015

Triplicate petite ponar samples were collected at the cove (Station 7) and river (Station 9) sites on monthly from May to September. Oligochaetes have generally been the most common invertebrates collected in these samples and were found at a greater density at Station 7 than at Station 9 (Figure 69a). Chironomids have generally been second in abundance, but in recent years have decreased. In 2015 amphipods were the second most abundant taxon and were very abundant at Station 9. Gastropods were found in roughly even numbers at both sites. Other taxa found chiefly in the river were Turbellaria (flatworms), isopods, bivalves (mostly the Asiatic clam (Corbicula) and Hirundinea (leeches).

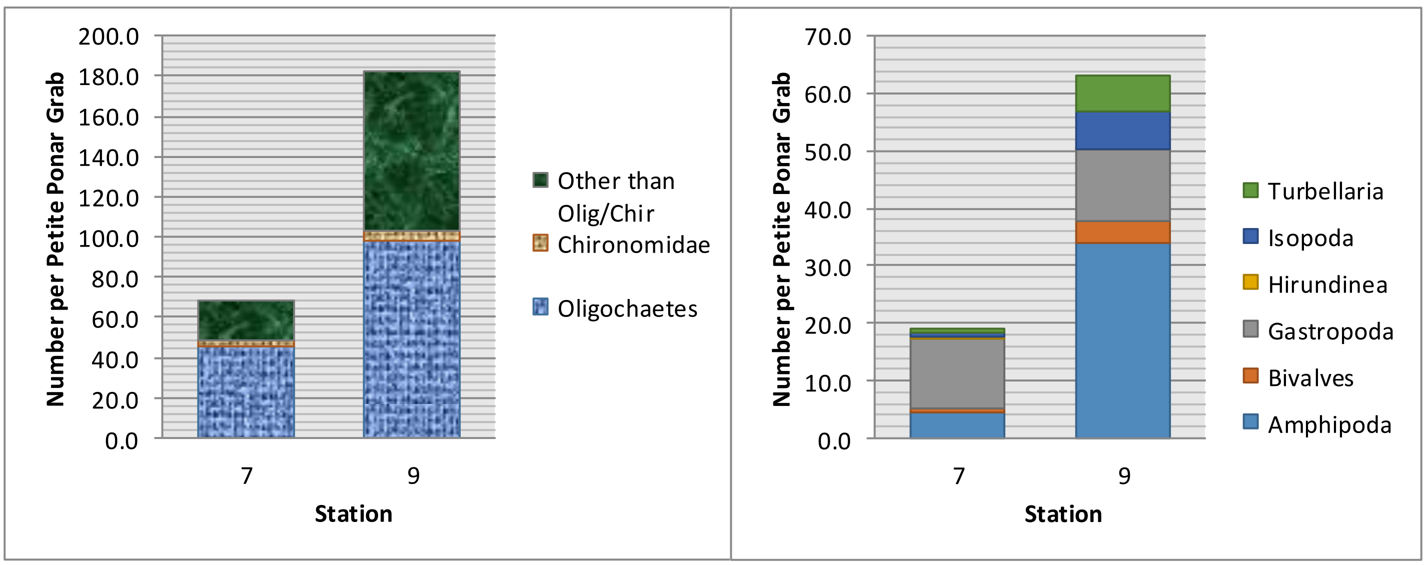


Figure 69. Average abundance of various benthic macroinvertebrate taxa in petite ponar samples collected on four dates in 2015. (a) dominant taxa. (b) “other” group from (a) broken out by taxa.

DISCUSSION

A. 2015 Data

The year 2015 was characterized by above normal temperatures for the entire study period with highest monthly average of 27.4°C in July. Monthly precipitation was over three times the normal amount in June and continued above normal into July which caused flow increases in both Accotink Creek and the river mainstem. Mean monthly discharge in Accotink Creek was highly elevated in June. Both river and Accotink Creek flows were substantially below normal in August and September.

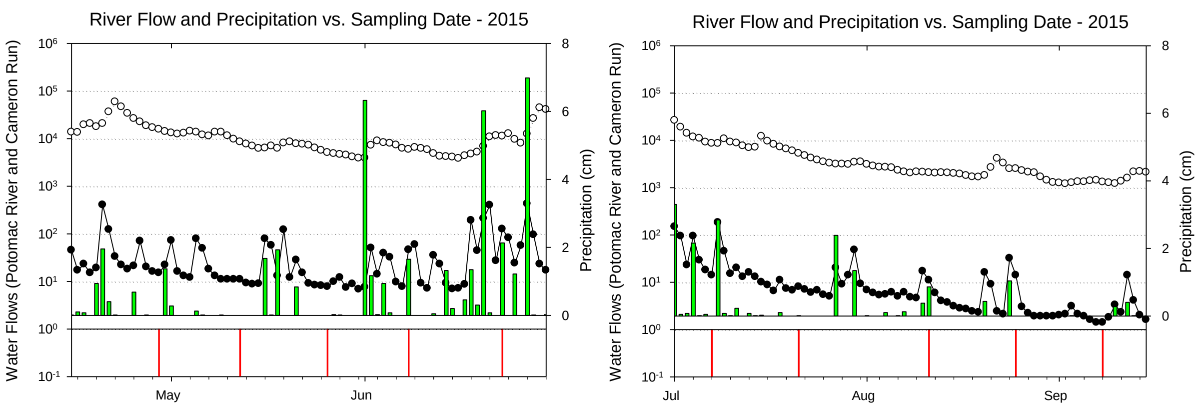


Figure 70. Precipitation (green bars), Accotink Creek flows (solid circles), Potomac River flows (open circles) and water quality/plankton sampling events (red lines at bottom).

Major flow events in June were significant enough to have impacts on the biota and water quality of the cove. Other runoff events were smaller or did not occur directly before sampling and would not be expected to have major impacts on observations. Since flows were not highly elevated in the Potomac mainstem in June, any effects of high flows could be attributed directly to tributary inflows.

Mean water temperature peaked in July at the time of the highest air temperatures of the year. Temperatures increased rapidly in early May. The cove station was typically slightly warmer on a given date. Specific conductance was generally in the 200-400 µS/cm range and remarkably similar at both sites. At both sites values declined in June, probably due to flow events. Chlorides showed a gradual increase seasonally at both sites. Indicators of photosynthetic intensity (dissolved oxygen-percent saturation and field pH) indicated strong photosynthesis in the cove in two periods early spring and late summer, the first probably the result of strong phytoplankton production and the second SAV photosynthesis. In the river values were generally moderate with little seasonal trend indicating lower photosynthetic activity in the river than in the cove. Light penetration dropped markedly in June in the aftermath of the local flow and flushing events. But as the summer went on Secchi depth in the cove rose markedly reaching a record depth of 1.9 m. Low light attenuation and low turbidity also indicated clear water in late August and early September. Total alkalinity was generally 60-100 mg/L as $CaCO_3$ with consistently higher values in the river.

Ammonia nitrogen was low (<0.08 mg/L) on most dates with highest values in late June in both cove and river. The un-ionized form was extremely scarce. Nitrate was found at moderate levels at both sites in the spring and decreased steadily in the early summer. In both regions nitrate dropped below 0.2 mg/L by the end of August. Nitrite nitrogen was much lower being less than the limit of detection in the most cove samples with a few higher values in the river. Organic nitrogen was similar at the two sites with little consistent seasonal pattern. Total phosphorus was also similar at both sites and showed little seasonal pattern. SRP values were generally much lower being mostly below 0.01 mg/L in almost all samples. N to P ratio (by weight) was often similar at the two sites, but in late summer was typically lower in the river. Values indicated phosphorus limitation of primary producers (phytoplankton and SAV) and did not approach ratios associated with the onset of nitrogen limitation (7.2). BOD showed a summer maximum at both sites, but the cove station was typically higher. Total suspended solids and volatile suspended solids were similar at both sites and showed little seasonal pattern.

Algal populations as measured by chlorophyll *a* were higher in the cove in the spring, peaking at about 43 ug/L in early June. From thereon chlorophyll *a* values steadily declined through early September to less than 5 ug/L in the cove. In late September chlorophyll increased somewhat in the cove. In the river values increased slowly through the end of June, but remained below cove values until late August. Maximum chlorophyll in the river was about 25 ug/L. Surface chlorophyll values were similar to depth-integrated at both sites. Total phytoplankton cell density and biovolume in the cove increased steadily through late May exhibiting a marked decline in June. Biovolume continued to decline in late June whereas cell density started to increase again. Both measures increased in the cove in July whereas chlorophyll was decreasing. Both measures decreased in August, but at different rates. In the river both cell density and biovolume showed muted seasonal patterns relative to the cove stations, but generally increased through the study period as had chlorophyll.

Phytoplankton cell density was dominated by cyanobacteria on all dates and at both sites due to their small size. The filamentous diatom *Melosira* and Pennate 2 were the most important diatoms on most dates at both sites. *Cryptomonas*, *Chroomonas* and *Dictyosperium* were the most important other algae in both study areas.

Diatoms dominated biovolume in the cove and river for most of the year. *Oscillatoria* had the highest biovolume for cyanobacteria on all dates. The filamentous diatom *Melosira* and discoid centrics were the most important diatoms on most dates at both sites. *Cryptomonas* was consistently among the dominant other algae in both study areas.

Rotifers were the most numerous zooplankton in the study area with abundances similar at the two study sites with peak densities of 1000-1500/L. *Brachionus* and *Keratella* were the dominants at both sites. Rotifer populations in the cove declined in June following runoff events. Maxima later occurred in both late July and late September. In the river, rotifer maxima occurred in late May and early September. The small cladoceran *Bosmina* was found in moderate densities in early May at both sites. The larger abundant cladoceran *Diaphanosoma* had spring maxima at both sites, but levels were greatly reduced compared to most previous years. *Daphnia* had a short-lived peak in early May in the cove. Populations of the other herbaceous cladocera, *Ceriodaphnia*, and *Moina*, were quite low. *Leptodora*, the predaceous cladoceran, was found at moderate densities in late May in the cove. Nauplii (immature copepods) did not display a strong seasonal pattern at either site. Densities were 50-150/L on most dates. *Eurytemora*, a calanoid copepod, reached a peak of nearly 5000/m^3 in the river at both sites in spring. Cyclopoid copepods were much reduced in 2015 compared to 2014.

In 2015 ichthyoplankton was dominated by clupeids, most of which were *Dorosoma* sp. (Gizzard Shad), but with a relatively high density of river herring (Alewife and Blueback Herring) also present. *Morone sp.* (White Perch or Striped Bass) larvae were found in relatively low densities. A non-Clupeid species, Inland Silverside, was found in relatively high densities in the ichthyoplankton samples in 2015. The highest density of fish larvae occurred in mid-May, which is slightly earlier than usual (typically the peak is late May). This peak was driven by a high density of Clupeid larvae. Most clupeids are spawn from March –May 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.

In trawls, the majority of the adult and juvenile fish collected were represented by 4 taxa: White Perch (*Morone Americana*), Spottail Shiner (*Notropis hudsonius*), American Shad (*Alosa sapidissima*), and Alewife (*Alosa pseudoharengus*). White Perch was by far the most abundant species and the vast majority of all fish caught with trawls were found at Station 7. Spottail Shiner was found throughout the year, but almost all specimens were collected at station 7, as in previous years. Blue Catfish was found throughout the year and all were from the Potomac mainstem. *Alosa sp*. were abundant, which hopefully is an early sign of a potential recovery of the river herring stock.

In seines the most abundant species by far was Banded Killifish (*Fundulus diaphonus*), followed by White Perch. 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). Gizzard shad were third most abundant followed by American Shad. White perch were mainly found in the seine samples from near the mainstem and Gizzard Shad at a site in Pohick Bay.

Fyke nets were part of the sampling regime again in 2015. Banded killifish were most abundant in the fyke nets followed by white perch. Sunfish were particularly well-sampled by this gear with three species of *Lepomis* much more abundant here than either seines or trawls. Continued use of the fyke nets in monitoring is allowing much better assessment of long-term trends in fish composition.

Oligochaetes were the most abundant benthic taxon at both sites. In the river amphipods were also very abundant and gastropods were common. In the cove gastropods were the second most abundant taxon and chironomids were much reduced compared with previous years. The introduced bivalve *Corbicula* constituted the majority of bivalves, but several specimens of native Unionid river mussels were also found. Submersed aquatic vegetation coverage in 2015 was increased over 2013 and 2014 and was near record levels.

B. Water Quality Trends: 1983-2015

To assess long-term trends in water quality, data from 1983 to 2015 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 14 and 15). This was similar to the analysis performed in previous reports.

Table 14
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1984-2015
GMU Water Quality Data
June-September

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Temperature	0.185	0.056	0.001	0.103	----	NS
Conductivity, standardized to 25°C	0.190	2.49	0.001	0.047	----	NS
Dissolved oxygen, mg/L	0.021	----	NS	0.205	0.027	0.001
Dissolved oxygen, percent saturation	0.044	----	NS	0.227	0.387	<0.001
Secchi disk depth	0.713	1.80	<0.001	0.400	0.654	<0.001
Light attenuation coefficient	0.673	0.098	<0.001	0.176	0.019	0.016
pH, Field	-0.174	-0.012	0.007	0.197	0.010	0.005
Chlorophyll, depth-integrated	-0.558	-3.91	<0.001	-0.226	-0.644	<0.001
Chlorophyll, surface	-0.574	-4.00	<0.001	-0.122	-0.731	<0.001

For Station 7, n=281-300 except pH, Field where n=234 and Light extinction coefficient where n=218.
For Station 9, n=239-253 except pH, Field where n=201 and Light extinction coefficient where n=188.

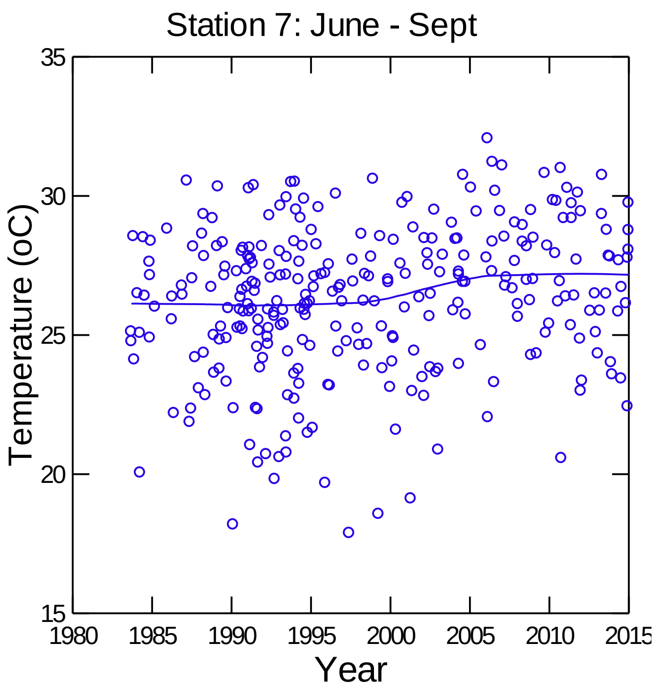
Significance column indicates the probability that a correlation coefficient this large could be due to chance alone. If this probability is greater than 0.05, then NS (not significant) is indicated.

Table 15
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1983-2015
Fairfax County Environmental Laboratory Data
June-September

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Chloride	0.029	---	NS	0.006	----	NS
Lab pH	0.463	-0.033	<0.001	0.244	-0.013	<0.001
Alkalinity	0.127	0.162	0.007	0.298	0.415	<0.001
BOD	0.641	-0.174	<0.001	0.459	-0.052	<0.001
Total Suspended Solids	0.329	-0.920	<0.001	0.132	-0.149	0.007
Volatile Suspended Solids	0.396	-0.644	<0.001	0.363	-0.137	<0.001
Total Phosphorus	0.543	-0.004	<0.001	0.257	-0.0009	<0.001
Soluble Reactive Phosphorus	0.089	----	NS	0.079	----	NS
Ammonia Nitrogen	0.300	-0.017	<0.001	0.308	-0.003	<0.001
Un-ionized Ammonia Nitrogen	0.325	-0.004	<0.001	0.321	-0.0004	<0.001
Nitrite Nitrogen	0.410	-0.003	<0.001	0.316	-0.002	<0.001
Nitrate Nitrogen	0.563	-0.035	<0.001	0.660	-0.040	<0.001
Organic Nitrogen	0.550	-0.048	<0.001	0.311	-0.011	<0.001
N to P Ratio	0.278	-0.326	<0.001	0.556	-0.624	<0.001

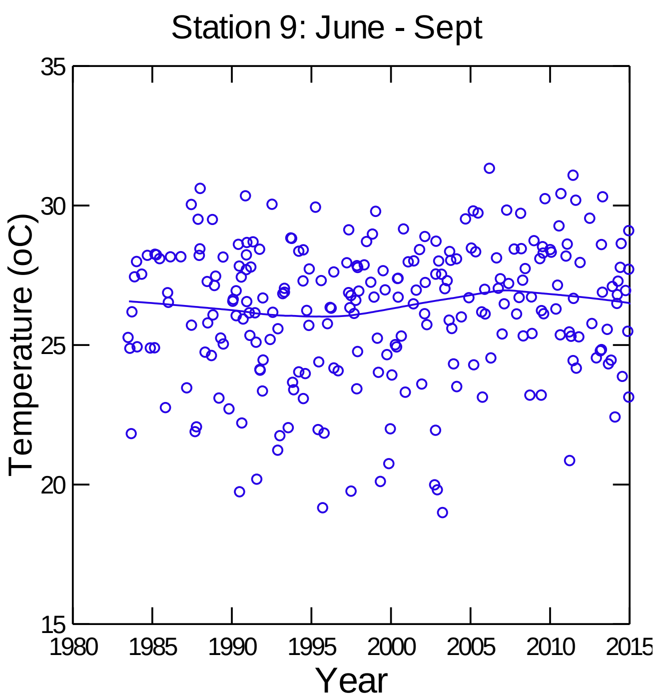
For Station 7, n=417-460 except Nitrite Nitrogen where n=382.
For Station 9, n=4418-467 except Nitrite Nitrogen where n=382.

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.



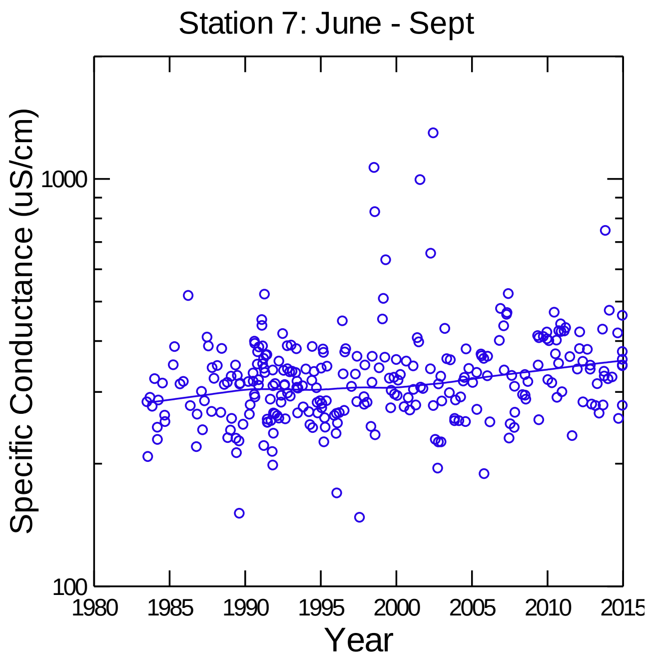
Water temperatures during the summer months generally varied between 20 ºC and 30ºC over the study period (Figure 66). The LOWESS curve indicated an average of about 26°C during the period 1984-2000 with a slight upward trend in the last few years to about 27ºC. Linear regression analysis indicated a significant linear trend in water temperature in the cove when the entire period of record is considered (Table 14). The slope of this relationship is 0.06°C/year.

Figure 66. Long term trend in Water Temperature (GMU Field Data). Station 7. Gunston Cove.



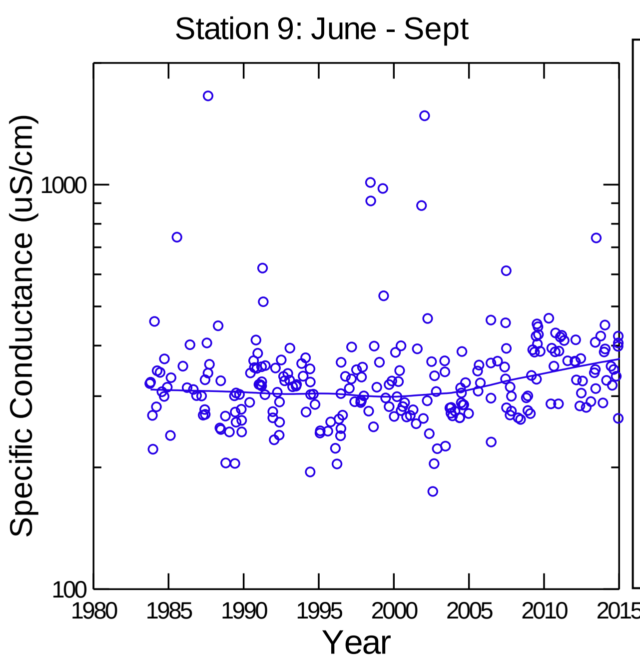
In the river summer temperatures have been similar to those in the cove (Figure 67). There appear to be somewhat fewer readings above 30° C in the river. Additionally, linear regression over the study period was not significant (Table 14).

Figure 67. Long term trend in Water Temperature (GMU Field Data). Station 9. Gunston Cove.



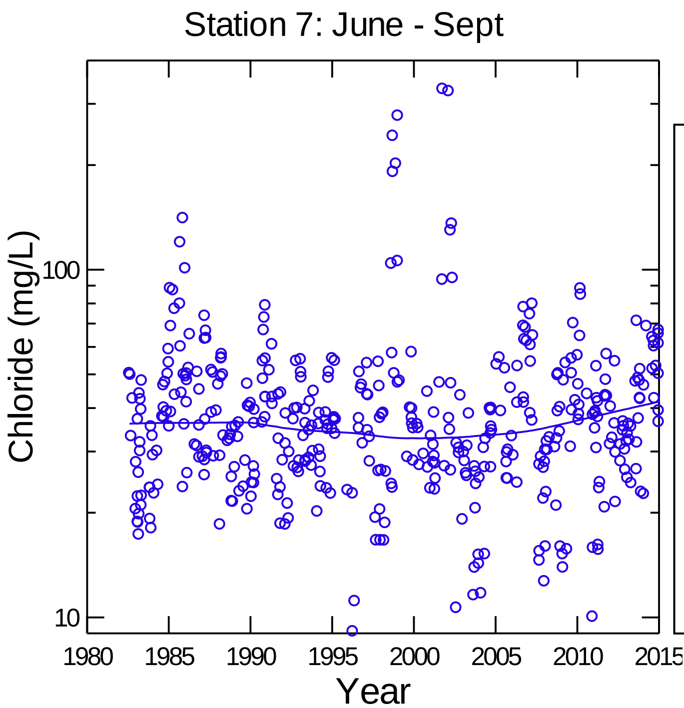
Specific conductance was generally in the range 200-500 µS/cm over the study period (Figure 68). Some significantly higher readings have been observed sporadically. A slight increase in specific conductance was suggested by the LOWESS line over the study period. This was confirmed by linear regression analysis which found a significant linear increase of 2.5 µS/cm per year over the long term study period (Table 14). This would yield a total increase of 80 uS/cm.

Figure 68. Long term trend in Specific Conductance (GMU Field Data). Station 7. Gunston Cove.



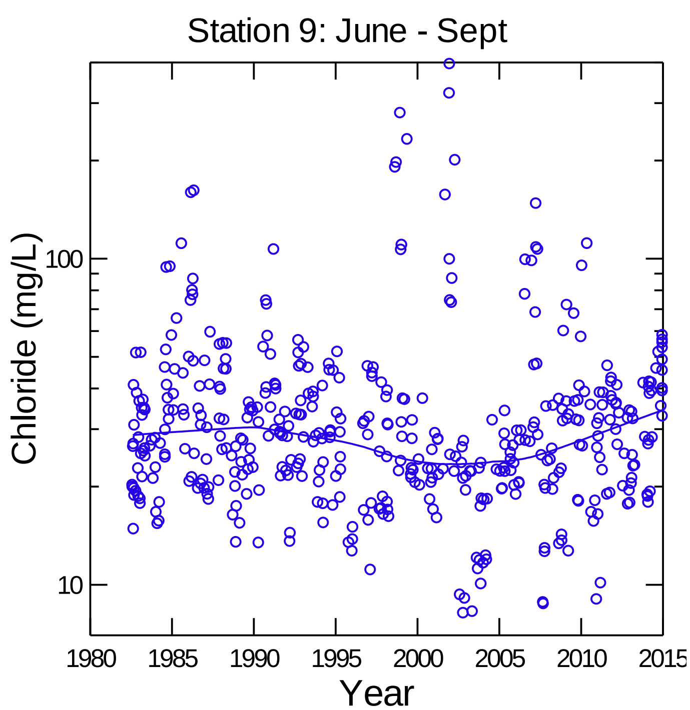
Conductivity values in the river were in the same general range as in the cove (Figure 69). Most values were between 200 and 500 µS/cm with a few much higher values. These higher values are probably attributable to intrusions of brackish water from downstream during years of low river flow. Linear regression did not reveal a significant trend in river conductivity (Table 14). However, the trend line has moved up in recent years from about 300 µS/cm to nearly 400 µS/cm.

Figure 69. Long term trend in Specific Conductance (GMU Field Data). Station 9. River mainstem.



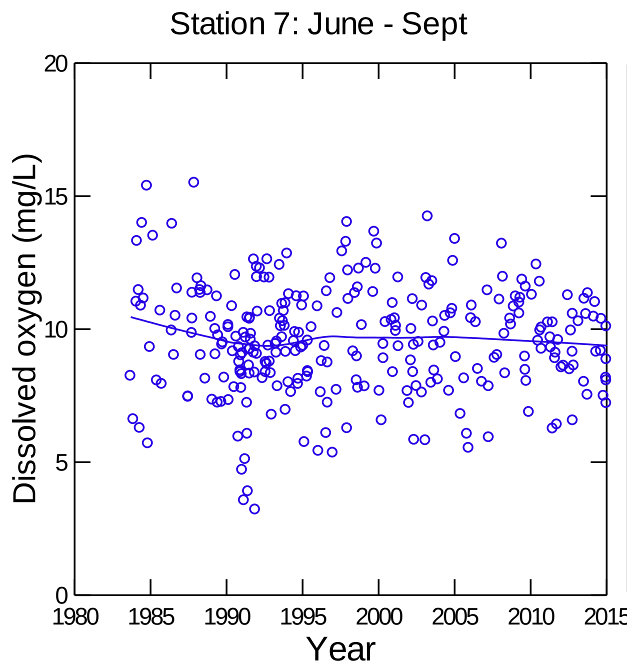
Chloride levels were clustered in a relatively narrow range of 20-60 mg/L for the entire study period (Figure 70). Higher values observed in some years were probably due to the estuarine water intrusions that occur in dry years. The trend line is nearly flat and a linear regression was not statistically significant (Table 15).

Figure 70. Long term trend in Chloride (Fairfax County Lab Data). Station 7. Gunston Cove.



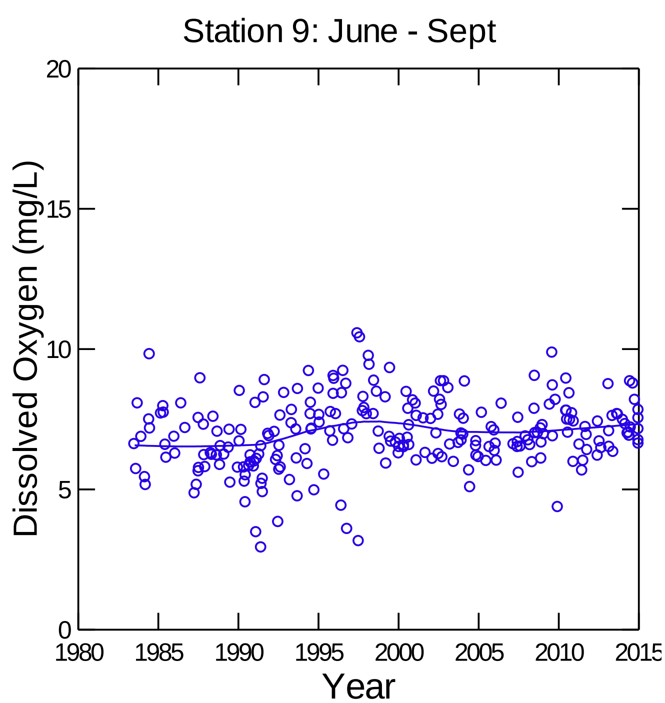
Chloride in the river has been slightly more variable than that in the cove, but in the same general range (Figure 71). The higher readings are again due to brackish water intrusions in dry years. A slight trend of increasing values in the 1980's followed by decreases in the 1990's and increases since 2005 was suggested by the LOWESS trend line. However, temporal regression analysis was not statistically significant (Table 12).

Figure 71. Long term trend in Chloride (Fairfax County Lab Data). Station 9. River mainstem.



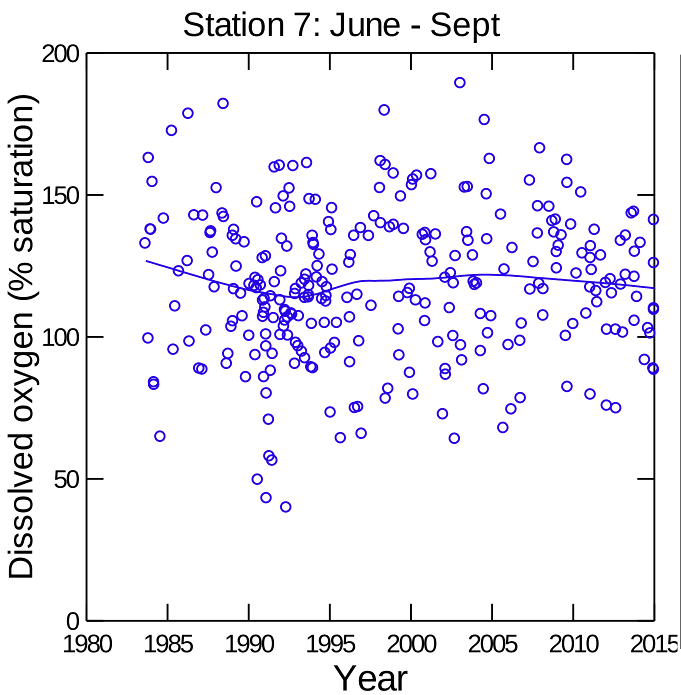
Dissolved oxygen in the cove has generally been in the range 7-13 mg/L during the summer months (Figure 72). A slight downward trend was observed through 1990, but since then the trend line has flattened, suggesting little consistent change and a mean of about 10 mg/L. In the cove dissolved oxygen (mg/L) did not exhibit a significant linear trend over the long term study period (Table 14).

Figure 72. Long term trend in Dissolved Oxygen, mg/L (GMU Data). Station 7. Gunston Cove.



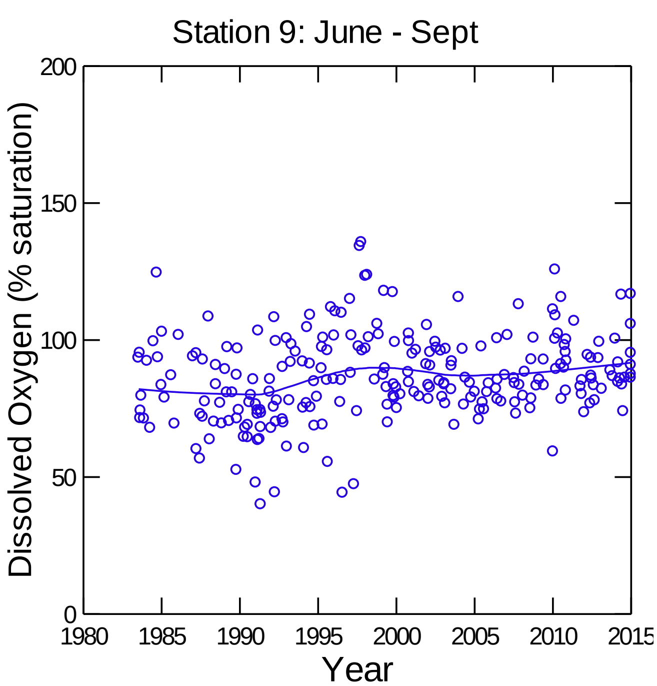
In the river dissolved oxygen values generally were in the range 5-9 mg/L over the long term study period (Figure 73). The LOWESS trend line suggested a slight decline in the 1980's, an increase in the early to mid 1990's, a slight decline in the early 2000's and steady values since. The linear regression analysis over the entire period indicated a significant positive trend with slope of 0.027 mg/L per year ir 0.8 mg/L over the period of record (Table 14). 2015 readings were clustered around the long term trend line.

Figure 73. 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 74). 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 14). 2015 values fell around the trend line.

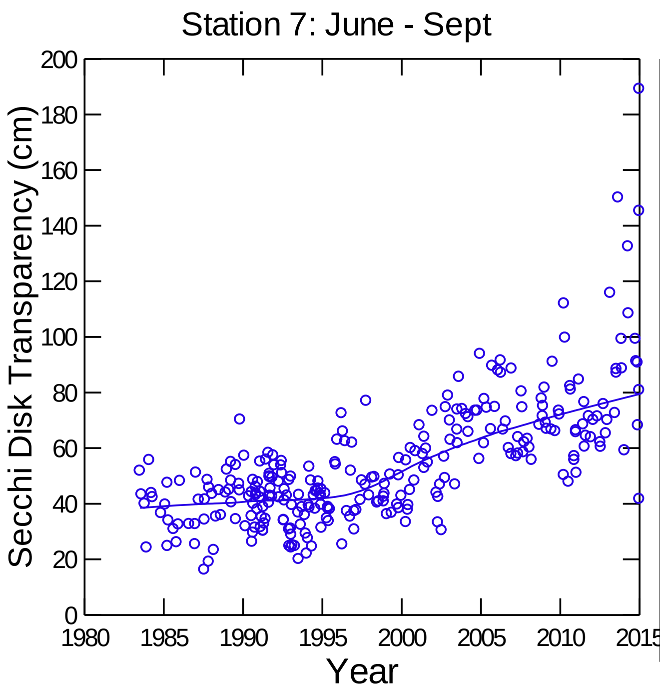
Figure 74. Long term trend in Dissolved Oxygen, % saturation (GMU Data). Station 7. Gunston Cove.



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 75). The trend line showed a very gradual increase which was statistically significant as indicated by regression analysis with a slope of 0.3% per year or about 12% over the course of the study (Table 14). 2015 readings were near the long term trend line.

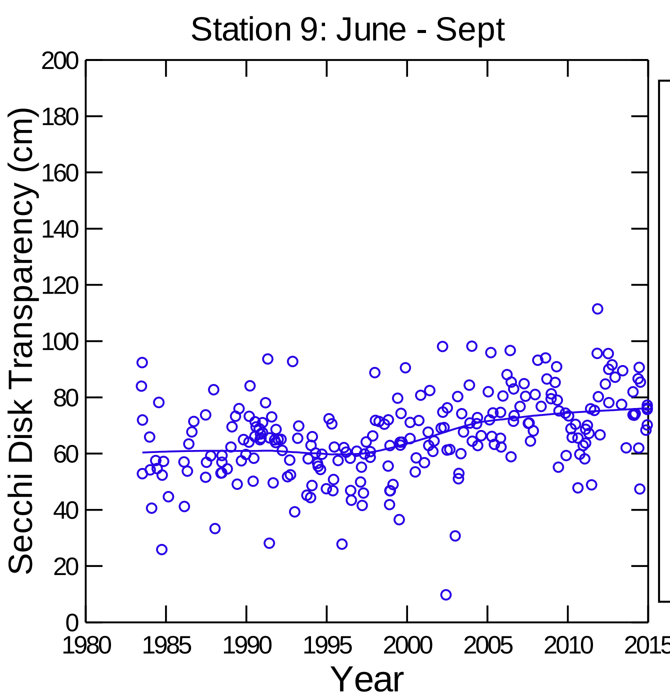
9

Figure 75. Long term trend in Dissolved Oxygen, % saturation (GMU Data). Station 9. Gunston Cove.



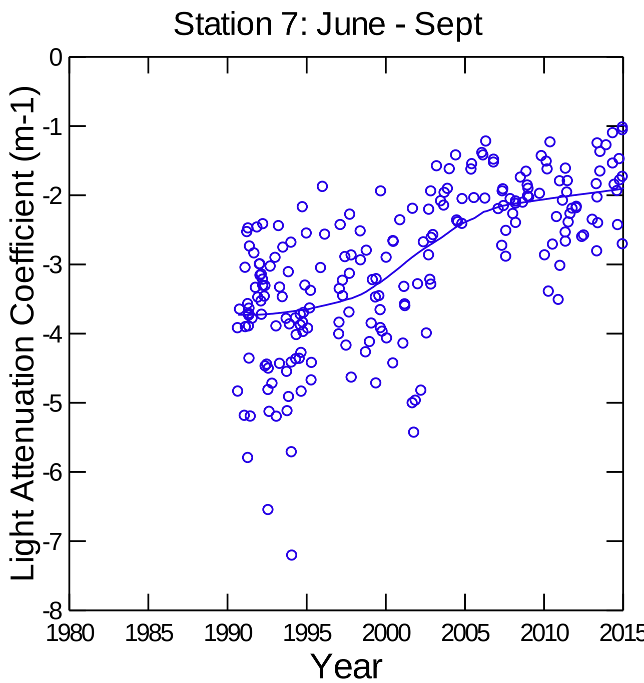
Secchi disk transparency is a measure of water clarity. Secchi disk was fairly constant from 1984 through 1995 with the trend line at about 40 cm (Figure 76). Since 1995 there has been a steady increase in the trend line from 40 cm to 80 cm in 2015. Linear regression was highly significant with a predicted increase of 1.80 cm per year or a total of 57 cm over the study period (Table 14). In 2015 most readings were above the trend line as in 2014. If this continues, the trend line will rise.

Figure 76. Long term trend in Secchi Disk Transparency (GMU Data). Station 7. Gunston Cove.



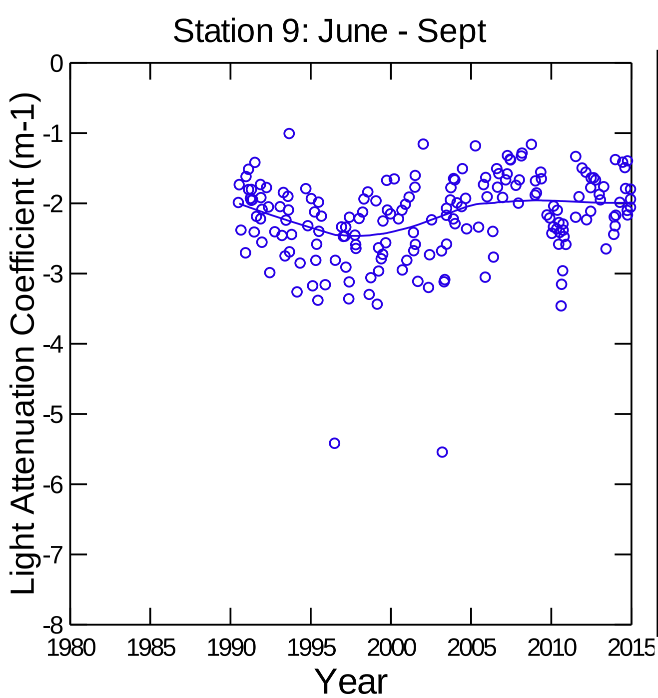
In the river Secchi depth was somewhat greater than in the cove initially (Figure 77). The trend line was fairly constant at about 60 cm until about 2000. A rise to about 75 cm was observed by 2005 where it has remained. Linear regression revealed a significant increase of 0.65 cm per year with total increase of 21 cm predicted over of the study period (Table 14).

Figure 77. Long term trend in Secchi Disk Transparency (GMU Data). Station 9. River mainstem.



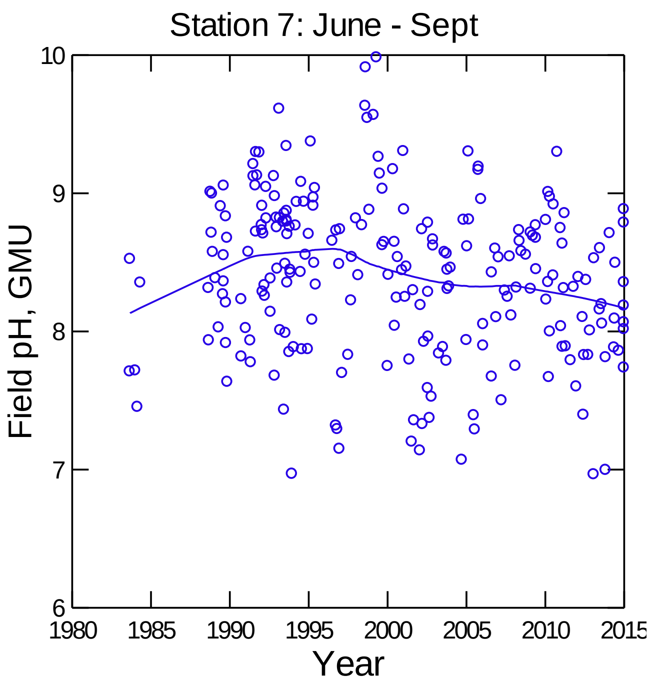
Light attenuation coefficient, another measure of water clarity, reinforces the conclusion that water clarity has been improving in the cove since 1995 (Figure 78). Trend line for the coefficient rose from about -4 to -2 m^{-1} during this time. And values for 2015 were generally above -2. Consistent with this was the regression analysis which revealed a significant linear increase in light attenuation coefficient over the period 1991-2015 with a slope of 0.1 per year yielding a prediction that light attenuation improved by about 2.3 units over this period (Table 14).

Figure 78. Long term trend in Light Attenuation Coefficient (GMU Data). Station 7. Gunston Cove.



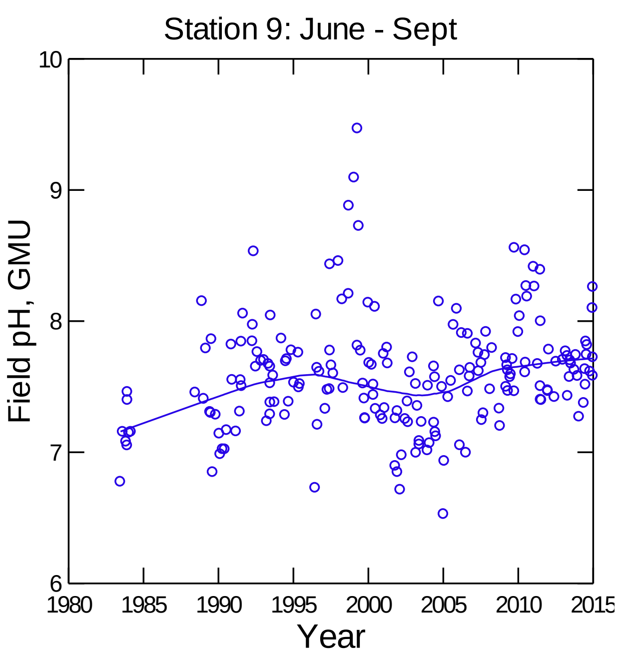
In the river light attenuation coefficient suggested a decline in light transparency between 1991 and 1997 followed by an increase through about 2008 (Figure 79). Between 2008 and 2015 the trend line indicates that light transparency has held fairly constant. Regression indicated a weak, but significant linear trend over the entire period (Table 14). The regression coefficient was 0.019 yielding a change of 0.5 units over the period, much less than found at Station 7.

Figure 79. Long term trend in Light Attenuation Coefficient (GMU Data). Station 9. River mainstem.



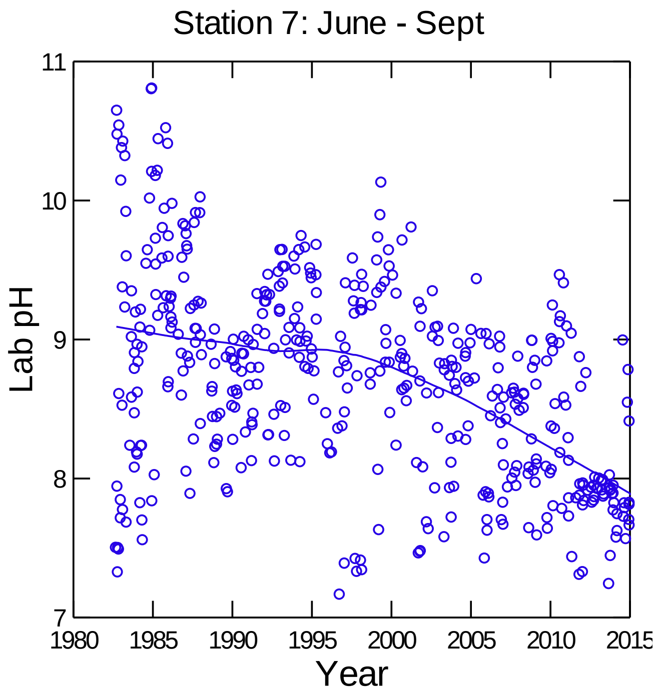
Field pH has not been measured as consistently over the entire study period as other parameters. Cove values have generally been in the 8-9 range. There is a clear trend of decreasing values since 1995 (Figure 80). Linear regression analysis now gives some evidence of a declining linear trend with a slope of -0.012 units per year when the entire study period was considered (Table 14).

Figure 80. Long term trend in Field pH (GMU Data). Station 7. Gunston Cove.



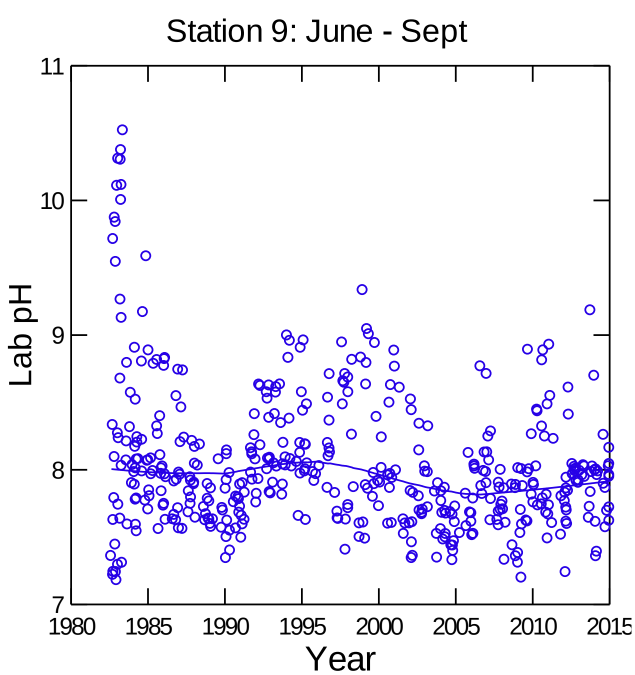
In the river a different pattern has been observed over this period (Figure 81). pH in the river has been consistently lower by about 1 pH unit than in the cove. If anything the trend line has shown a tendency to increase. When all years were considered, field pH in the river shows a significant increase at a rate of 0.01 units per year (Table 14).

Figure 81. Long term trend in Field pH (GMU Data). Station 9. River mainstem.



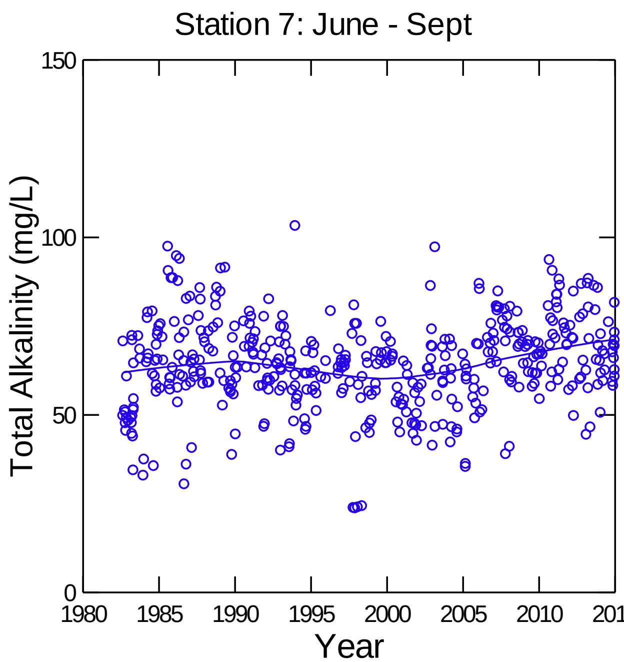
Lab pH as measured by Fairfax County personnel was generally in the range 8 to 10 over most of the long term study period (Figure 82). Since about 1997 a decline is very evident with the trend line decreasing from about 9.1 to about 7.8. Linear regression indicates a significant decline in lab pH over 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 15). 2015 data were below the trend line.

Figure 82. Long term trend in Lab pH (Fairfax County Lab Data). Station 7. Gunston Cove.



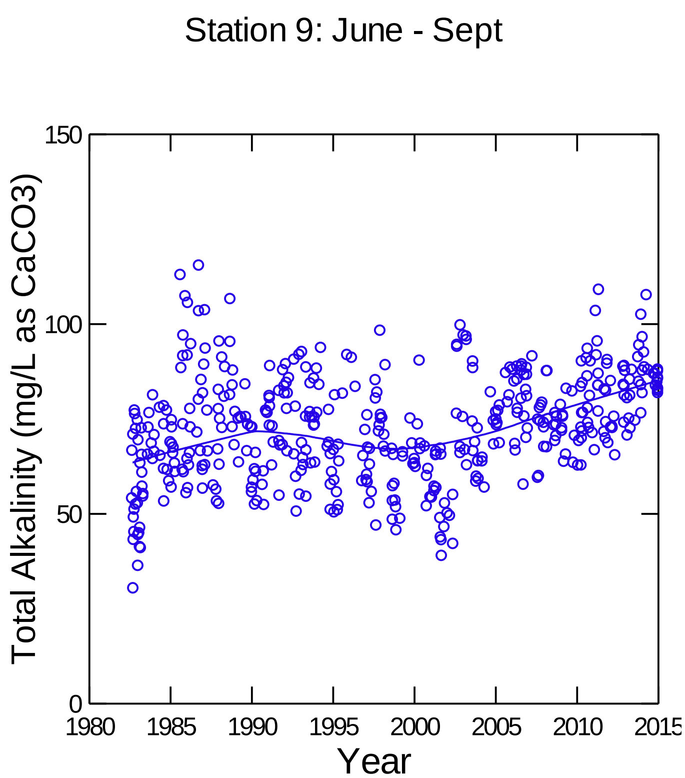
In the river, long term pH trends as measured by Fairfax County lab personnel indicate that most values fell between 7 and 8.5 (Figure 83). The trend line has increased and decreased slightly over the years. pH in the river showed a significant linear decline with a rate of 0.013 per year yielding a total decline of 0.43 units over the long term study period (Table 15).

Figure 83. Long term trend in Lab pH (Fairfax County Lab Data). Station 9. Potomac mainstem.



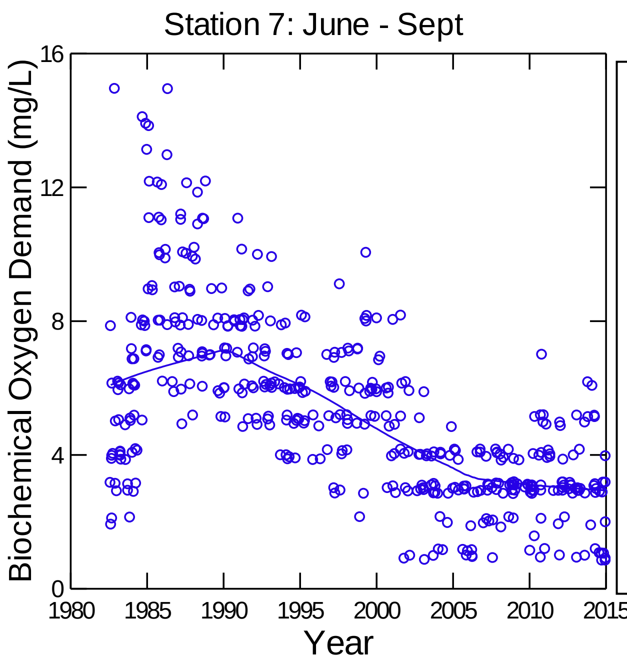
Total alkalinity as measured by Fairfax County personnel exhibited little variation early on and a slow increase since 2000 (Figure 84). The trend line at 2015 was slightly higher than it was in 1983. Overall, a statistically significant linear trend has developed in total alkalinity in the cove over this period with a slope of 0.16 mg/L per year yielding a projected increase of about 5 mg/L over the entire study period.(Table 15).

Figure 84. Long term trend in Total Alkalinity (Fairfax County Lab Data). Station 7. Gunston Cove.



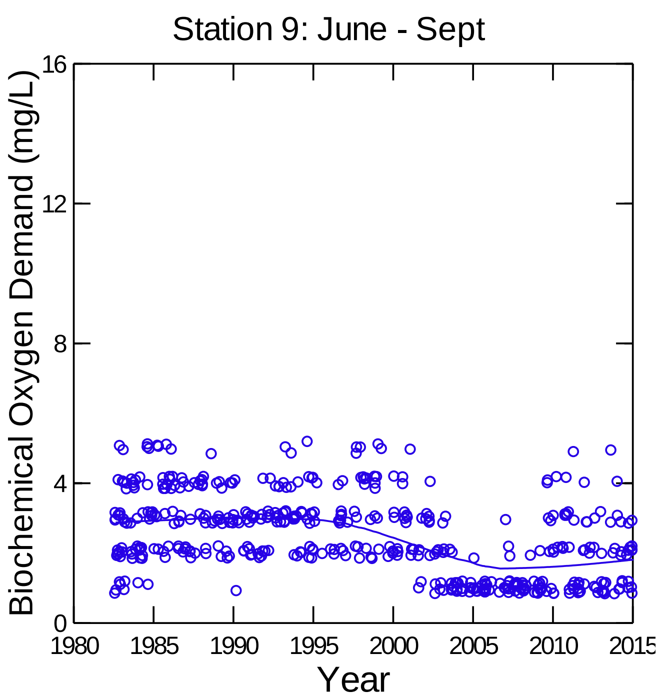
In the river a similar pattern has been observed over the three decades with an even clearer recent increase (Figure 85). There is a significant linear trend over the period with a slope of 0.415 mg/L suggesting a modest increase of about 13 mg/L over the entire study period (Table 15).

Figure 85. Long term trend in Total Alkalinity (Fairfax County Lab Data). Station 9. Potomac mainstem.



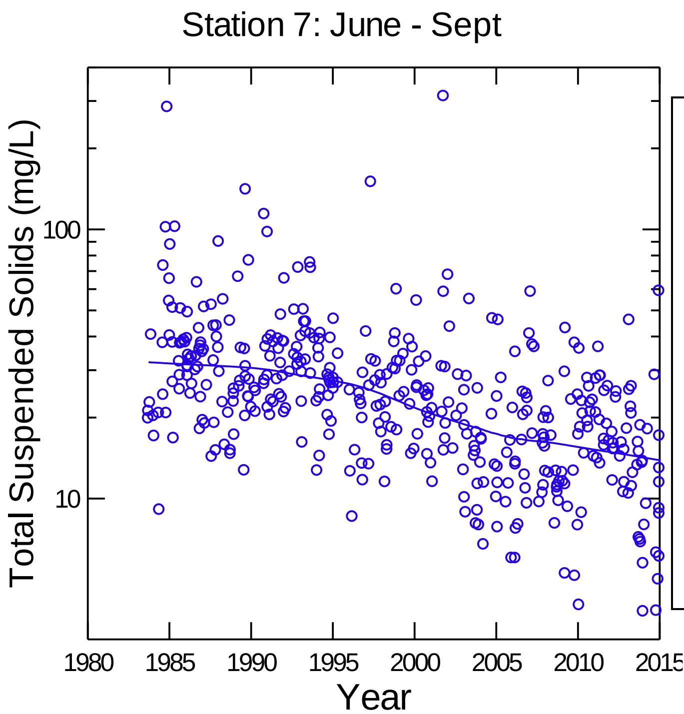
Biochemical oxygen demand has shown a distinct pattern over the long term study period in Gunston Cove (Figure 86). In the 1980's the trend line rose from about 6 mg/L to 7 mg/L by 1989. Since then there has been a steady decline such that the trend line has dropped back to about 3 mg/L. BOD has shown a significant linear decline over the entire study period at a rate of 0.17 mg/L per year yielding a net decline of about 5.4 mg/L over the entire period of record (Table 15).

Figure 86. Long term trend in Biochemical Oxygen Demand (Fairfax County Lab Data). Station 7. Gunston Cove.



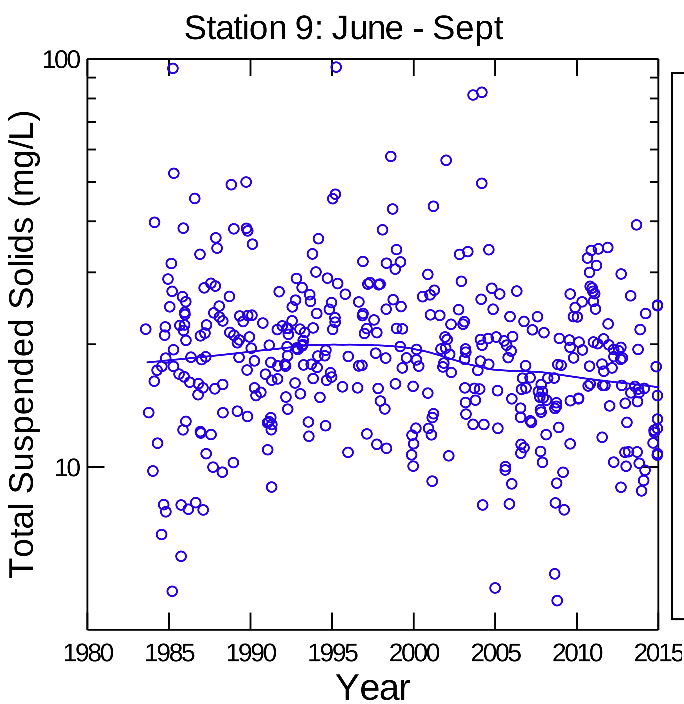
In the river biochemical oxygen demand exhibited a less distinct pattern through the mid 1990's (Figure 87). However, since that time it has decreased steadily to a trend line value of about 1.5 mg/L. BOD in the river has exhibited a significant linear decrease at a rate of 0.05 units when the entire period of record was considered (Table 15). This would project to an overall decrease of 1.6 units.

Figure 87. Long term trend in Biochemical Oxygen Demand (Fairfax County Lab Data). Station 9. Potomac mainstem.



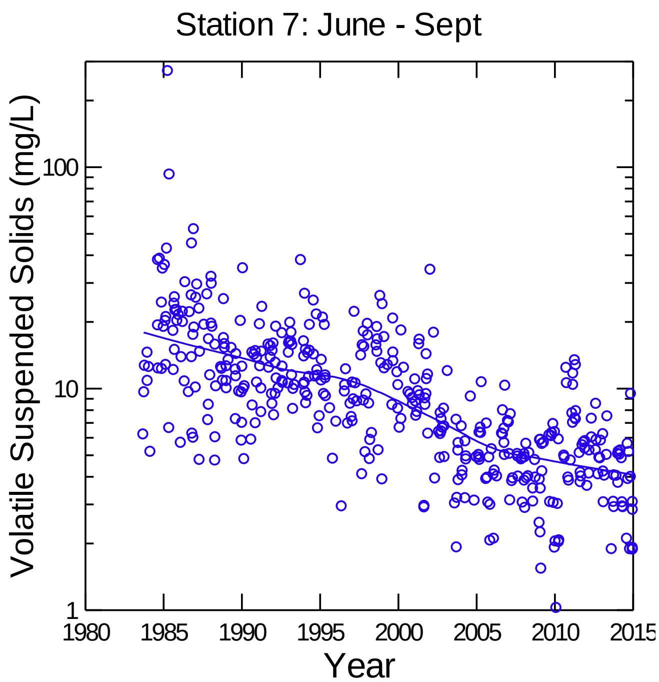
Total suspended solids (TSS) has shown a great deal of variability over the long term study period. Nonetheless, a decreasing trend in TSS is clear in the cove with the trend line decreasing from about 32 mg/L in 1983 to about 15 mg/L in 2015 (Figure 88). Linear regression was significant indicating a decline of 0.92 mg/L per year yielding a total decline of 29.5 mg/L since 1984 (Table 15).

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



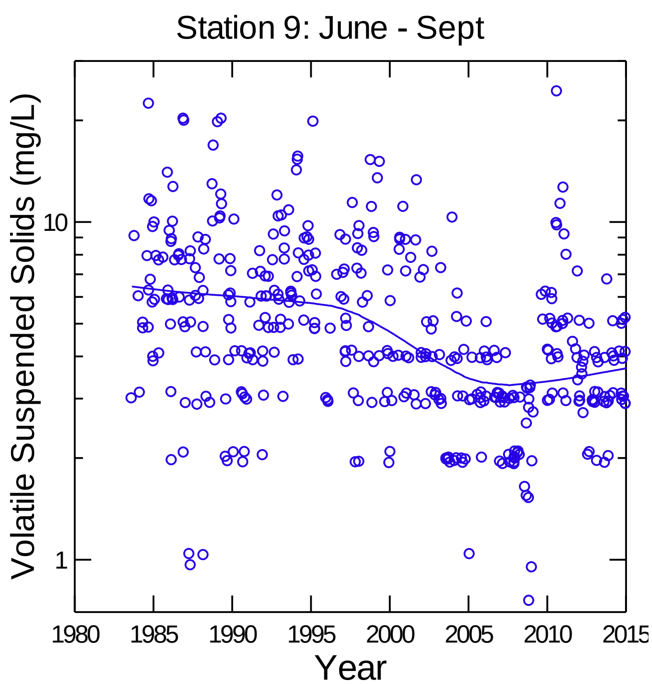
In the river TSS trends have not been as apparent (Figure 89). While much higher values have been observed sporadically, the LOWESS line remained steady at about 18-20 mg/L through most of the period with a slight decrease to about 16 mg/L suggested recently. In the river TSS exhibited a weak, but significant linear decline over the period of record (Table 15).

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



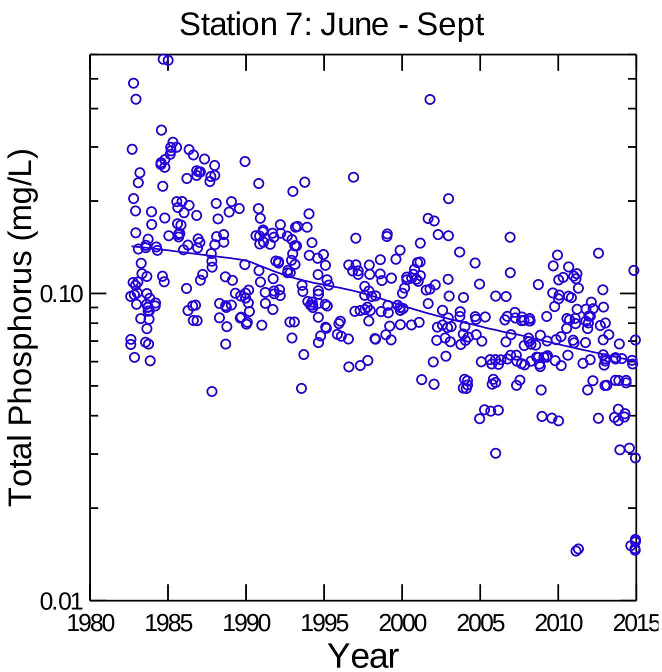
Volatile suspended solids have consistently declined over the study period (Figure 90). The LOWESS trend line has declined from 20 mg/L in 1984 to about 3 mg/L in 2015. VSS has demonstrated a significant linear decline at a rate of 0.64 mg/L per year or a total of 20 mg/L over the study period (Table 15).

Figure 90. Long term trend in Volatile Suspended Solids (Fairfax County Lab Data). Station 7. Gunston Cove.



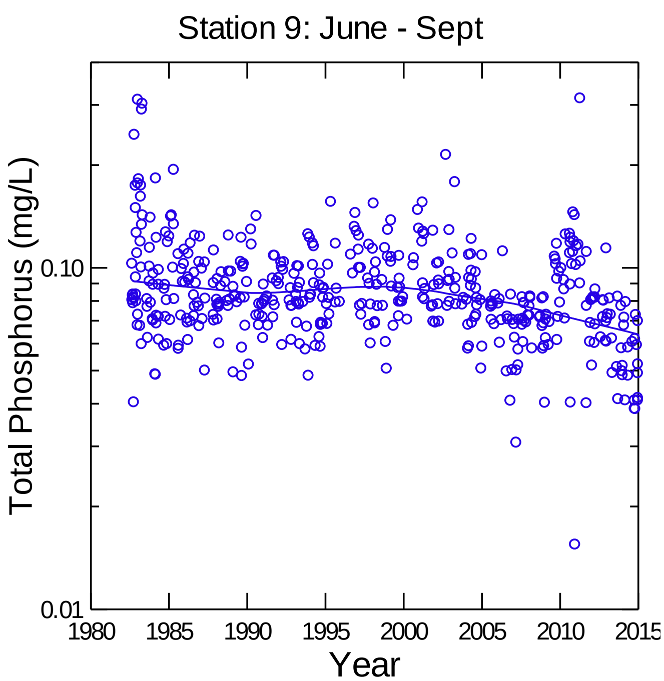
In the river the trend line for volatile suspended solids (VSS) was steady from 1984 through the mid 1990's, but decreased from 1995 to 2005. Trend line values of about 7 mg/L in 1984 dropped to about 3 mg/L by 2005 (Figure 91). VSS in the river demonstrated a significant linear decline at a rate of 0.14 mg/L per year or 4.5 mg/L since 1984 (Table 15).

Figure 91. Long term trend in Volatile Suspended Solids (Fairfax County Lab Data). Station 9. Potomac mainstem.



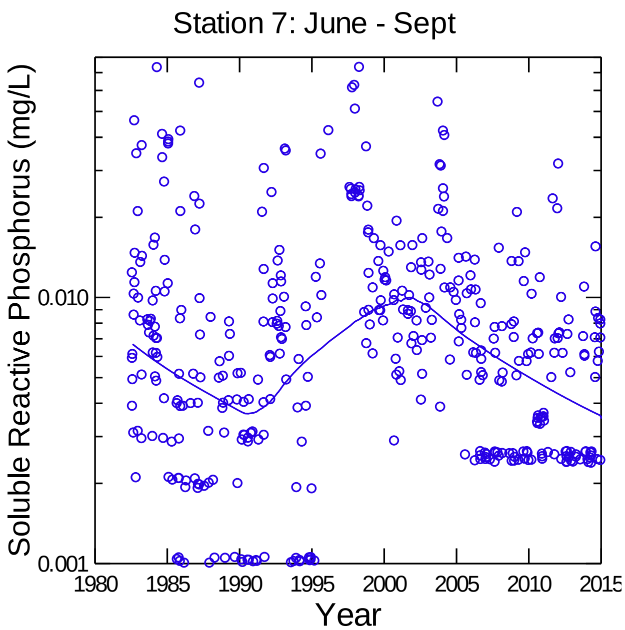
In the cove, total phosphorus (TP) has undergone a consistent steady decline since the late 1980's in the cove (Figure 92). By 2015 the trend line had dropped to 0.06 mg/L. Linear regression over the entire period of record indicated a significant linear decline of -0.004 mg/L per year or 0.13 mg/L over the entire study period (Table 15).

Figure 92. Long term trend in Total Phosphorus (Fairfax County Lab Data). Station 7. Gunston Cove.



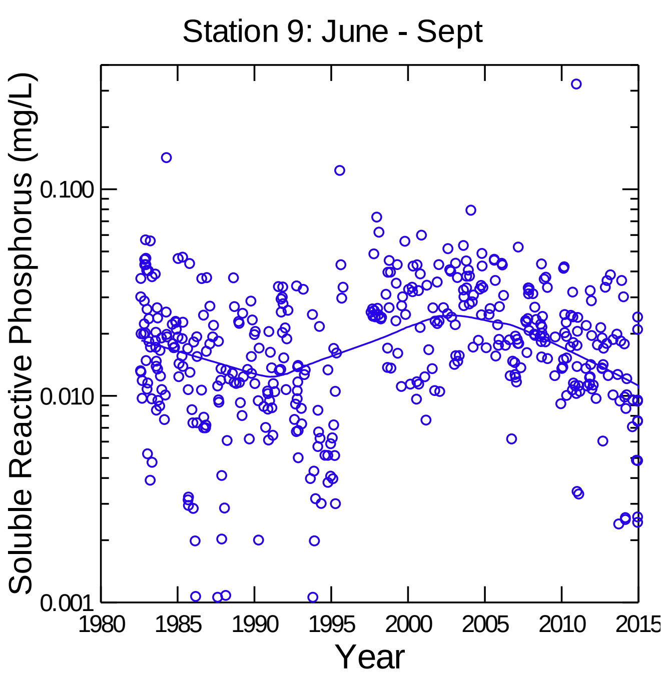
Total phosphorus (TP) values in the river have shown less of a trend over time (Figure 93). Values were steady through about 2000, then declined. TP exhibited a slight, but significant linear decrease in the river over the long term study period with a very modest slope of -0.0009 mg/L per year (Table 15).

Figure 93. Long term trend in Total Phosphorus (Fairfax County Lab Data). Station 9. Potomac mainstem.



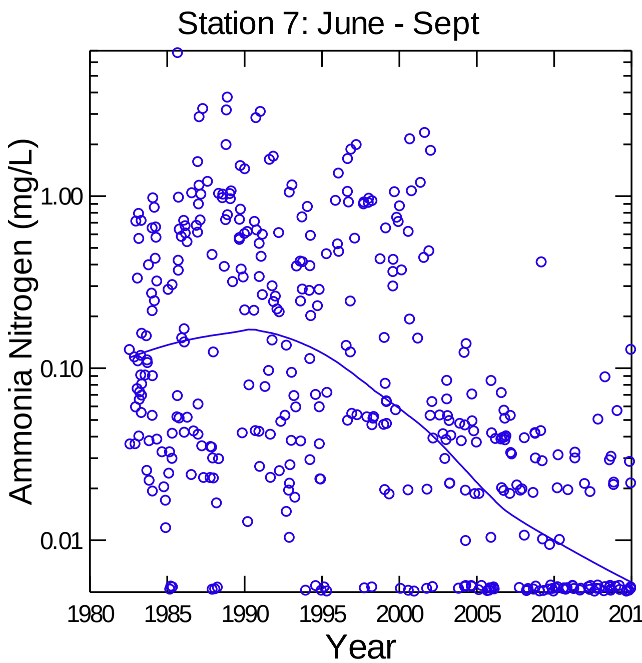
Soluble reactive phosphorus (SRP) declined in the cove during the first few years of the long term data set, but demonstrated an increase to near its initial level by 2000 (Figure 94). Since then a decline has ensued. (Table 15). One possibility is that less SRP is entering the cove water; another is that increased SAV is taking more up. Note also that the detection limit has changed.

Figure 94. Long term trend in Soluble Reactive Phosphorus (Fairfax County Lab Data). Station 7. Gunston Cove.



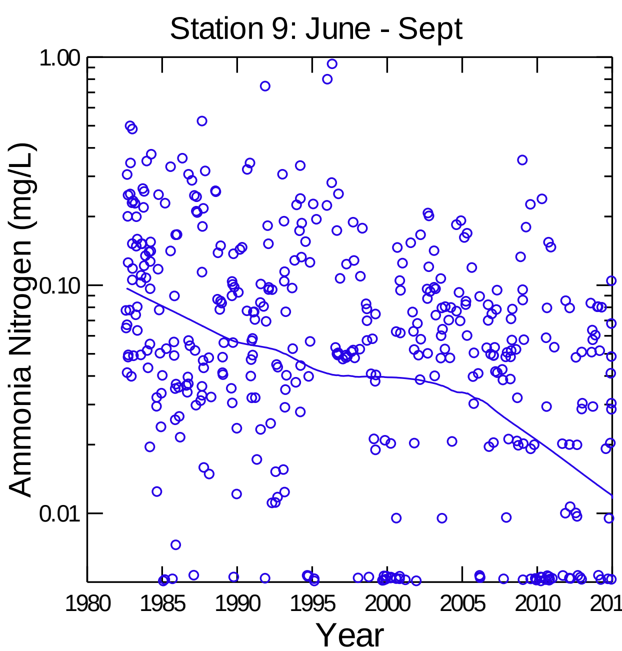
Soluble reactive phosphorus (SRP) in the river has generally been present at higher levels than in the cove, but has undergone a similar decline-resurgence-decline (Figure 95). Linear regression was not significant (Table 15).

Figure 95. Long term trend in Soluble Reactive Phosphorus (Fairfax County Lab Data). Station 9. Potomac mainstem.



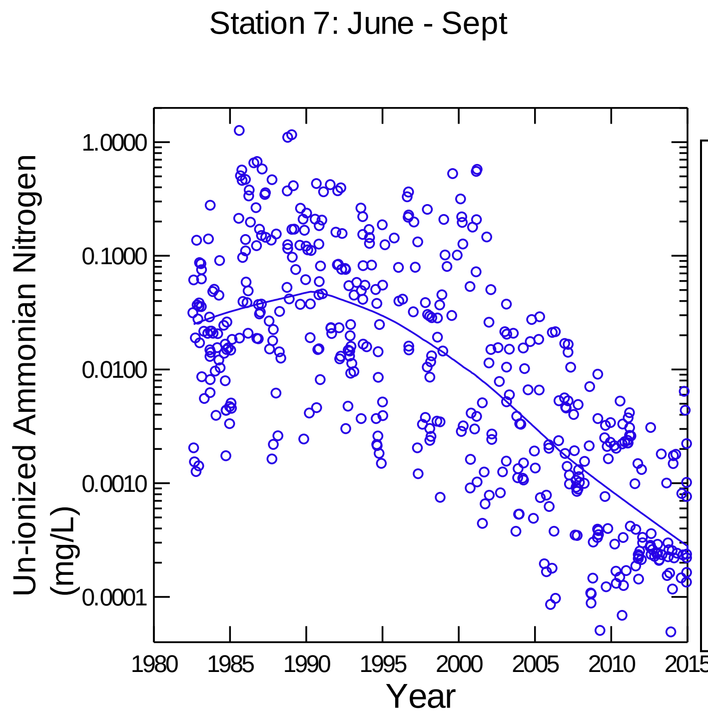
Ammonia nitrogen levels were very variable over the long term study period in the cove, but a trend of decreasing values is evident from the LOWESS trend line (Figure 96). Since 1989 the trend line has decreased from about 0.2 mg/L to less 0.01 mg/L. Linear regression has revealed a significant decline 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 15). Note the increase in values below the detection limit over time (clustered at bottom of graph).

Figure 96. Long term trend in Ammonia Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



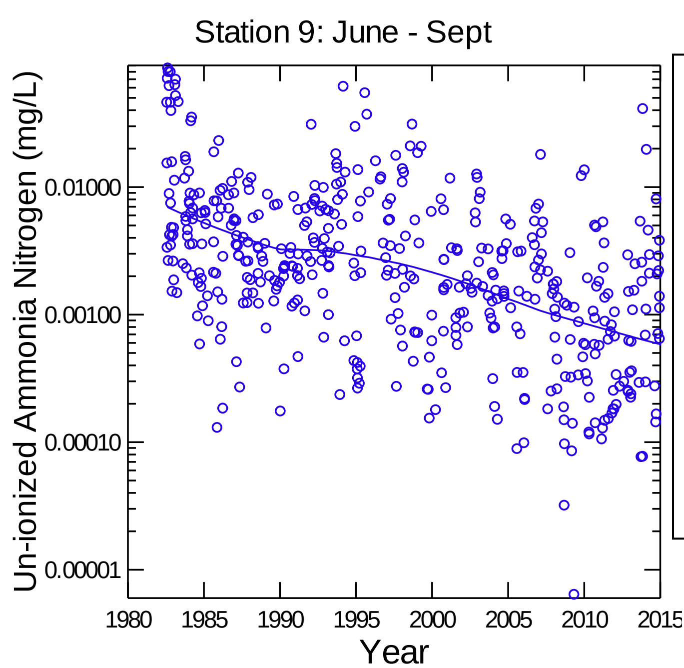
In the river a decreasing trend in ammonia nitrogen has also been observed over most of the study period (Figure 97). Between 1983 and 1999 the trend line dropped from 0.1 mg/L to 0.04 mg/L. Since 1999 it has continued to decline and is now at about 0.01 mg/L. Overall, in the river ammonia nitrogen has 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 15).

Figure 97. Long term trend in Ammonia Nitrogen (Fairfax County Lab Data). Station 9. Potomac mainstem.



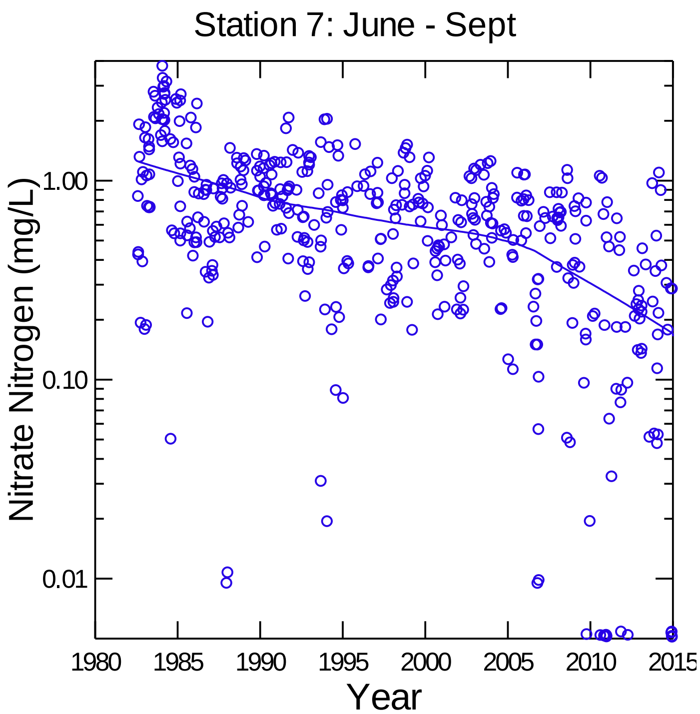
Un-ionized ammonia nitrogen in the cove demonstrated a clear increase in the 1980's with a continuous decline since that time (Figure 98). The LOWESS trend peaked at about 0.05 mg/L and is now less than 0.0003 mg/L. When considered over the entire time period, there was a significant decline at a rate of 0.004 mg/L per year or a total of 0.15 mg/L over the 33 years (Table 15).

Figure 98. Long term trend in Un-ionized Ammonia Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



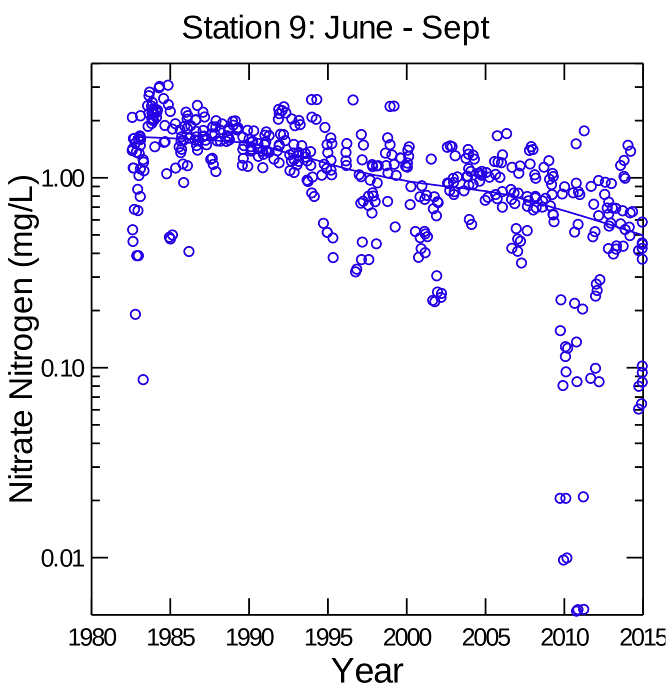
Un-ionized ammonia nitrogen in the river declined fairly consistently over the entire study period (Figure 99). LOWESS values have dropped from about 0.007 mg/L to about 0.0005 mg/L. Linear regression analysis over the entire period of record suggested a significant decline at a rate of 0.0004 units per year (Table 15).

Figure 99. Long term trend in Un-ionized Ammonia Nitrogen (Fairfax County Lab Data). Station 9. Potomac mainstem.



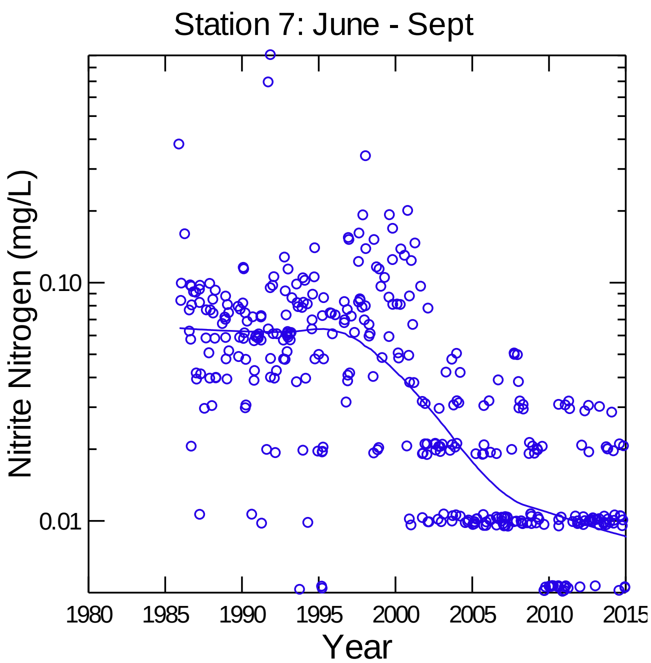
Nitrate nitrogen has demonstrated a steady decline in the cove over the entire period of record (Figure 100). The trend line was at about 1 mg/L in 1983 and by 2015 was below 0.20 mg/L. Linear regression suggested a decline rate of 0.035 mg/L per year yielding a total decline of 1.1 mg/L over the long term study period (Table 15).

Figure 100. Long term trend in Nitrate Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



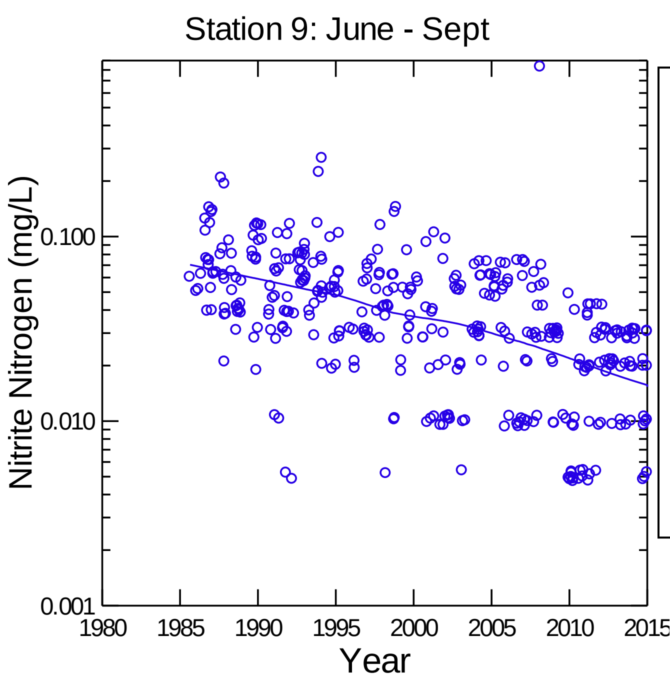
In the river nitrate nitrogen has declined steadily since about 1985 (Figure 101). The trend line dropped from 1.5 mg/L in the mid 1980's to 0.5 mg/L in 2015. Linear regression indicated a rate of decline of -0.04 mg/L per yr which would have yielded a 1.3 mg/L decrease in nitrate nitrogen over the study period (Table 15).

Figure 101. Long term trend in Nitrate Nitrogen (Fairfax County Lab Data). Station 9. River mainstem.



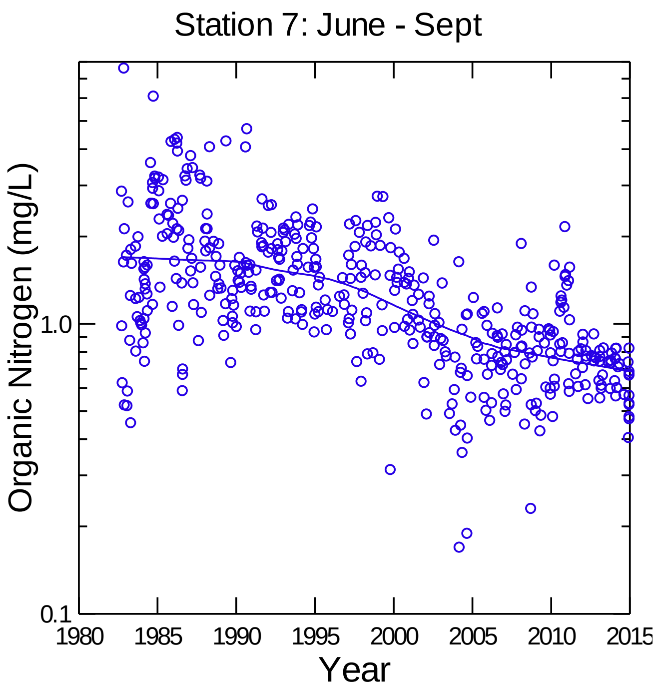
The trend line for nitrite nitrogen indicated steady values at about 0.06-0.07 mg/L through 1999 (Figure 102). Since then there is clear evidence for a decline with the LOWESS line reaching about 0.01 in 2015. Linear regression revealed a significant decline with a slope of 0.003 mg/L per year when the entire period of record was considered (Table 15).

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



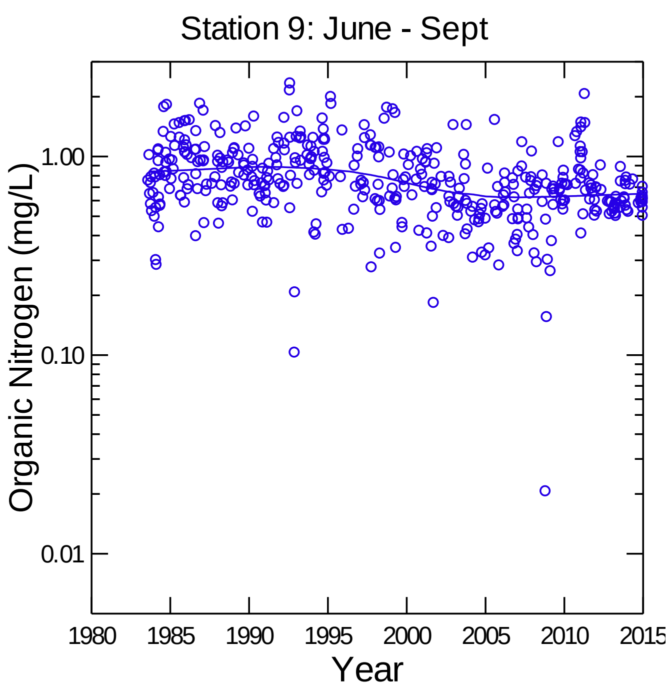
Nitrite nitrogen in the river demonstrated a pattern of decrease during the long term study period (Figure 103). The LOWESS line dropped from 0.07 mg/L in 1986 to 0.02 mg/L in 2014. Linear regression indicated a significant linear decline at a rate of 0.002 mg/L per year or 0.06 mg/L over the study period (Table 15).

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



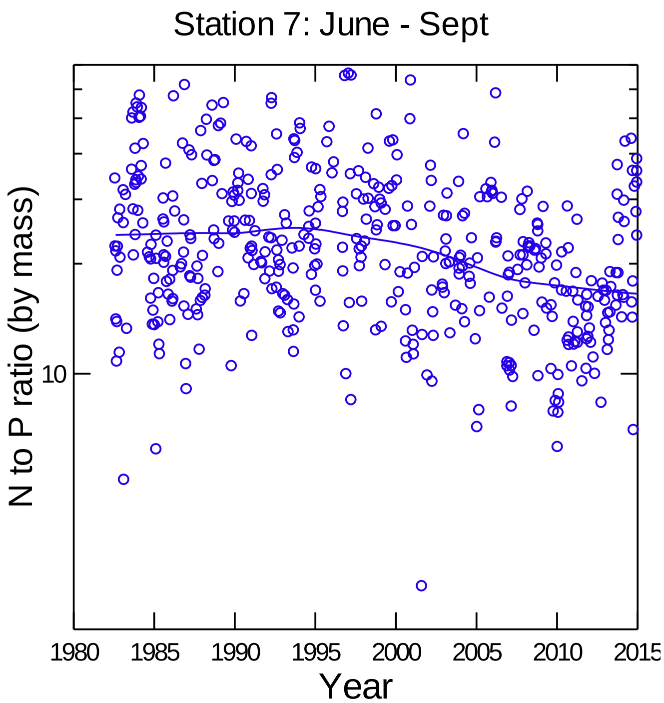
Organic nitrogen in the cove was fairly high in the 1980's and has since undergone a consistent decline through 2015 (Figure 104). In 1983 the trend line was at 1.5 mg/L and dropped below 0.7 mg/L by 2015. Regression analysis indicated a significant decline over the study period at a rate of about 0.048 mg/L per year or a total of 1.5 mg/L over the whole study period (Table 15).

Figure 104. Long term trend in Organic Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



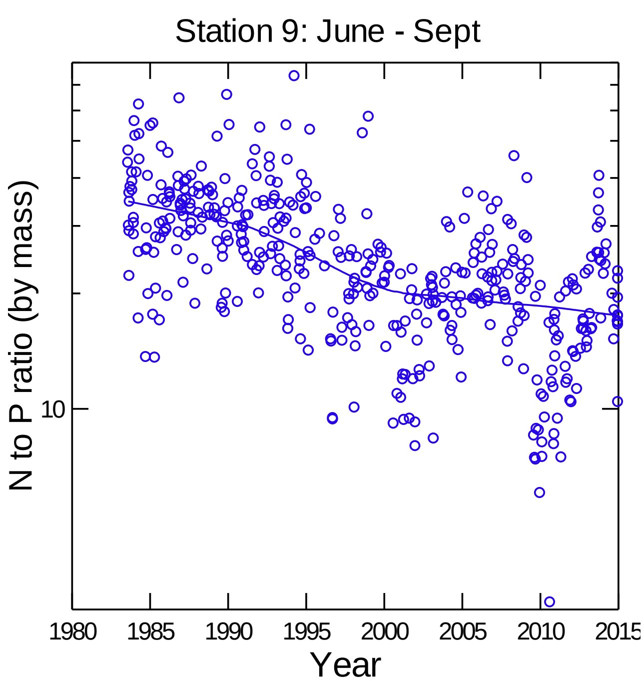
In the river organic nitrogen was steady from 1984 through 1995 and since then has shown perhaps a modest decline (Figure 105). The LOWESS line peaked at about 0.9 mg/L and has dropped to about 0.7 mg/L. Regression analysis indicated a significant linear decline at a rate of 0.01 mg/L when the entire period of record was considered for a total decline of 0.3 mg/L (Table 15).

Figure 105. 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 12 by 2015 (Figure 106). Regression analysis over the period of record indicates a statistically significant decline at a rate of 0.33 per year or about 10.5 units over the entire period (Table 15). Values in 2015 were well above the trend line.

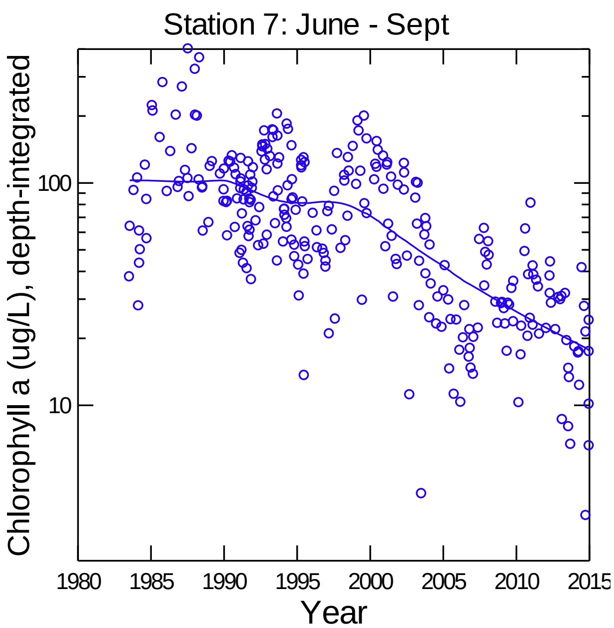
Figure 106. Long term trend in N to P Ratio (Fairfax County Lab Data). Station 7. Gunston Cove.



Nitrogen to phosphorus ratio in the river exhibited a strong continuous decline through about 2000 and has declined more slowly since then (Figure 107). The LOWESS trend line declined from about 35 in 1984 to 17 in 2013. Linear regression analysis confirmed this decline and suggested a rate of 0.62 units per year or a total of 20 units over the long term study period (Table 15). Values in 2015 were clustered above the trend line.

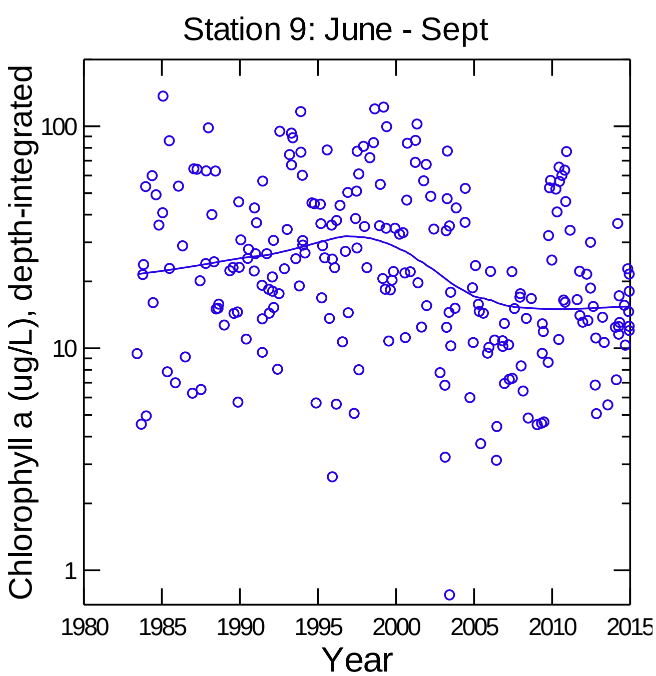
Figure 107. Long term trend in N to P Ratio (Fairfax County Lab Data). Station 9. River mainstem.

C. Phytoplankton Trends: 1984-2015



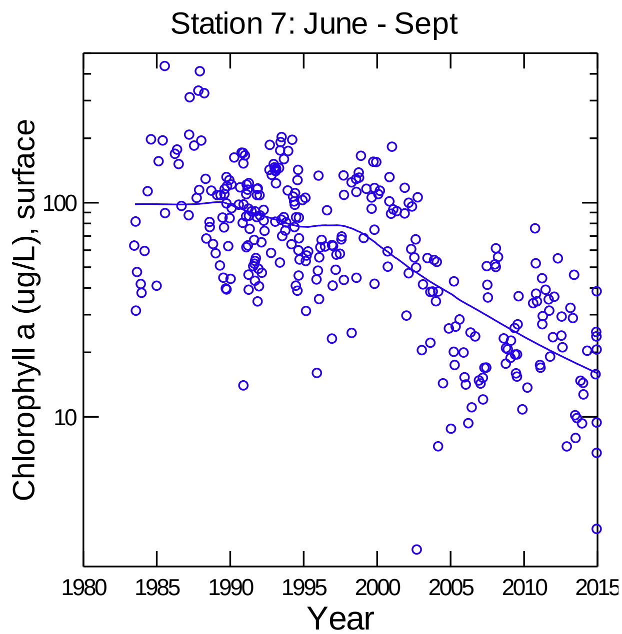
After increasing through much of the 1980's, depth-integrated chlorophyll *a* in the cove demonstrated a gradual decline from 1988 to 2000 and a much stronger decrease since then (Figure 108). The LOWESS line has declined from about 100 µg/L to less than 20 µg/L in 2015. The observed decrease has resulted 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 3.9 µg/L per year or 125 µg/L over the 32-year long term data set (Table 14).

Figure 108. Long term trend in Depth-integrated Chlorophyll *a* (GMU Lab Data). Station 7. Gunston Cove.



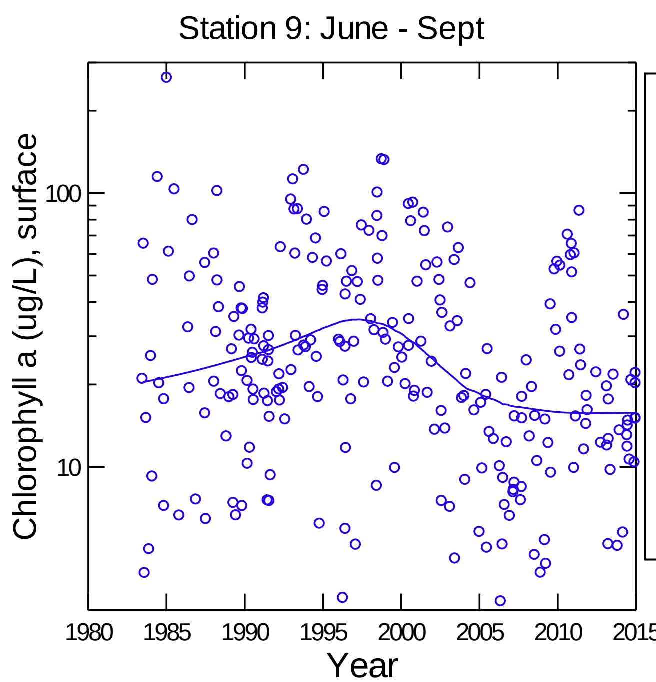
In the river depth-integrated chlorophyll *a* increased gradually through 2000 with the trend line rising from 20 to 30 µg/L (Figure 109). This was followed by a strong decline through about 2005 reaching a rather constant value of about 18 µg/L. Regression analysis revealed a significant linear decline at a rate of 0.64 µg/L/yr when the entire period is considered (Table 14) yielding a total decline of about 20 ug/L.

Figure 109. Long term trend in Depth-integrated Chlorophyll *a* (GMU Lab Data). Station 9. River mainstem.



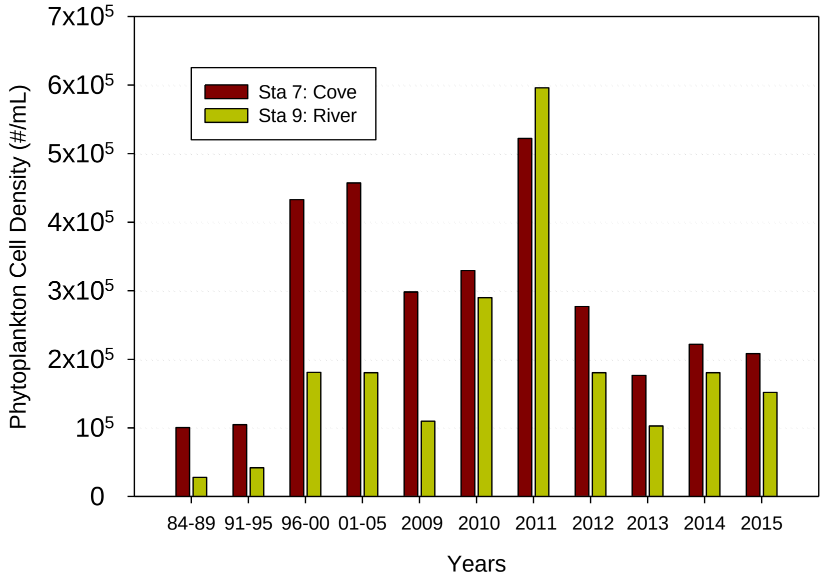
Surface chlorophyll *a* in the cove also exhibited a clear decline over the long term study period, especially since 2000 (Figure 110). Trend line values of about 100 µg/L in 1988 dropped to about 18 µg/L in 2015. The observed decrease has brought chlorophyll values into the range of water clarity criteria which are 43 µg/L and 11 µg/L to allow SAV growth to 0.5 m and 1.0 m, respectively. Linear regression confirmed the linear decline and suggested a rate of 4.0 µg/L per year or 128 µg/L over the entire study (Table 14).

Figure 110. Long term trend in Surface Chlorophyll *a* (GMU Data). Station 7. Gunston Cove.



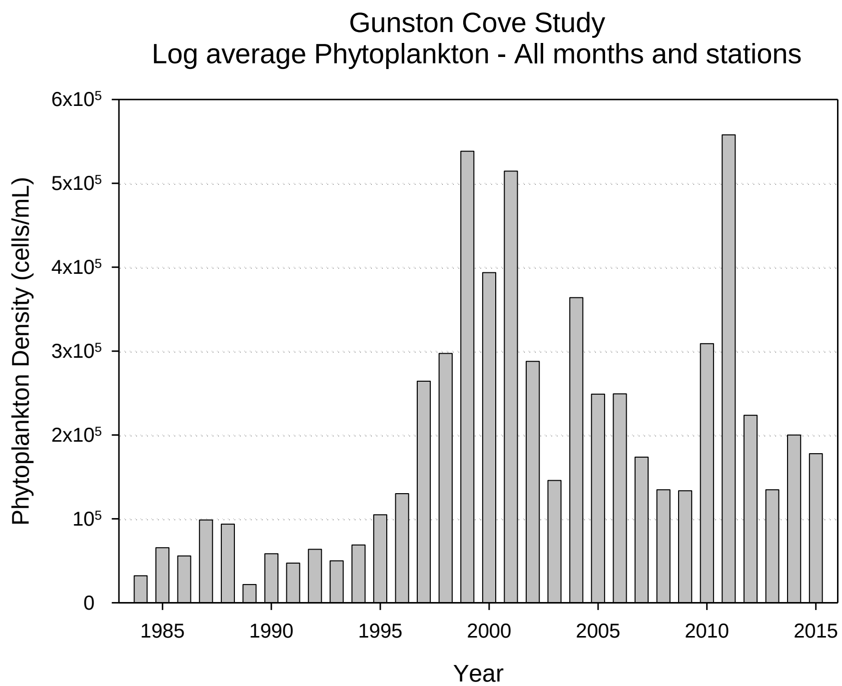
In the river the LOWESS line for surface chlorophyll *a* increased slowly from 1983 to 2000 and then declined markedly through 2005 (Figure 111). Values have stabilized since then at about 16 µg/L. Linear regression revealed a significant decline in surface chlorophyll across this period with a rate of 0.73 µg/L/yr or about 23 µg/L over the whole period (Table 14).

Figure 111. Long term trend in Surface Chlorophyll *a* (GMU Data). Station 9. River mainstem.



Phytoplankton cell density in both the cove and the river in 2015 was similar to values observed since 2012 (Figure 112). 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.

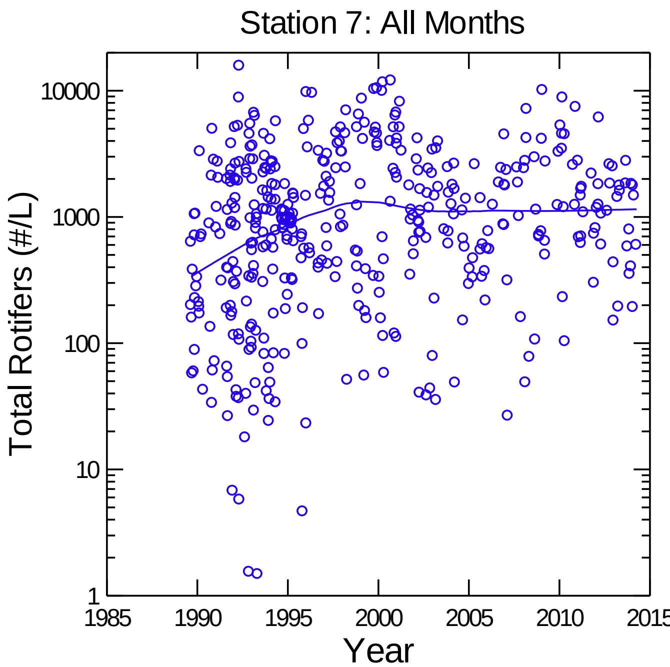
Figure 112. Interannual Comparison of Phytoplankton Density by Region.



By looking at individual years (Figure 113), we see that phytoplankton densities in 2015 remain lower than the high levels observed during the 1995 to 2005 period.

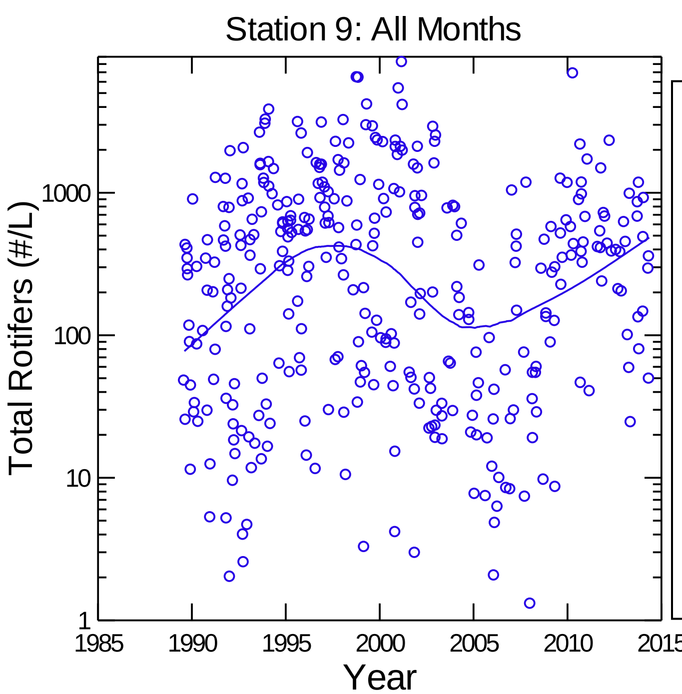
Figure 113. Interannual Trend in Average Phytoplankton Density.

D. Zooplankton Trends: 1990-2015



In the Cove total rotifers continued to show a leveling off after an initial decade (1990-2000) of steady increase (Figure 114). The LOWESS fit line indicated about 1000/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 16).

Figure 114. 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 115). Trend line values in 1990 were about 80/L and now are about 500/L approaching 1998 values. However, when the entire 1990-2015 period was considered, total rotifers did not exhibit a significant linear trend in the river (Table 16).

Figure 115. Long term trend in Total Rotifers. Station 9. River mainstem.

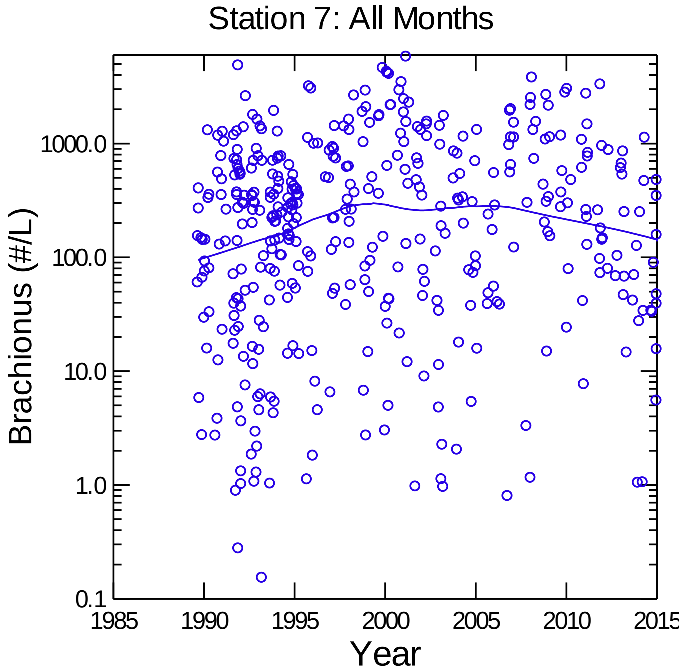
Table 16
Correlation and Linear Regression Coefficients
Zooplankton Parameters vs. Year for 1990-2015
All Nonzero Values Used, All Values Logged to Base 10

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Brachionus (m)	0.088 (415)	---	NS	0.051 (338)	---	NS
Conochilidae (m)	0.167 (370)	0.015	0.001	0.028 (291)	---	NS
Filinia (m)	0.131 (359)	0.015	0.013	0.137 (242)	-0.013	0.033
Keratella (m)	0.341 (426)	0.035	<0.001	0.151 (351)	0.017	0.005
Polyarthra (m)	0.206 (407)	0.021	<0.001	0.103 (330)	---	NS
Total Rotifers (m)	0.151 (443)	0.014	0.001	0.030 (363)	---	NS
Bosmina (m)	0.044 (251)	---	NS	0.084 (296)	---	NS
Diaphanosoma (M)	0.084 (346)	---	NS	0.080 (250)	---	NS
Daphnia (M)	0.024 (277)	---	NS	0.038 (181)	---	NS
Chydorid cladocera (M)	0.214 (242)	0.023	<0.001	0.195 (160)	0.017	0.013
Leptodora (M)	0.158 (193)	-0.020	0.028	0.215 (136)	-0.021	0.011
Copepod nauplii (m)	0.436 (422)	0.035	<0.001	0.236 (359)	0.023	<0.001
Adult and copepodid copepods (M)	0.011 (538)	---	NS	0.112 (403)	0.008	NS

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

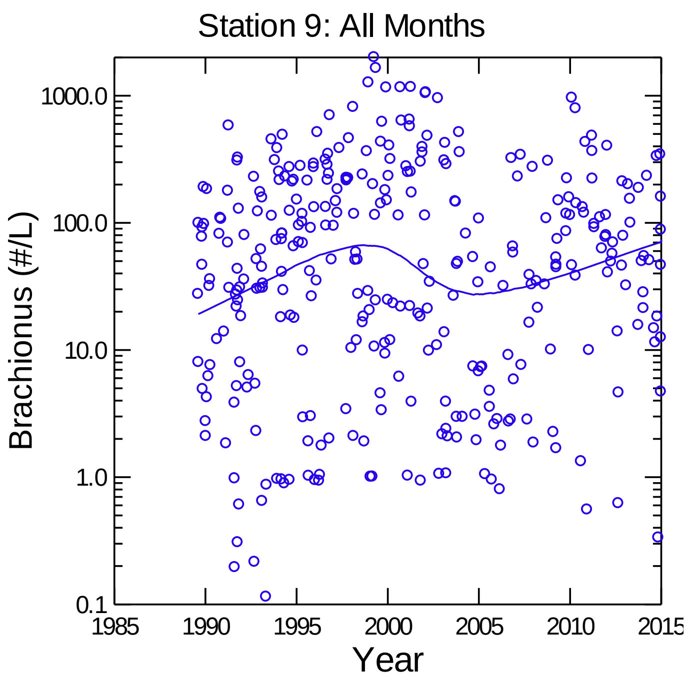
Significance column indicates the probability that a correlation coefficient this large could be due to chance alone. If this probability is greater than 0.05, then NS (not significant) is indicated. * = marginally significant.

M indicates species was quantified from macrozooplankton samples; m indicates quantification from microzooplankton samples.



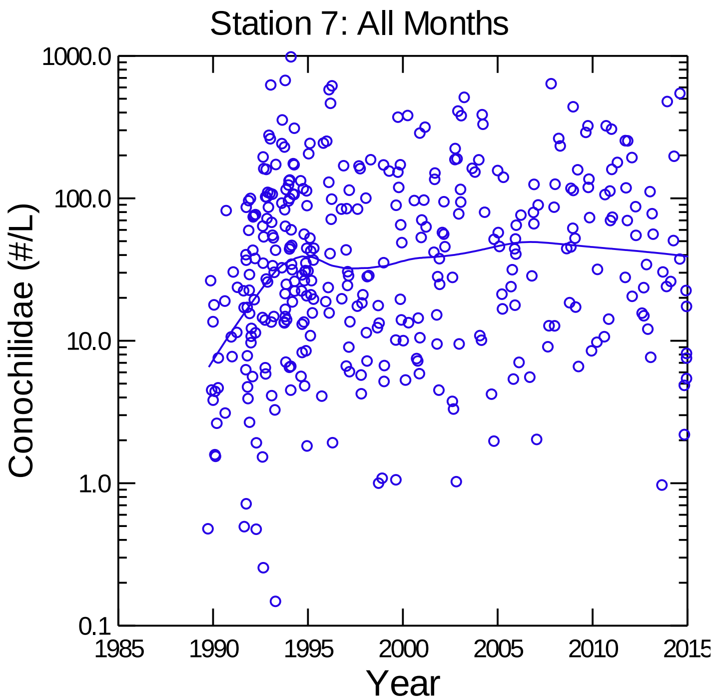
Brachionus is the dominant rotifer in Gunston Cove and the trends in total rotifers are generally mirrored in those in *Brachionus* (Figure 116). The LOWESS line for *Brachionus* suggested about 150/L in 2015, only slightly greater than the 100/L found in 1990. No linear trend was found over the study period (Table 16).

Figure 116. Long term trend in *Brachionus*. Station 7. Gunston Cove.



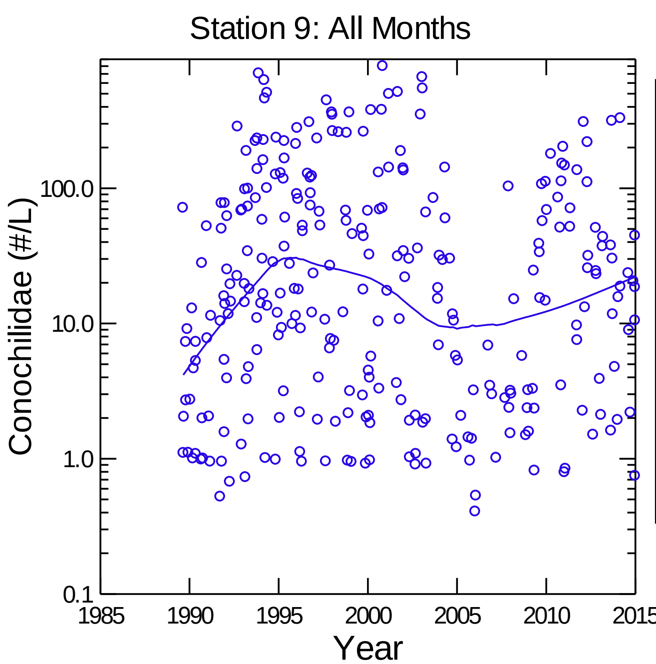
Brachionus was found at lower densities in the river. In the river the LOWESS line for *Brachionus* increased through 2000, but dropped markedly from 2000-2005.Since 2005 an increase has been noted, with the LOWESS value in 2013 of about 70/L, higher than the initial 20/L and near the previous peak of 80/L in 1999 (Figure 117). No linear trend was indicated when the entire study period was considered (Table 16).

Figure 117. Long term trend in *Brachionus*. Station 9. River mainstem.



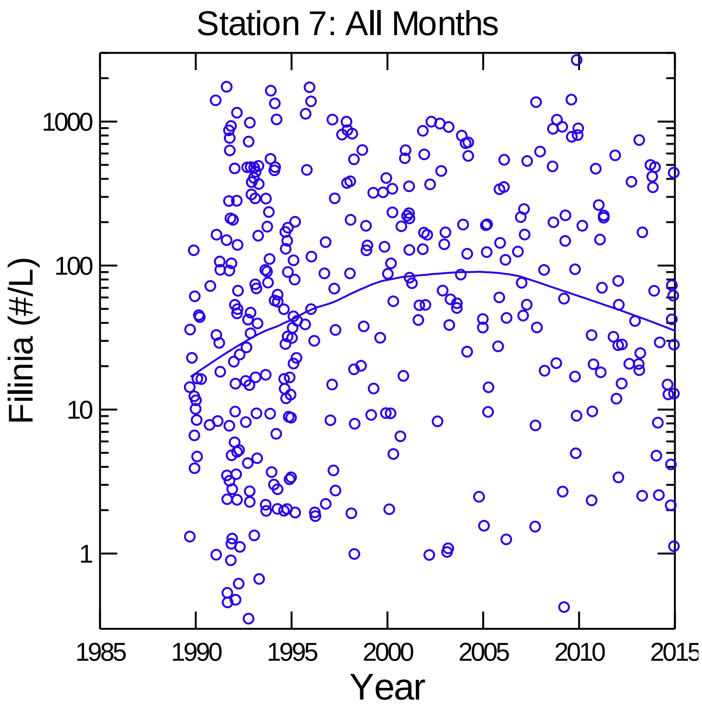
Conochilidae increased strongly from 1990-1995 and since then has leveled off. In 2015 the LOWESS trend line stood at about 40/L (Figure 118). This was well above levels of about 5/L in 1990. Over the entire period of record, a significant linear increase was found (Table 16).

Figure 118. Long term trend in Conochilidae. Station 7. Gunston Cove.



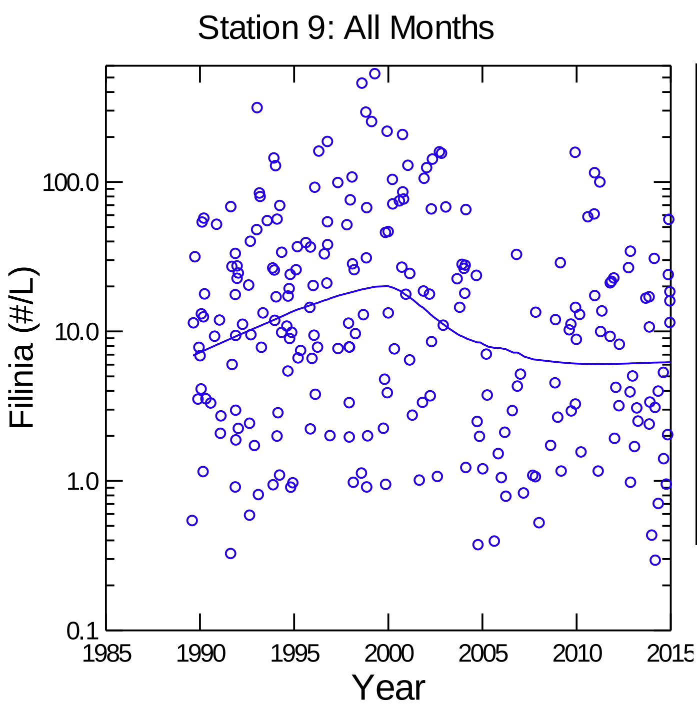
In the river, Conochilidae exhibited a strong increase in the early 1990's similar to that observed in the cove (Figure 119). This was followed by a period of decline and recently a renewed increase. The trend line has gone from 3/L in 1990 to 35/L in 1995 to 10/L in 2005 to 20/L in 2015. When the entire period of record was examined, there was not a significant linear trend (Table 16).

Figure 119. Long term trend in Conochilidae. Station 9. River mainstem.



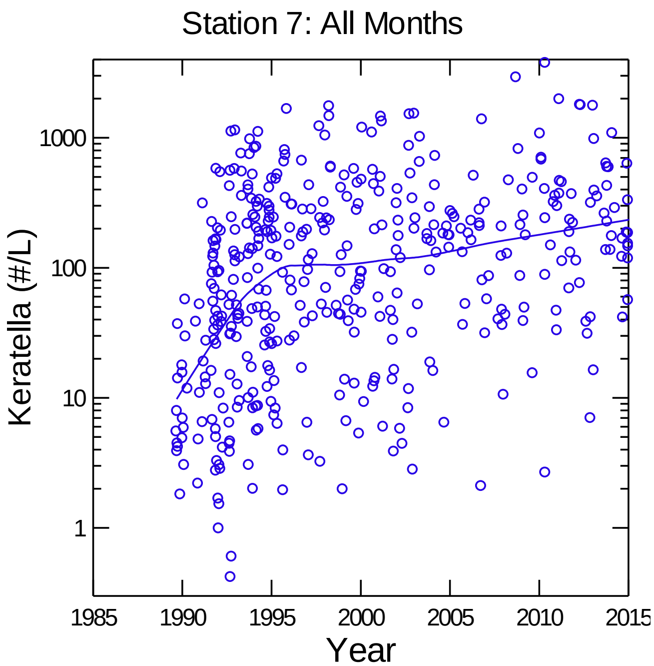
In the cove *Filinia* exhibited a steady increase from 1990 through 2000 rising from about 20/L to nearly 100/L (Figure 120). It has shown a gradual decline in recent years to about 30/L. When the entire period of record was considered, there is evidence for a linear increase in the cove despite the recent declines (Table 16).

Figure 120. Long term trend in *Filinia*. Station 7. Gunston Cove.



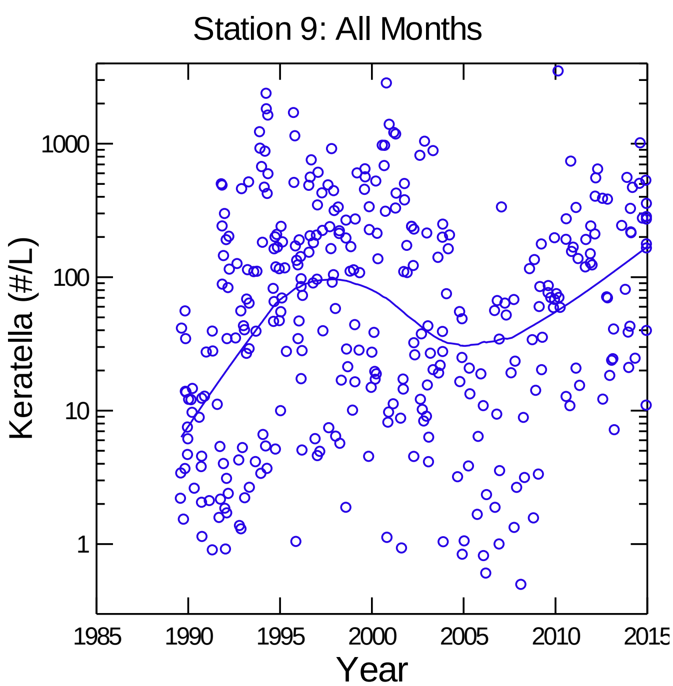
In the river *Filinia* demonstrated an increase through about 2001, declined from 2000-2005 and remained steady since. The trend line indicates about 5/L in 2015, about equal to the 7/L in 1990, but well below the peak of 20/L in 2000 (Figure 121). When the entire period of record was examined, there was a barely significant negative linear trend (Table 16).

Figure 121. Long term trend in *Filinia*. Station 9. River mainstem.



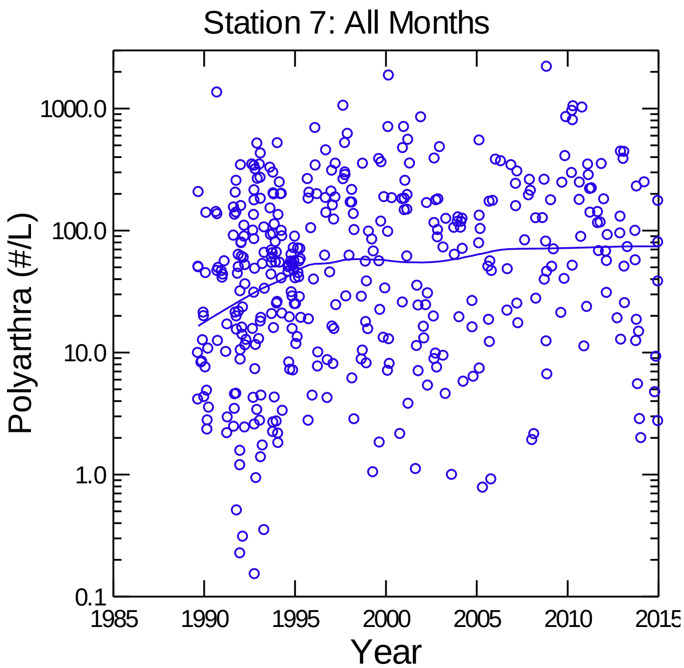
Keratella increased strongly from 1990 to 1995 and has shown a milder increase since then with the trend line approaching 250/L in 2015 (Figure 122). When the entire period of record was examined, there was a significant linear increase (Table 16).

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



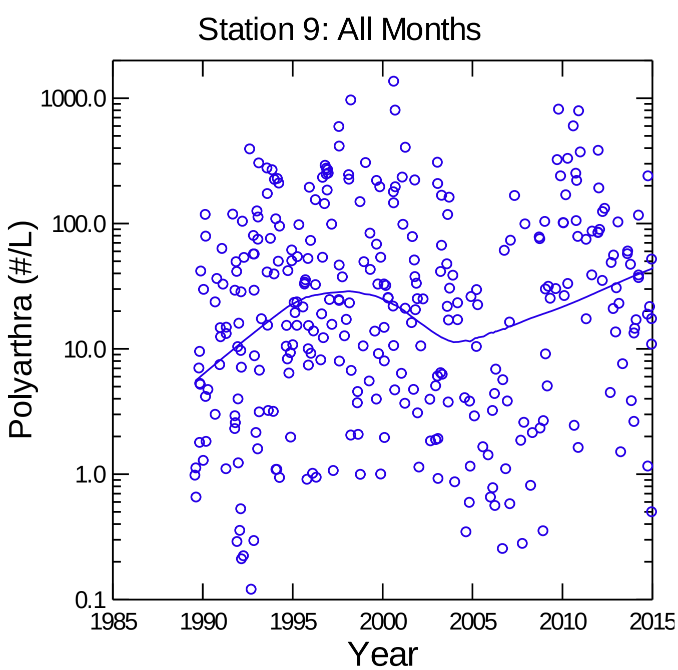
In the river *Keratella* increased from less than 10/L in 1990 to peak values of about 100/L in the mid to late 1990's (Figure 123). The trend line then declined to about 25/L, but since 2005 it has increased to about 150/L. Linear regression showed no evidence of a linear increase when the entire study period was considered (Table 16).

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



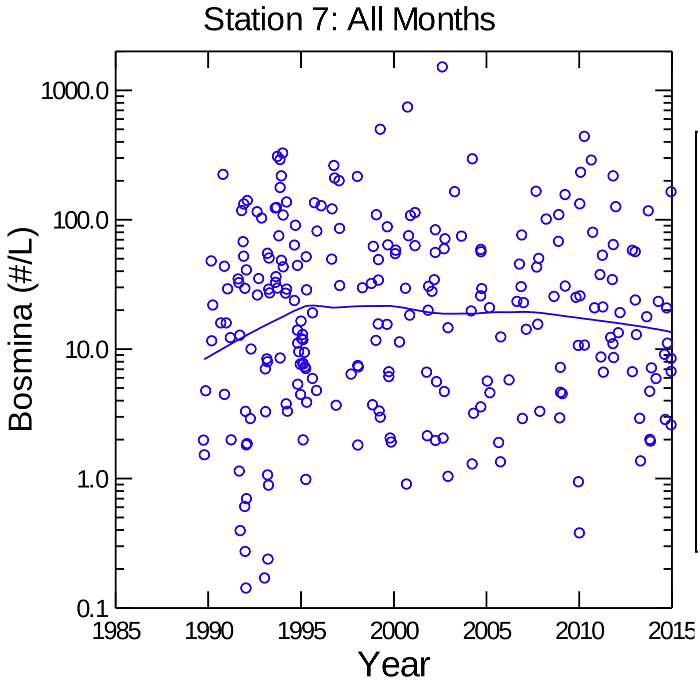
The trend line for *Polyarthra* in the cove increased steadily from 1990 to about 2000 rising from 15/L to about 60/L (Figure 124). Since 2000 densities have increased more slowly with the trend line reaching about 80/L by 2014. Regression analysis indicated a significant linear increase when the entire period of record was examined (Table 16).

Figure 124. Long term trend in *Polyarthra*. Station 7. Gunston Cove.



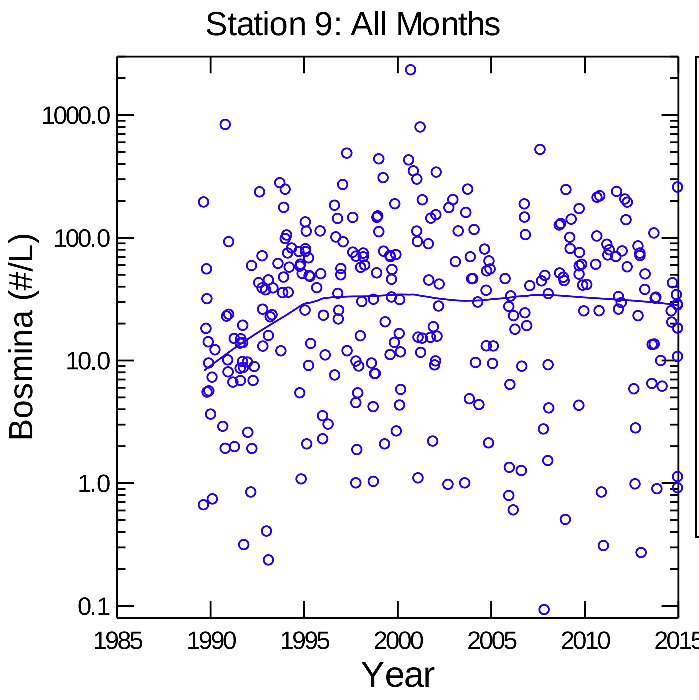
In the river *Polyarthra* showed a marked increase from 1990 to 2000 and then a decline to 2005. Recently values have increased again and by 2015 the trend line reached 40/L (Figure 125). Linear regression analysis did not indicate a significant positive trend over the period of record (Table 16).

Figure 125. Long term trend in *Polyarthra*. Station 9. River mainstem.



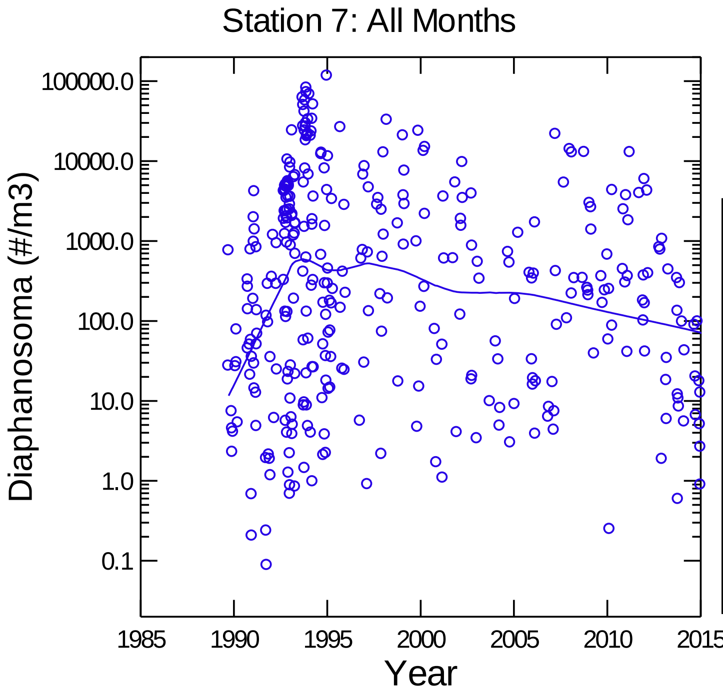
The trend line for *Bosmina* in the cove showed an increase from 8/L in 1990 to about 20/L in 2000 (Figure 126). Since 2000 densities have not changed much. Linear regression did not indicate a significant trend in the cove over the entire period of record (Table 16).

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



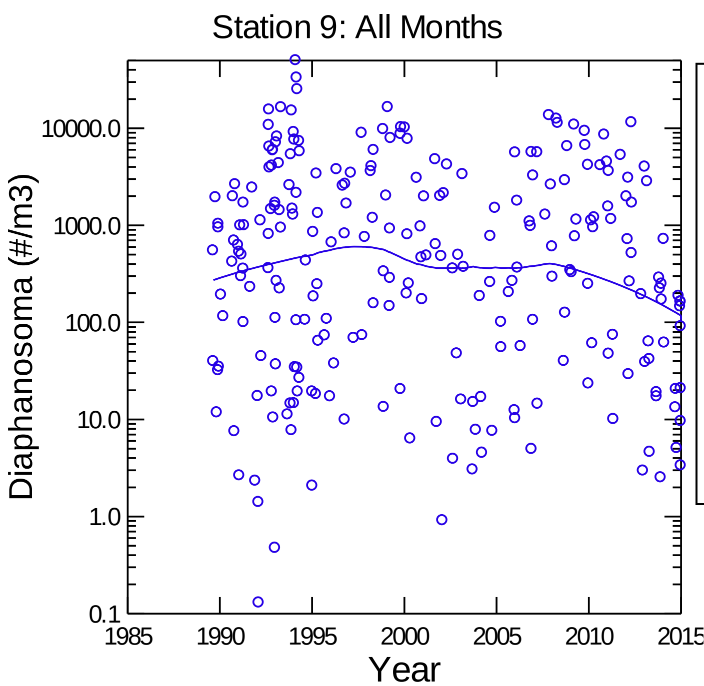
In the river mainstem the LOWESS curve for *Bosmina* increased from 1990 to 1995, and remained rather constant from 1995 to 2005 at about 40/L in 2015 (Figure 127). Regression analysis did not indicate a significant linear increase over the entire period of record (Table 16).

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



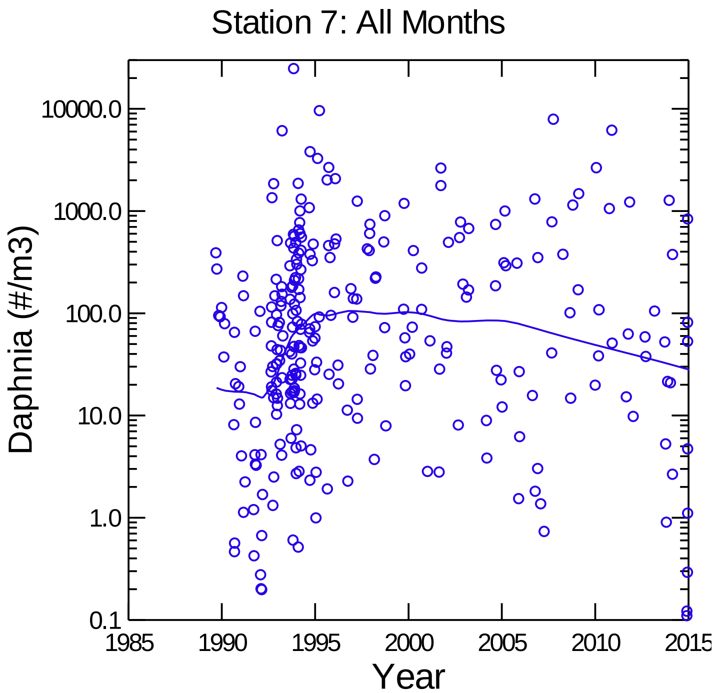
Diaphanosoma increased strongly in the early 1990s from about 12/m^3 nearly 1000/m^3. It gradually declined through 2015 to about 100/m^3 (Figure 128). Many 2015 values were below 100/m^3. Linear regression analysis of the entire period of record indicated no significant linear trend (Table 16).

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



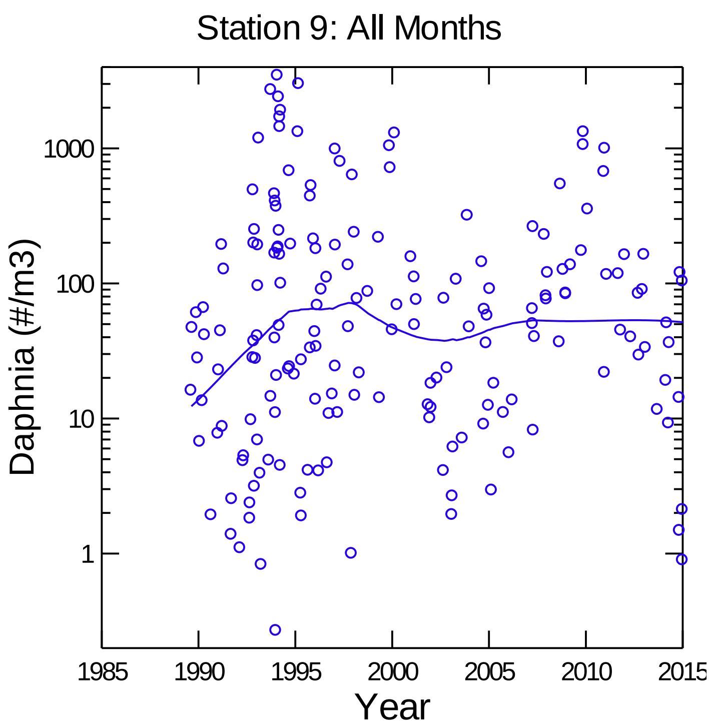
In the river the LOWESS line suggested a generally stable pattern in *Diaphanosoma* (Figure 129). The trend line value of 300/m^3 found in 2014 compared with values as high as 600/m^3 in 1999. Recently densities have declined. Regression analysis indicated no significant linear trend over the period of record (Table 16).

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



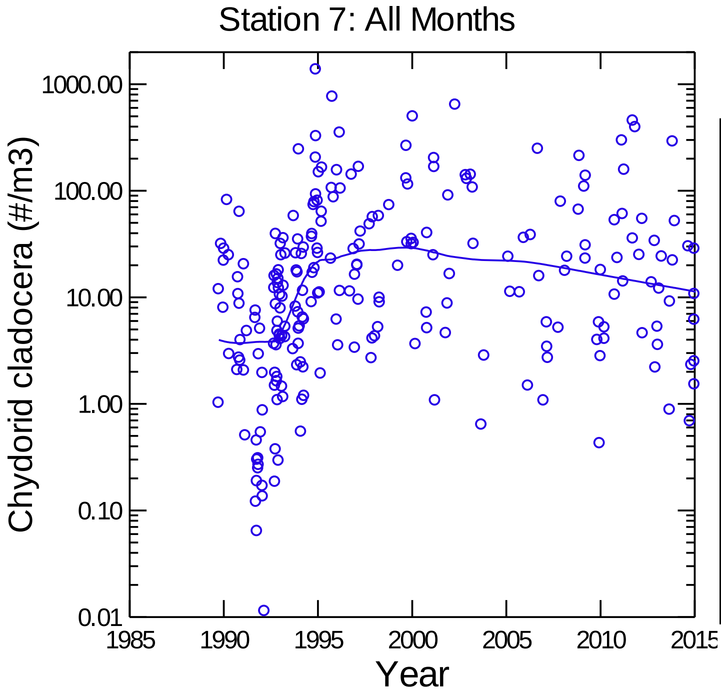
Daphnia in the cove has been relatively stable since 1995 at about 70-100/m^3 (Figure 130). This is up from the low of about 20/m^3 in 1992 and the starting value of 40/m^3 in 1990. The trend line has declined to about 30/m^3. Regression analysis examining the entire period of record gave some support for a linear increase (Table 16).

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



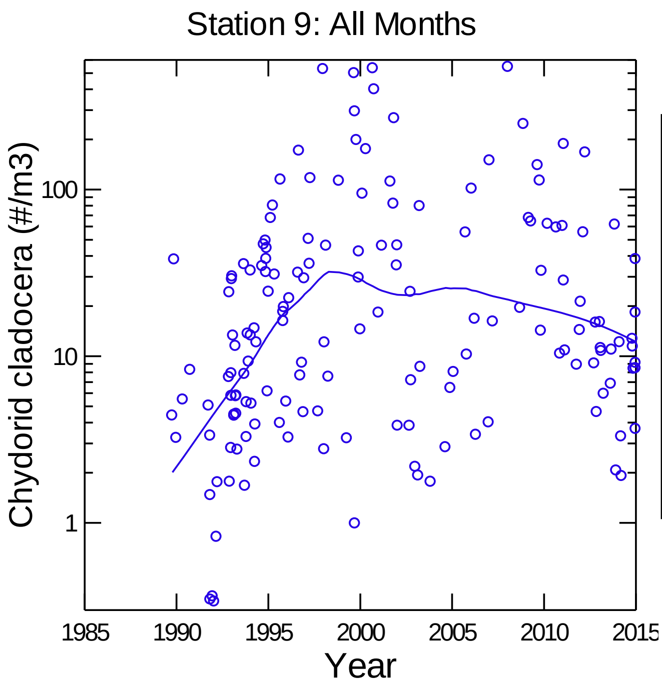
Daphnia in the river increased early on, but has since declined (Figure 131). The trend line in 2015 approached 50/m^3, substantially higher than the level observed at the beginning of the record in 1990. Regression analysis did not indicate a significant positive trend over the study period (Table 16).

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



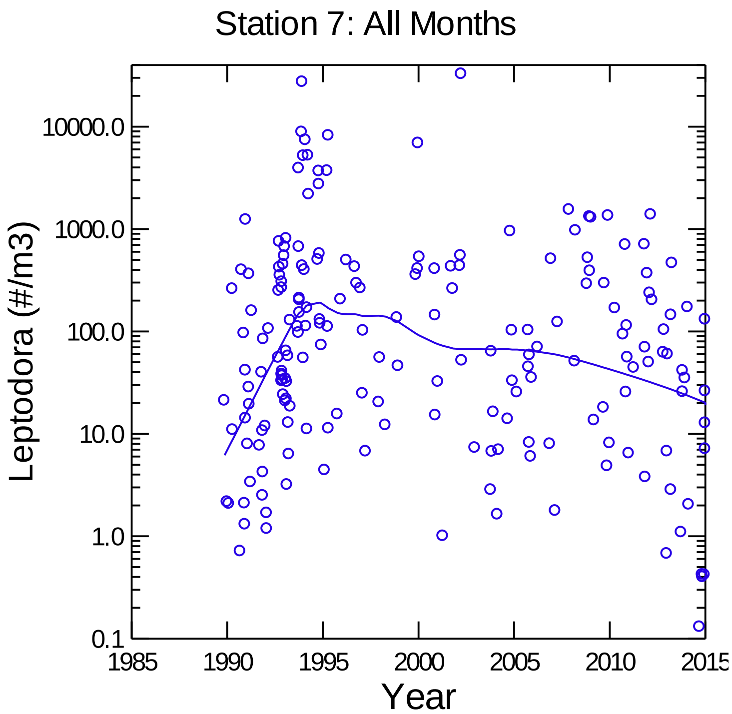
Chydorid cladocera in the cove have maintained a consistent population of about 10-20/m^3, substantially higher than the low of 3/m^3 in 1992 and the initial value of 8/m^3 in 1990, but below trend line values of 30/m^3 observed in 2000 (Figure 132). Regression analysis gave evidence for a linear increase over the study period (Table 16).

Figure 132. Long term trend in Chydorid Cladocera. Station 7. Gunston Cove.



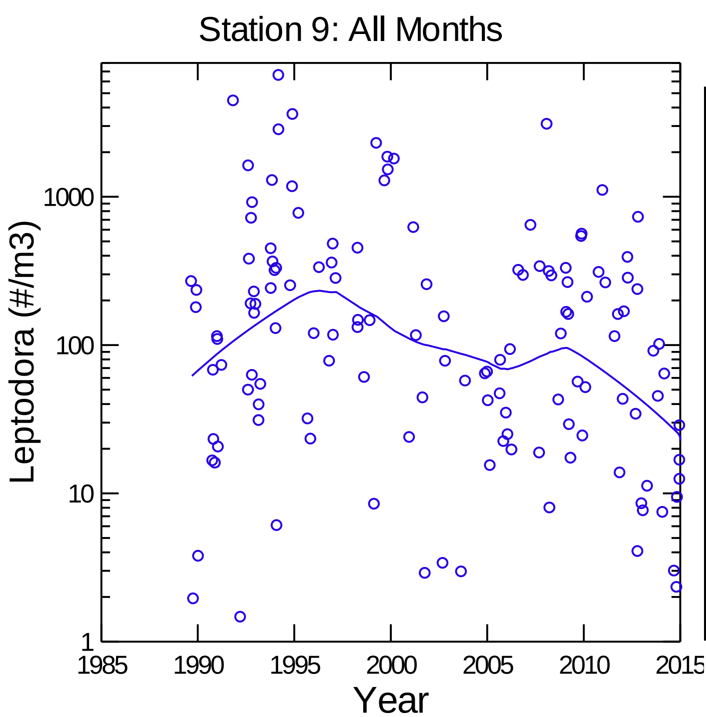
In the river chydorids continued a gradual decrease to about 12/m^3, well above the low of about 2/m^3 in the early 1990's (Figure 130). There was some evidence for a linear increase in chydorids over the entire study period as indicated by linear regression analysis (Table 16).

Figure 133. Long term trend in Chydorid Cladocera. Station 9. River mainstem.



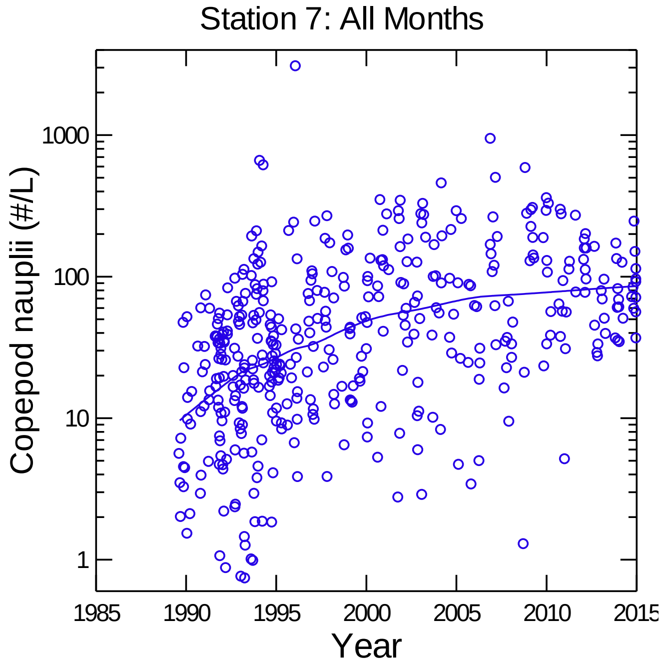
In the cove the trend line for *Leptodora*, the large predaceous cladoceran, has gradually decreased to about 20/m^3, down from its high of about 200/m^3 in 1994, and only slightly above the 1990 value of 10/m^3 (Figure 134). There was weak evidence for a significant linear change in *Leptodora* over the entire study period (Table 16).

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



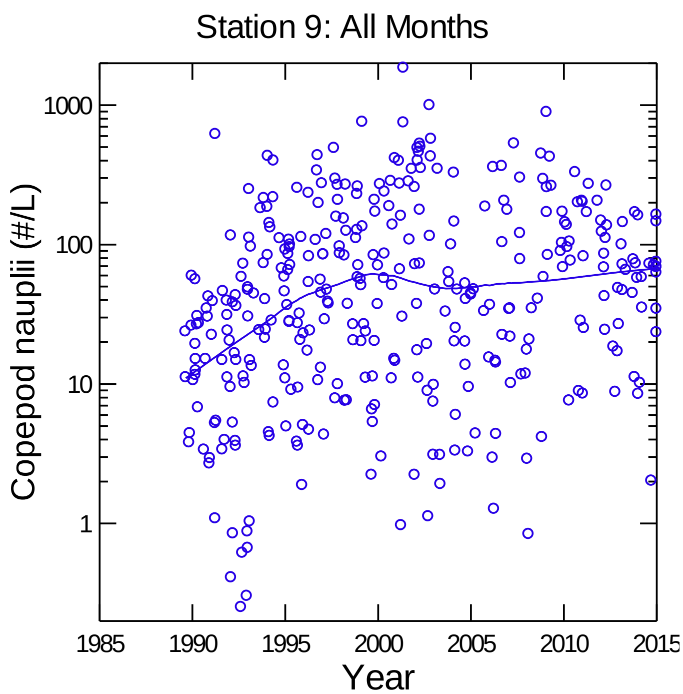
In the river, *Leptodora* densities continued a general decline which began in 1995 resulting in trend line values of about 30/m^3 for 2015 (Figure 135). These values are almost equal to those observed in 1990, and are well below the peak of 300/m^3 in 1994. Linear regression analysis detected a weak significant linear trend when the whole study period was considered (Table 16).

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



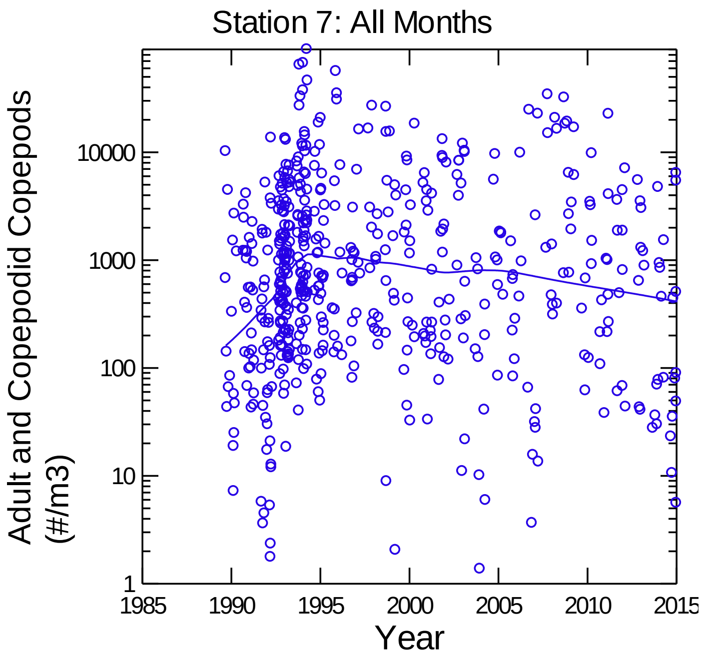
Copepod nauplii, the immature stages of copepods, continued their upward trend reaching almost 85/L (Figure 136). These values are well above the initial values of about 10/L in 1990. A strong linear increase was observed over the study period (Table 16).

Figure 136. Long term trend in Copepod Nauplii. Station 7. Gunston Cove.



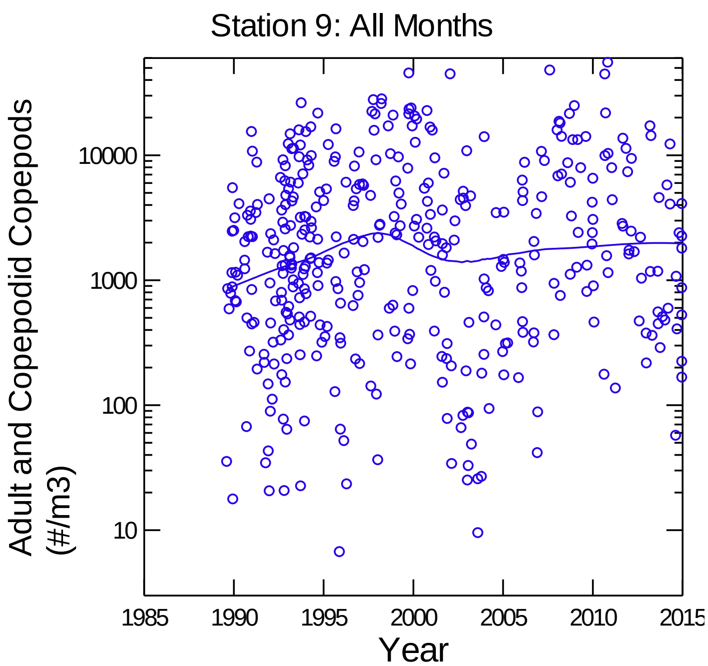
In the river, copepod nauplii showed a gradual increase since 2005 (Figure 137). The 2015 LOWESS trend line value was about 80/L, up from an initial value of 10/L in 1990, similar to the previous peak of about 70/L. A significant linear increase was found for nauplii over the study period (Table 16).

Figure 137. Long term trend in Copepod Nauplii. Station 9. River mainstem.



In the cove, adult and copepodid copepods increased strongly in the early 1990's and since have decreased slowly to about 400/m^3 (Figure 138). Copepods did not exhibit a significant linear trend in the cove over the study period (Table 16).

Figure 138. Long term trend in Adult and Copepodid Copepods. Station 7. Gunston Cove.



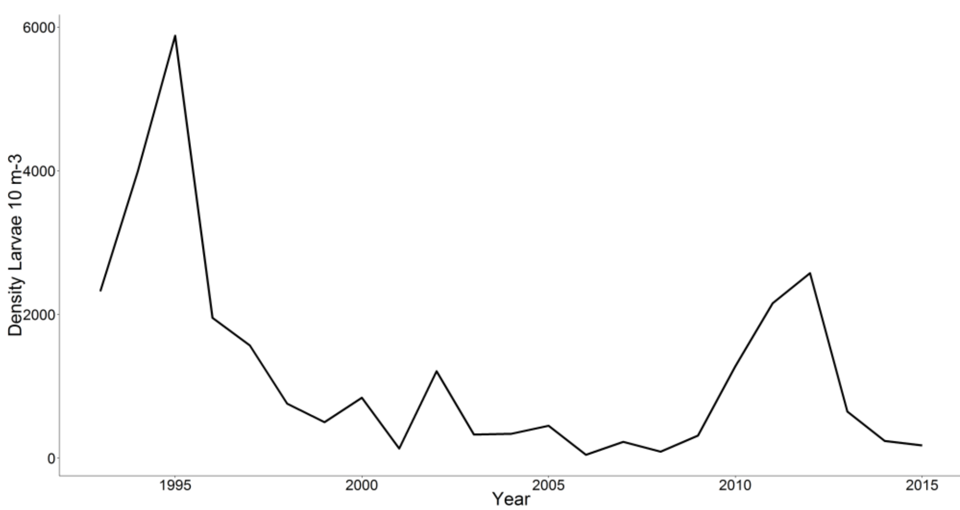
Adult and copepodid copepods have not changed greatly over the study period (Figure 139). The trend line in 2015 was about 2000/m^3, slightly below the previous maximum of 2500/m^3 in 1998. No linear increase was found when the entire study period was considered (Table 16).

Figure 139. Long term trend in Adult and Copepodid Copepods. Station 9. River mainstem.

E. Ichthyoplankton Trends: 1993-2015

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 sensitivity of these larval fishes to the availability of food and environmental variables makes them great indicators of water quality and habitat suitability. 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, which we survey as well, providing the link between food availability and larval survival. When the occurrence of fish larvae overlaps with their zooplankton which are their food, 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 140; Table 17). Especially 2010-2012 showed very high density of these larvae, while numbers decreased again in 2013. With continued relatively low densities in 2014 and 2015, the high densities of 2010-2012 appear to be a peak rather than a rebound to higher densities. It is possible that this is natural variation, and that these populations rely on a few highly successful yearclasses.



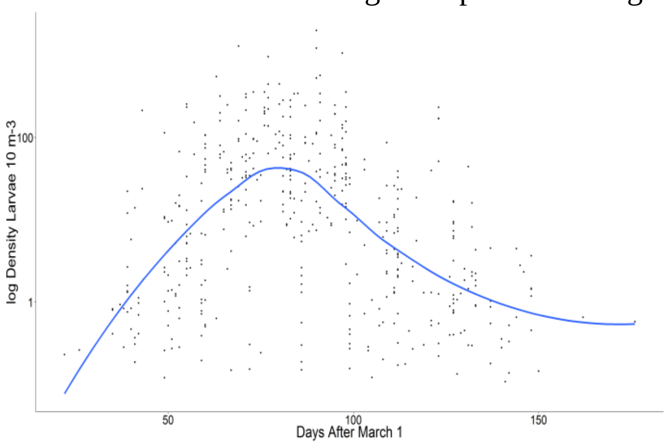
A graph of clupeid fish larvae averaged over all stations from 1993 through 2015 is shown in Figure 140. A peak from 2010-2012 sustains the population after years of declining densities since the mid 1990’s.

Figure 140. Long-term trend in Clupeid Larvae (abundance 10 m^{-3}).

Table 17. Density of larval fishes Collected in Gunston Cove and the Potomac mainstem (abundance per m^3)

Taxon	Common Name	2007	2008	2009	2010	2011	2012	2013	2014	2015
Alosa sp.	Alewife, herring, or shad	17.20	3.60	37.90	246.60	149.10	1005.70	53.00	122.72	41.31
Dorosoma sp.	Gizzard and Threadfin Shad	208.70	85.00	276.10	1032.00	2006.90	1334.90	25.00	115.72	28.90
Lepomis sp.	sunfish	0.00	0.00	0.00	0.20	2.00	3.70	6.00	0.21	0.22
Morone sp.	perch and bass	39.60	60.50	58.10	88.10	62.80	640.90	27.00	0.21	1.70
Perca flavescens	Yellow Perch	12.00	1.20	0.30	14.80	0.40	0.40	3.00	1.04	0.00
Menidia beryllina	Inland Silverside	5.30	1.40	1.70	10.50	2.50	21.50	7.00	1.28	20.68

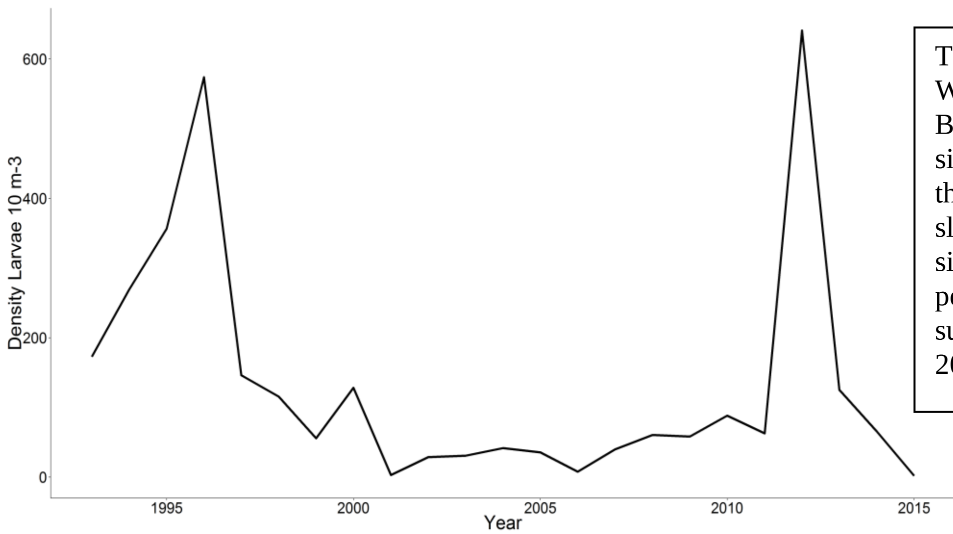
The peaks in abundance over the season reflect characteristic spawning times of each species (Figures 141, 143, 145, and 147). The earliest peak is from Yellow Perch (Figure 147), which may even be at its highest before our sampling starts. An early peak is also seen for *Morone sp*., which is mostly White Perch (Figure 143). White Perch begin spawning early and larval densities slowly taper off. Consequently, White Perch larvae are found throughout most of the sampling season. Clupeid larval density shows a distinct peak mid-May (Figure 141). 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. Silversides have a less pronounced peak in early June, with low densities continuing to be present throughout the season (Figure 145).



The seasonal pattern in clupeid larvae for 1993-2015 (Figure 141) shows that a peak in density occurs about 80 days after March 1, or mid-May. The occurrence of the peak late in the spring may indicate a dominance of Gizzard Shad larvae in the samples. Since river herring are spawned more upstream, this late spring peak also shows the time it takes for these larvae to drift down to Gunston Cove after river herring spawning season of mid-March to mid-May.

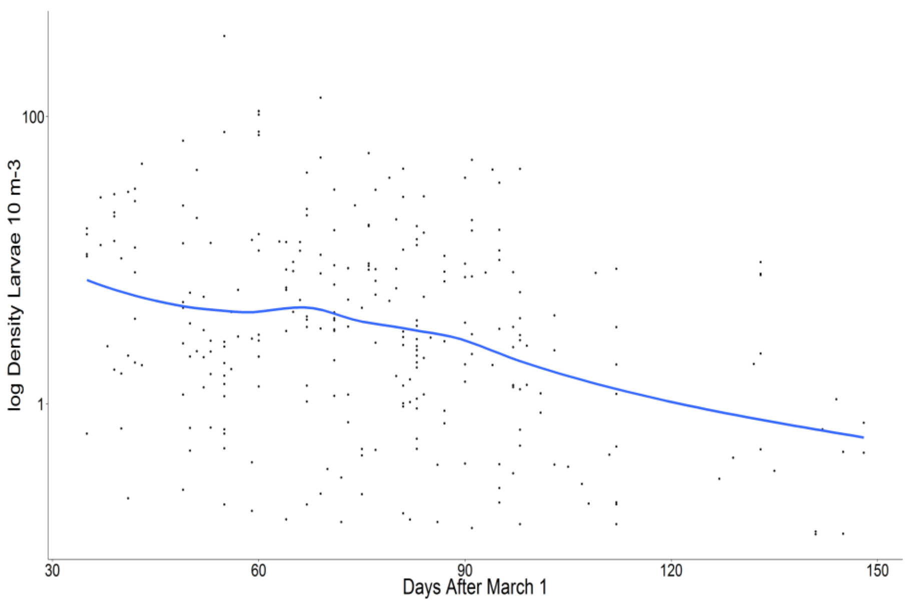
Figure 141. Seasonal pattern in Clupeid larvae (*Alosa* sp. and *Dorosoma* sp.; abundance 10 m^{-3}). The x-axis represents the number of days after March 1.

The long-term trend in annual average density of *Morone* larvae shows a high similarilty with that of Clupeid larvae (figure 142). While densities our 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 143), 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.



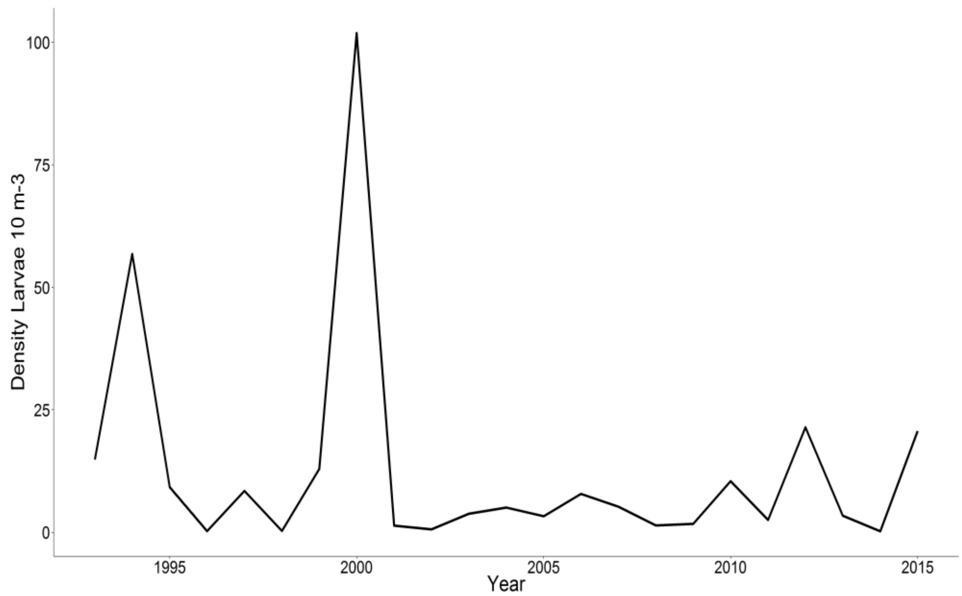
The trend in number of White Perch and Striped Bass larvae per 10 m^3 since 1993 is depicted in the graph in Figure 142. A slow increase can be seen since 2004, with a high peak in 2012, and subsequent decreases unto 2015.

Figure 142. Long term trend in *Morone* sp. larvae (abundance 10 m^{-3}).



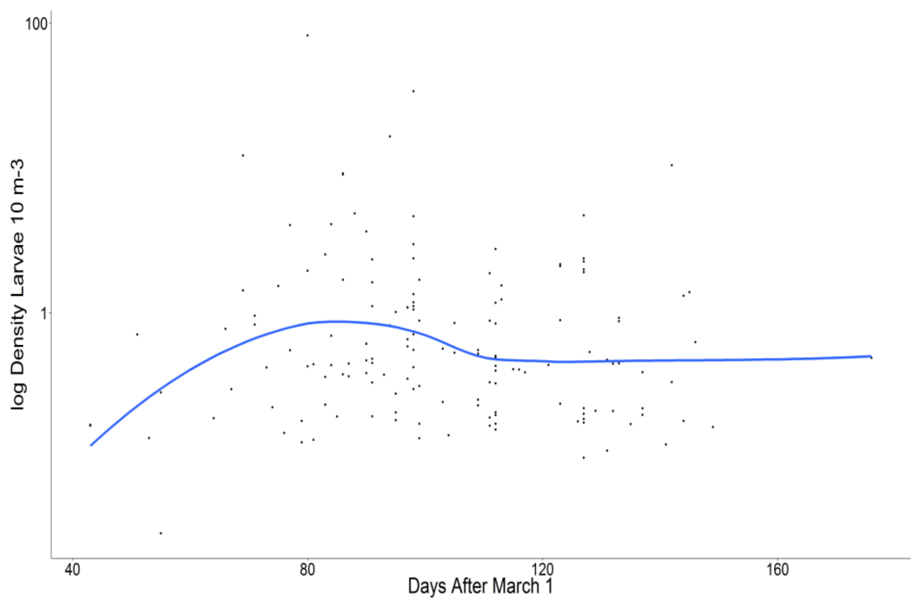
The seasonal density of *Morone* sp. larvae per 10 m^3 is shown in Figure 143. A small peak can be seen about 60 days after March 1 followed by declines in density thereafter. This peak occurs end of April, while highest densities are at the start of the sampling season.

Figure 143. Seasonal pattern in *Morone sp.* larvae (abundance 10 m^{-3}). X-axis represents days after March 1st.



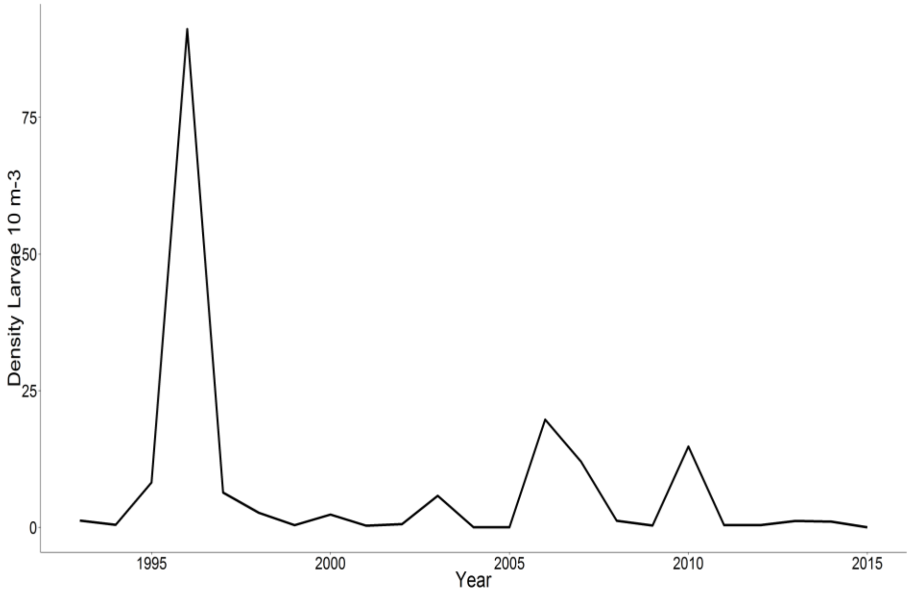
The long-term trend in density of Atherinid larvae (probably all Inland Silverside larvae) is presented in Figure 144. After a high peak in 2000, densities have been moderate to low with some small peaks in 2010, 2012, and 2015.

Figure 144. Long-term trend in *Menidia beryllina* larvae (abundance 10 m^{-3}).



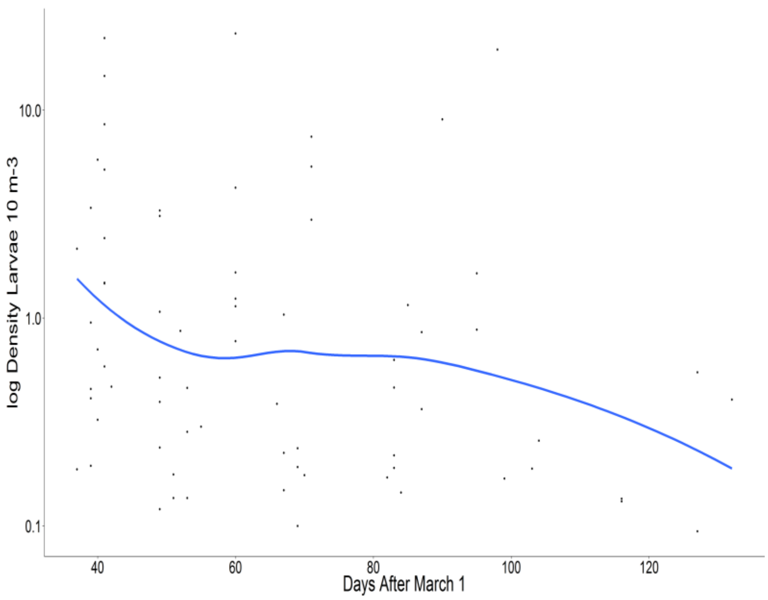
The seasonal occurrence of Atherinid larvae per 10m^3 is shown in a LOWESS graph in Figure 145. The pattern shows maximum density around 90 days after March 1, or around the first week of June.

Figure 145. 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 while the general trend remains variable.

Figure 146. Long-term trend in Yellow Perch 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 147. 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 147. Seasonal pattern in Yellow Perch larvae (abundance 10 m^{-3}). The x-axis represents the number of days after March 1.

F. Adult and Juvenile Fish Trends: 1984-2015
Trawls

Overall patterns

Annual abundance of juvenile fishes inside Gunston Cove is indexed by mean catch per trawl in the inner cove (stations 7 and 10 combined; Table 18, Figure 148). Since 1984, this index has fluctuated by over an order of magnitude, and the pattern was predominately due to changes in the catch rate of White Perch (Figure 148). The one high peak in 2004 that was not caused by high White Perch abundance was caused by a large catch of Blueback Herring (Figure 149). 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 2015 is similar to previous years and higher than the last two years. Trawl catches in station 7 and 10 were dominated by White Perch and Spottail Shiner. Alewife and Blueback Herring were represented in the catches with high abundances as well.

Table 18. Mean catch per trawl of adult and juvenile fishes at Stations 7 and 10 combined. 1984-2015.

Year	All Spp.	White Perch	Blueback Herring	Alewife	Gizzard Shad	Bay Anchovy	Spottail Shiner	Brown Bullhead	Pumpkinseed
2015****	307.9	186.7	28.3	4.5	0.3	0.1	69.8	0.1	1.2
2014*	98.7	49.4	2.2	1.4	0.2	1.5	16.7	0.4	0.6
2013***	42.7	16.2	0.0	0.0	0.1	0.8	6.0	0.6	1.6
2012*	159.3	127.7	0.0	0.0	0.5	0.4	11.8	0.6	2.1
2011**	95.2	43.6	1.0	0.1	0.2	0.0	20.0	0.1	2.0
2010*	397.8	265.5	0.2	6.9	2.3	0.4	6.4	0.4	1.4
2009	19.3	1.1	47.5	0.6	6.5	2.8	0.2	2.9	19.3
2008	70.7	16.2	0.0	0.1	4.0	0.3	2.6	0.6	7.0
2007	227.3	141.4	23.6	8.9	0.2	15.8	20.1	0.2	2.6
2006	26.1	9.6	1.6	0.6	0.2	2.3	3.0	0.4	1.8
2005	70.7	22.0	12.1	17.3	1.1	0.0	6.4	0.4	1.4
2004	408.4	23.4	337.5	33.1	0.9	0.6	8.0	0.1	0.5
2003	82.9	15.8	30.9	5.7	0.0	12.2	4.5	2.2	0.8
2002	93.4	17.9	11.3	32.7	0.1	18.1	0.8	1.0	2.0
2001	143.5	47.0	40.5	9.9	0.3	35.1	2.8	3.3	1.4
2000	72.1	56.5	3.8	2.0	2.5	1.8	1.4	2.1	0.7
1999	89.7	65.2	4.4	0.5	1.0	5.5	5.0	2.5	1.9
1998	83.2	63.9	2.2	0.5	0.6	3.7	6.8	1.0	1.7
1997	81.4	61.7	1.9	1.0	5.0	2.6	2.9	1.5	1.2
1996	48.0	35.4	2.5	1.6	0.5	0.2	2.6	0.5	2.1
1995	88.6	69.7	4.1	2.1	0.4	3.0	3.0	1.9	1.8
1994	92.2	66.9	0.8	0.0	0.1	0.5	6.2	3.2	2.7
1993	246.6	216.0	1.4	0.6	1.4	0.6	7.3	4.5	3.4

1992	112.9	81.6	0.3	0.0	0.9	0.8	2.4	11.5	5.1
1991	123.7	90.9	1.0	0.5	8.1	2.6	2.9	12.4	1.7
1990	77.7	35.5	23.3	3.5	0.1	1.2	1.2	10.7	0.5
1989	85.5	16.2	17.6	0.3	46.3	0.3	0.5	3.2	0.7
1988	96.0	45.1	11.2	8.8	12.7	8.3	1.8	5.3	0.9
1987	106.7	54.3	16.1	3.5	5.6	8.8	0.7	15.1	1.4
1986	124.6	65.4	1.9	24.0	4.1	4.2	0.5	18.4	0.6
1985	134.4	43.2	13.5	12.4	2.9	48.1	0.9	9.6	0.0
1984	169.2	105.2	6.6	0.6	10.8	7.6	1.6	30.4	0.4

*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.

Mean catch at station 9 was higher in 2015 than in the previous two years, but still below the long-term mean (54; Table 19). The mean catch of all stations combined in 2015 is above the long-term mean of 103 (Table 20). There was high variability between stations as well (Table 22). 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 21). 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 19. Mean catch per trawl of selected adult and juvenile fishes for all months at Station 9. 1988-2015

Year	All Spp.	White Perch	American Eel	Bay Anchovy	Spottail Shiner	Brown Bullhead	Channel Catfish	Tessellated Darter	Hogchoker
2015	17.5	1.6	0.0	0.5	0.2	0.2	0.2	0.0	0.0
2014	12.0	2.1	0.0	2.4	0.1	0.1	0.0	0.3	0.0
2013	13.4	1.7	0	1.8	0	0	0	0.2	0
2012	60.5	20.1	0.0	31.7	0.7	0.0	0.3	0.0	0.1
2011	34.0	21.3	0.1	0.0	0.2	0.1	6.4	0.2	0.0
2010	38.6	10.7	0.0	7.9	0.0	0.1	0.0	0.0	0.1
2009	40.4	15.2	0.0	8.6	0.5	0.2	0.7	0.1	0.4
2008	95.0	10.0	0.0	80.0	0.1	0.0	0.0	0.0	0.0
2007	253.8	195.7	0.0	0.7	1.1	0.0	0.0	0.9	0.0
2006	68.1	31.0	0.2	3.0	0.2	8.0	4.6	0.0	0.2
2005	91.1	36.5	0.0	12.1	1.8	2.2	4.7	0.1	0.1
2004	41.9	20.4	0.0	0.0	1.1	2.2	6.6	0.3	0.9
2003	62.5	29.9	0.1	0.0	0.6	2.1	14.1	1.2	6.6
2002	52.9	27.2	0.1	0.5	0.0	2.3	10.3	0.8	1.9
2001	68.0	35.4	0.2	19.6	0.1	0.8	4.8	0.7	1.1
2000	52.4	43.4	0.1	0.0	0.1	2.2	3.9	0.0	2.2
1999	23.1	19.1	0.1	0.3	0.0	0.3	2.4	0.0	0.9
1998	22.1	12.8	0.1	0.4	0.1	0.3	6.2	2.0	0.2
1997	49.6	37.2	0.2	0.0	1.1	0.3	9.2	0.4	0.3
1996	14.0	7.0	0.1	0.0	0.1	0.1	6.0	0.8	0.0
1995	31.9	17.4	0.3	0.2	0.2	4.3	8.5	0.1	0.5
1994	31.9	13.4	3.1	0.1	0.0	2.4	6.3	3.5	2.4
1993	31.3	6.8	1.6	0.0	6.6	1.3	5.5	7.9	1.3
1992	27.5	14.3	2.6	0.0	0.0	1.3	1.6	0.8	6.6

1991	67.9	42.4	0.4	1.9	0.1	1.0	13.2	0.4	6.3
1990	101.5	50.6	1.0	0.0	0.1	5.3	39.9	0.1	4.0
1989	14.3	7.9	0.2	0.4	0.0	1.5	2.0	0.3	0.2
1988	19.3	5.3	0.0	11.5	0.0	0.0	0.8	0.0	0.5

Table 20. Mean catch per trawl of selected adult and juvenile fishes for all months at Stations 7, 9, and 10 combined. 1984-2015.

Year	All Spp.	White Perch	Blueback Herring	Alewife	Gizzard Shad	Bay Anchovy	Spottail Shiner	Brown Bullhead	Channel Catfish
2015****	175.9	102.5	15.5	6.4	0.1	0.3	38.1	0.1	0.1
2014*	73.8	34.3	2.0	2.7	0.1	2.6	0.3	11.2	0.0
2013***	105.6	63.4	0	0	0.2	1.6	20.1	0.4	0.1
2012*	119.8	84.6	0.0	0.2	0.3	13.0	7.4	0.4	0.2
2011**	73.5	35.6	0.6	0.1	0.1	0.0	12.9	0.1	2.3
2010*	220.0	141.5	0.1	3.6	1.2	2.9	3.3	0.3	0.0
2009	76.2	17.9	0.9	31.9	0.4	7.2	2.0	0.2	0.4
2008	78.8	14.1	0.0	0.1	2.7	26.8	1.7	0.4	0.0
2007	236.1	159.5	16.6	11.6	0.1	10.7	13.8	0.1	0.0
2006	38.3	16.1	1.0	0.4	0.1	2.4	1.9	2.9	1.5
2005	75.7	28.3	7.5	15.8	0.6	4.3	4.6	1.0	1.8
2004	240.9	19.8	187.6	19.5	0.5	0.3	4.8	0.8	2.2
2003	54.4	16.4	12.6	2.3	0.0	4.9	2.0	1.6	5.3
2002	71.7	19.6	6.6	19.0	0.1	10.6	0.4	1.3	4.6
2001	112.7	41.3	25.4	6.3	0.2	28.5	1.8	2.3	1.7
2000	64.1	51.1	2.4	1.3	1.7	1.1	0.9	2.1	1.4
1999	65.6	48.5	2.8	0.3	0.7	3.7	3.2	1.7	0.8
1998	62.8	46.9	1.5	0.4	0.4	2.6	4.5	0.7	2.1
1997	70.8	53.5	1.3	0.7	3.3	1.7	2.3	1.1	3.1
1996	36.7	25.9	1.6	1.1	0.3	0.1	1.7	0.4	2.0
1995	69.7	52.3	2.7	1.5	0.3	2.1	2.0	2.7	2.9
1994	73.2	50.1	0.5	0.0	0.1	0.4	4.3	2.9	2.2
1993	167.8	140.4	0.9	0.4	0.9	0.4	6.8	3.3	1.8
1992	88.5	62.3	0.2	0.0	0.6	0.6	1.7	8.6	0.5
1991	103.8	73.6	0.6	0.4	5.2	2.4	1.9	8.4	4.7
1990	82.4	39.1	14.6	2.2	0.1	0.8	0.8	8.4	13.3
1989	57.1	12.6	11.0	0.3	28.4	0.3	0.3	2.5	0.7
1988	85.7	39.8	9.7	7.6	11.0	8.7	1.6	4.6	0.3
1987	106.7	54.3	16.1	3.5	5.6	8.8	0.7	15.1	0.0
1986	124.6	65.4	1.9	24.0	4.1	4.2	0.5	18.4	0.0
1985	134.4	43.2	13.5	12.4	2.9	48.1	0.9	9.6	0.0
1984	202.6	133.3	6.6	0.6	13.4	8.0	1.6	35.0	0.1

*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.

Table 21. The number of trawls per station in each month at Stations 7, 9, and 10 in each year

Year	Station	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	7	0	0	1	2	2	2	2	1	0	0	0
2015	9	0	0	1	2	2	2	2	1	0	0	0
2015	10	0	0	1	1	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	0	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	1	0	0	0	0	0
2009	7	0	0	1	2	2	2	2	1	0	0	0
2009	9	0	0	1	2	2	2	2	1	0	0	0
2009	10	0	0	1	2	2	2	2	1	0	0	0
2008	7	0	0	1	2	2	2	2	1	0	0	0
2008	9	0	0	1	1	2	1	2	1	0	0	0
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	0	1	2	2	1	1	1	0	0
2003	9	0	1	2	1	2	2	1	1	1	1	1
2003	10	0	0	0	1	2	2	1	1	0	1	0
2002	7	0	1	2	1	2	2	2	2	1	0	1
2002	9	0	1	2	2	2	2	2	2	1	0	0
2002	10	0	0	2	2	2	2	2	2	1	0	0
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	2	2	1	1	0

Year	Station	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1999	7	0	1	2	2	2	2	2	2	0	1	1
1999	9	0	1	1	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	1	2	2	1	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	0	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	0	0
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	0	1	1	1	1	1	1	0	0
1990	10	0	0	1	1	1	1	1	1	1	0	0
1989	7	0	1	1	1	1	1	2	2	1	1	0
1989	9	1	1	1	0	0	1	2	2	1	1	0
1989	10	0	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	10	0	1	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	0	2	3	2	3	2	3	4	2	1
1984	10	0	1	2	4	2	3	2	3	4	2	1

Table 22. Mean catch per trawl of adult and juvenile fishes in all months at each station.

Year	Station 7	Station 9	Station 10
2015****	360.0	17.5	47.5
2014*	114.4	24.0	70.4
2013***	234.2	12.2	30.2
2012*	217.7	60.5	21.2
2011**	114.0	34.0	72.2
2010*	615.6	38.6	5.8
2009	142.8	40.4	45.3
2008	50.1	95.0	91.3
2007	390.1	253.8	64.4
2006	40.7	68.1	6.2
2005	104.6	91.1	21.4
2004	658.2	41.9	22.4
2003	61.3	62.5	39.4
2002	91.2	52.9	70.9
2001	157.9	68.0	112.1
2000	95.1	52.4	44.8
1999	117.2	23.1	56.6
1998	88.3	22.1	78.1
1997	111.5	49.6	51.4
1996	64.5	14.0	31.5
1995	107.6	31.9	69.6
1994	122.3	31.9	62.1
1993	354.9	31.3	109.2
1992	155.5	27.5	70.2
1991	173.9	67.9	73.6
1990	77.3	101.5	68.4
1989	52.6	14.3	104.3
1988	95.8	19.3	96.2
1987^{+}	84.3	-	131.9
1986^{+}	95.8	-	153.4
1985^{+}	122.6	-	146.1
1984^{+}	197.1	-	141.3

*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.$^{+}$Station 9 was not sampled from 1984-1987.

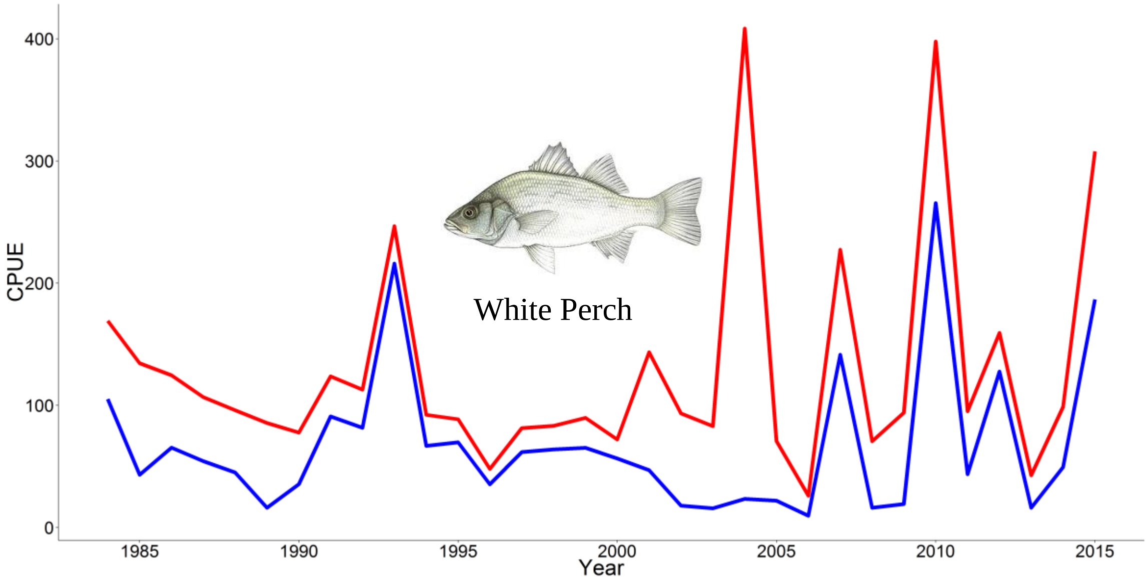


Figure 148. Trawls. Annual Averages. All Species (red) and White Perch (blue). Cove Stations 7 and 10. 1984-2015.

Mean total number of fish per trawl sample has remained steady over the course of the study; the pattern is highly dominated by catches of White Perch (Figure 148). 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.

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 2000 and 2005; and moderate to large proportion of the catch from 2005 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 148; Figure 149). Annual trends in other dominant species captured by the trawl survey are presented below.

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. Then after low catches since 2010, Blueback herring saw an increase again in 2015. These figures do not include the *Alosa* sp. not identified to the species level, so total numbers of river herring are higher than shown here.

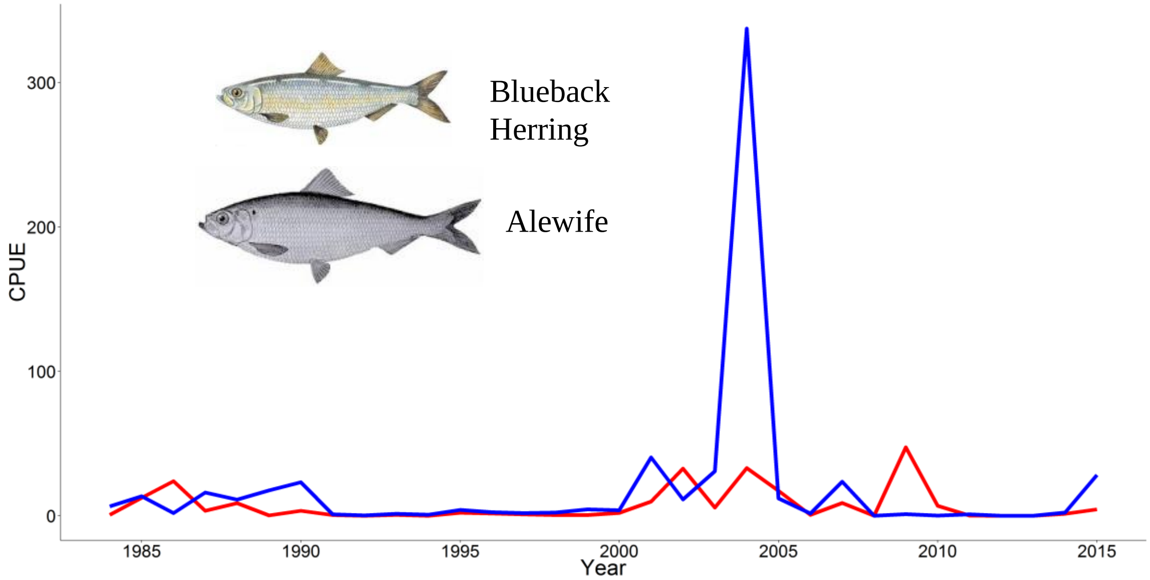


Figure 149. Trawls. Annual Averages. Blueback Herring (blue) and Alewife (red). Cove Stations 7 and 10.

Gizzard Shad catch rates in trawls in 2015 were low which contributes to a pattern of low abundance since 1992 (Figure 150). Bay Anchovy catch rates were a little lower than 2014 at inner cove stations, and trends in the data suggests a sinusoidal but 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 the sinusoidal trend continues, 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.

Spottail Shiner and sunfishes (Bluegill and Pumpkinseed) have been consistently collected in the majority of all trawl and seine samples (Figure 151). An increasing trend has been observed for Spottail Shiner since the beginning of the survey. In recent years (since 2000), a more sharply increasing pattern is seen in the midst of high variability, with high numbers in 2007, 2011, and 2014 (Figure 151). 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. The trends for sunfish show lower overall abundance, with a decrease in abundance after a 2008 peak.

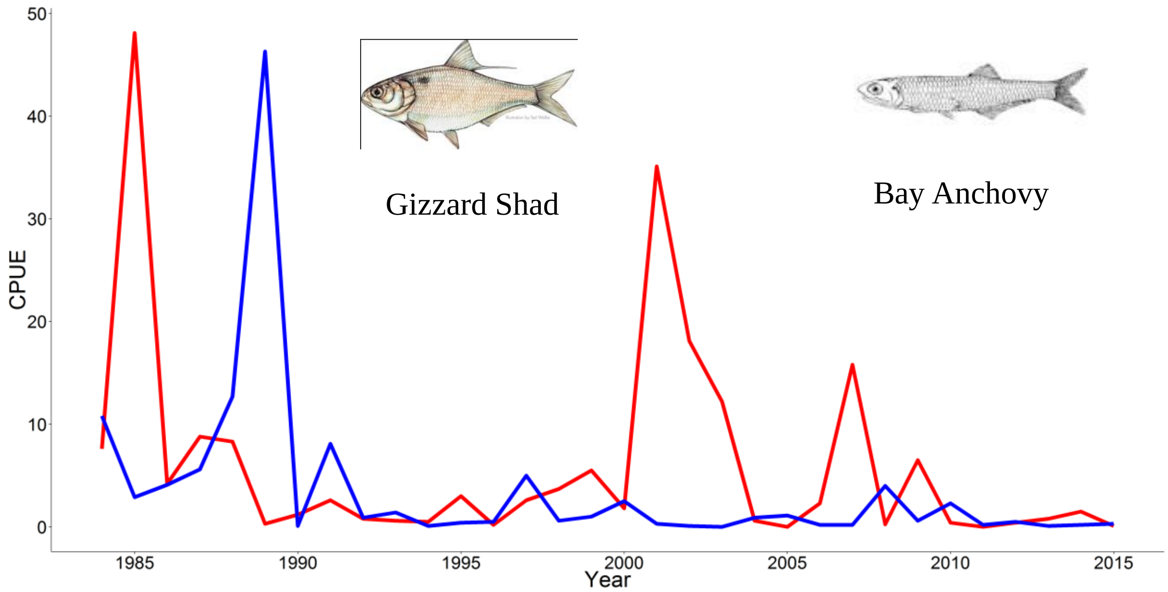


Figure 150. Trawls. Annual Averages. Cove Stations 7 and 10. Gizzard Shad (blue) and Bay Anchovy (red).

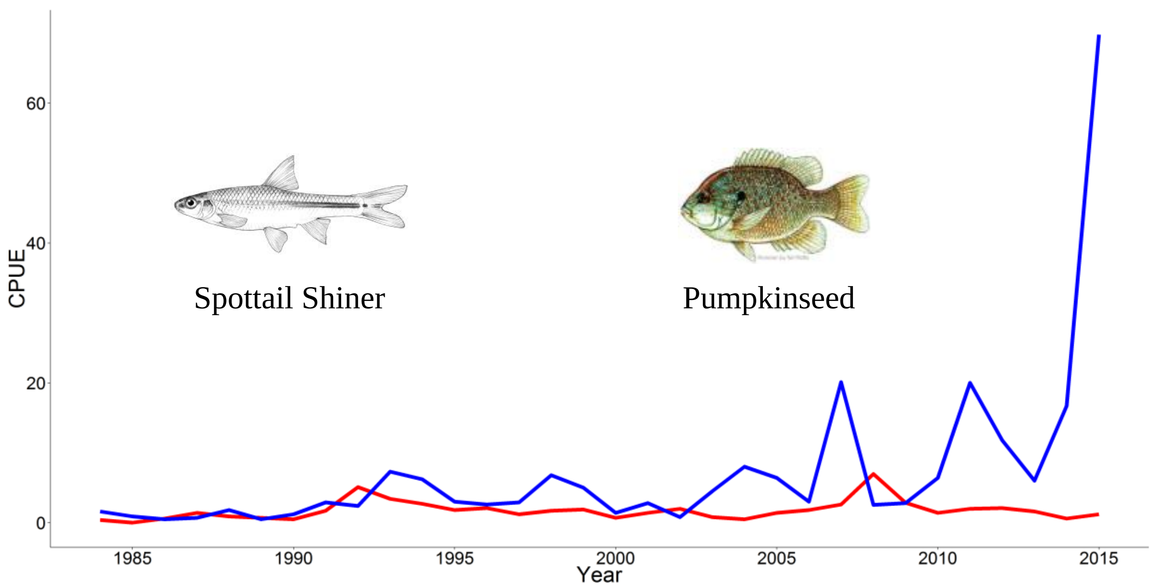


Figure 151. Trawls. Annual Averages. Spottail Shiner (blue) and Pumpkinseed (red). Cove Stations 7 and 10.

Very few Brown Bullhead specimens were captured in trawls in 2015, continuing a declining trend that has proceeded continuously since the start of the survey (Figure 152a). While we captured a relative high abundance of Brown Bullhead in fyke nets in 2014, possibly indicating a location shift in Brown Bullhead away from open water rather than extirpation of this species, we did not catch any Brown Bullheads in 2015 in the fyke nets. Since the fyke net catch is low and variable, further years will indicate if a small stable population remains in the inner Cove.

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 2015 again (Figure 152b).

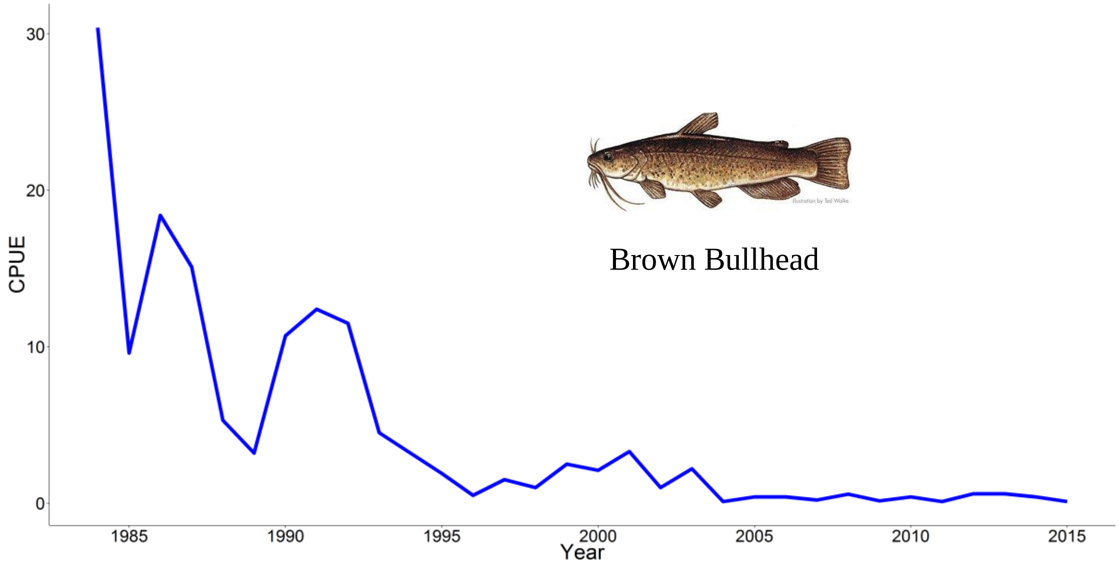


Figure 152a. Annual Averages. Brown Bullhead. Cove Stations 7 and 10.

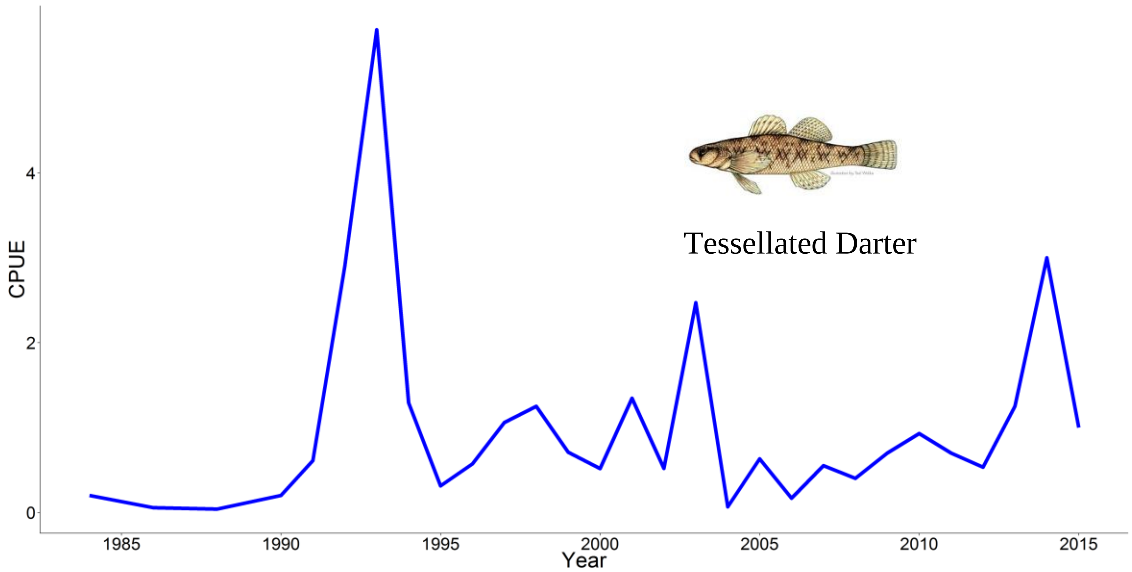


Figure 152b. Trawls. Annual Averages of Tessellated Darter (*Etheostoma olmstedi*). Cove stations 7 and 10.

At the river channel station (station 9), catches were higher than the last two years (Figure 153). The 2015 mean was pretty consistent with the period of record except for a peak in 2007, due to a high abundance of White Perch. As in the inner cove, much of the variation at station 9 is directly attributable to the catch of White Perch.

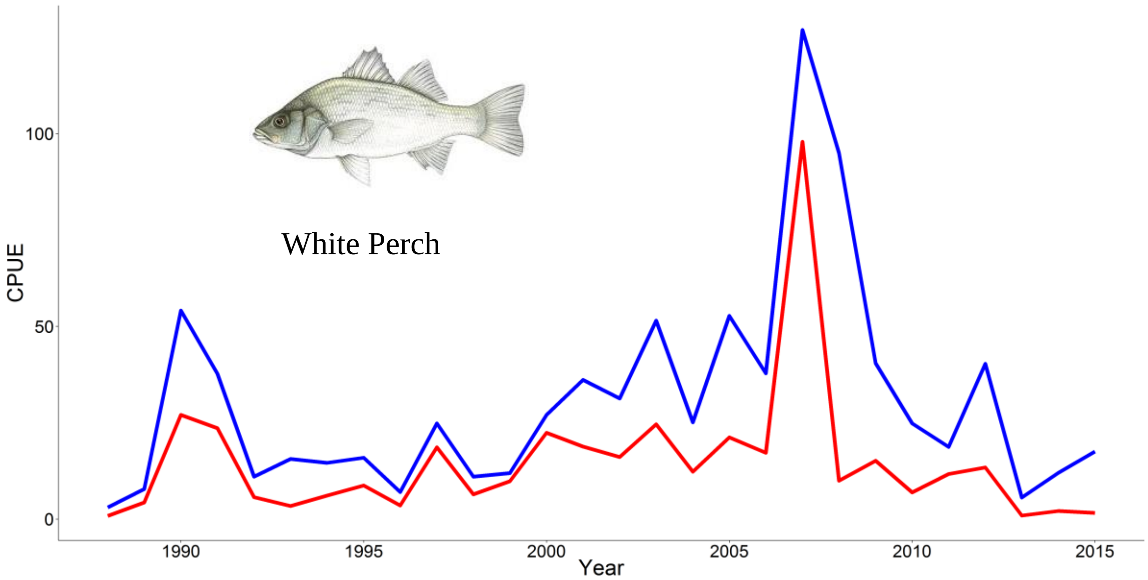


Figure 153. Trawls. Annual averages. River Station (9). Total catch (blue), White Perch (red).

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 154). We find high abundance of Bay Anchovy once every 5 years or so, and while abundance in 2014 was low, an overall increasing trend in Bay Anchovy abundances is observed (Figure 154). Spottail Shiner is found in low numbers every year at station 9, while American Eel has been rare since 1995.

Catch rates for native catfish species have been variable and low at station 9 since 2007 (Figure 155). Low catches were observed for Brown Bullhead and Channel Catfish again in 2015 (but Channel Catfish was present in the samples unlike last year). Long-term mean trends identify a decline in both Brown Bullhead and Channel Catfish (Figures 155). 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 155). 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 (Figure 155). 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.

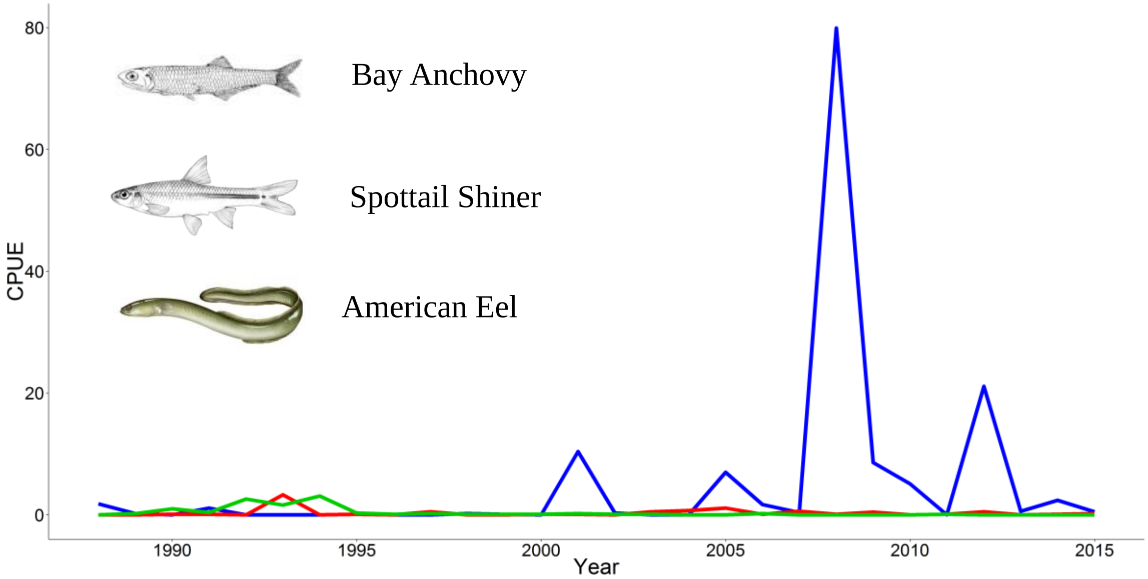


Figure 154. Trawls. Annual Averages. River Station (9). Bay Anchovy (Blue) Spottail Shiner (red) Americal eel (green).

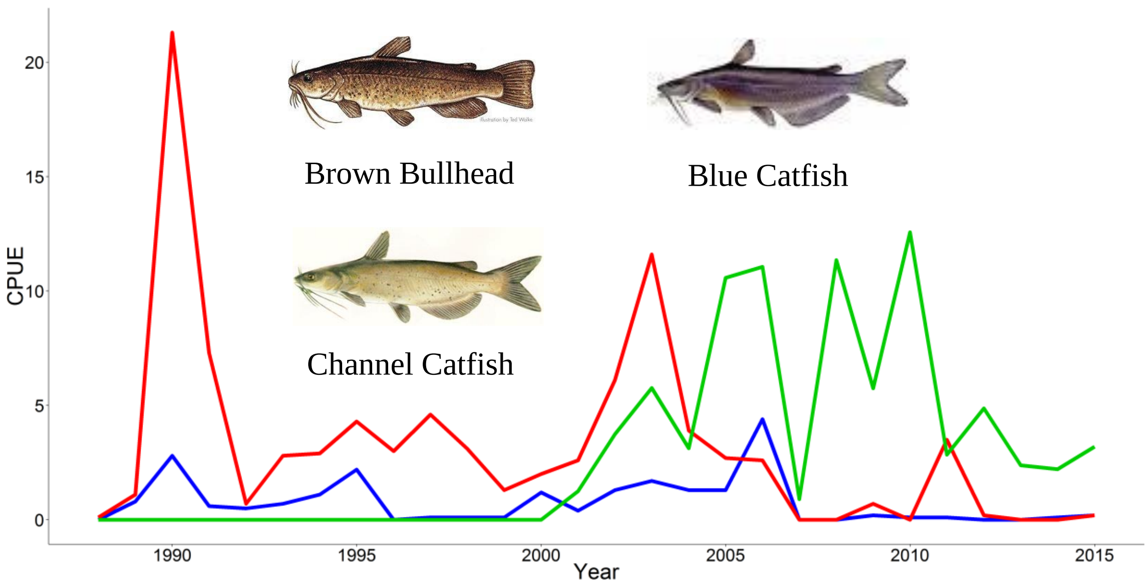


Figure 155. Trawls. Annual Averages. River Station (9). Brown Bullhead (blue), Channel Catfish (red), and Blue Catfish (green).

Station 9 represented low catch rates for the demersal species Tessellated Darter and hogchoker (Figure 156). While there was a small increase in mean catch of Tessellated Darter in 2014, high catches have not occurred since 2004 (Figure 156). The mean annual trend seems to indicate a general decline in catch rates for each of these species over the time-span of the survey (Figure 156).

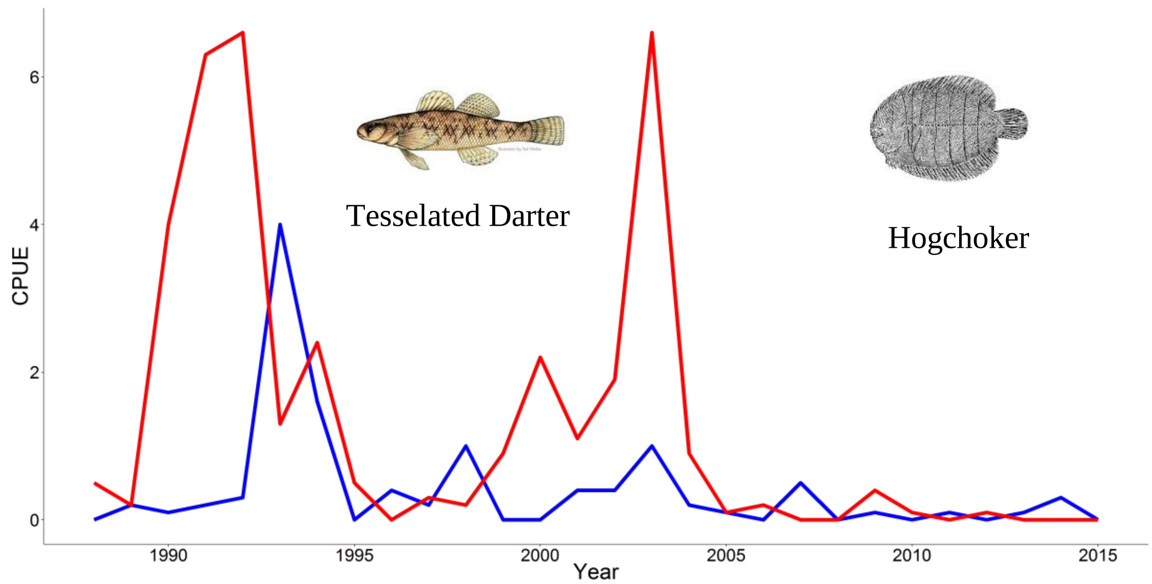


Figure 156. Trawls. Annual Averages. Tessellated Darter (blue) hogchoker (red). River Station (9).

Seines and fyke nets

Overall Patterns

Mean annual seine catch rates were generally higher than trawl catch rates. The long-term trend of seine catches shows a stable pattern of catches amidst inter-annual variability (Figures 157). The overall pattern shows a very slight increase in catches over the course of the survey (Figure 157). Of the three most abundant years high catches were due to a high abundance of alosines those years: 1994 and 2004 were driven primarily by large catches of Alewife, whereas high catch rates in 1991 were a result of high catch rates of Blueback Herring (Table 23). Overall, Banded Killifish and White Perch have been the dominant species in seine samples throughout the survey. In 2015 the general trend of decreasing White Perch catches and increasing Banded Killifish catches over the period of record seems to stabilize (Figure 158). 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. The number of seine tows over the period of record is shown in Table 24. Fyke nets collected less specimens than the previous years, and collections were dominated by Banded Killifish. Like previous years, the relative contribution of other species in fyke nets is different than collected with trawl or seine nets, and mainly represents SAV-associated species such as several species of sunfishes.

Table 23. Mean Catch per Seine of Selected Adult and Juvenile Fishes at all Stations and all Months. 1985-2015.

Year	All Spp.	White Perch	Banded Killifish	Blueback Herring	Alewife	Spottail Shiner	Inland Silverside
2015	176.2	34.0	78.3	0.5	0.4	5.3	4.8
2014	169.5	11.9	121.4	3.5	0.1	4.1	4.1
2013	120.2	8.4	94.8	0.0	0.0	0.4	0.8
2012	187.3	5.4	135.3	0.0	0.1	6.1	12.4
2011	148.5	32.3	80.2	3.5	0.7	2.5	1.6
2010	247.2	18.9	163.2	0.0	0.0	1.8	1.3
2009	169.9	22.5	61.3	0.3	0.2	4.2	9.0
2008	185.5	15.7	50.8	0.3	0.1	2.4	14.9
2007	113.4	10.6	32.2	8.0	2.6	3.6	2.6
2006	165.3	7.6	113.7	3.2	0.4	3.6	16.2
2005	230.4	45.3	139.9	1.2	6.7	10.7	6.6
2004	304.5	6.8	99.0	11.1	73.8	38.0	9.5
2003	97.9	6.8	43.3	2.4	3.0	6.7	3.2
2002	168.4	23.1	89.7	4.1	2.2	12.5	14.4
2001	131.6	29.5	53.4	0.4	4.8	14.0	7.4
2000	154.0	30.0	26.2	1.7	6.6	24.7	49.6
1999	100.6	17.1	17.6	13.5	0.4	11.4	23.0
1998	111.6	22.4	31.5	2.1	1.0	25.9	8.7
1997	119.2	19.1	36.0	27.7	0.8	5.0	13.7
1996	102.0	29.8	20.6	8.4	6.1	12.8	2.7
1995	66.4	20.6	7.0	1.6	2.0	5.5	10.5
1994	272.9	15.5	10.9	0.1	228.7	9.4	0.1
1993	61.5	6.9	20.0	2.8	1.7	8.9	8.8
1992	140.0	39.3	11.3	54.3	0.0	10.0	4.1
1991	249.1	38.1	24.1	97.0	0.2	26.0	8.5
1990	91.9	34.8	8.7	5.0	1.3	10.2	3.3
1989	131.9	47.9	8.1	2.4	0.6	9.9	2.1
1988	119.9	53.6	8.7	3.0	0.4	7.1	5.8
1987	91.9	41.9	6.0	0.1	0.0	9.1	13.8
1986	96.4	46.0	5.6	0.2	1.1	7.6	7.8
1985	96.7	50.2	0.6	0.4	0.4	12.3	14.7

Table 24. The number of seines in each month at Station 4, 4B, 6, and 11 in each year. 1985-2015.

Year	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
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	2	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	0	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	2	3	2	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	3	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	0	0	0	1	2	0	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
2006	4B	0	0	0	1	2	1	0	0	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

Year	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
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	1	1	1	1	1
2003	6	0	0	1	1	2	2	2	1	1	1	1	1
2003	11	0	0	1	2	2	2	2	1	1	1	0	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	0
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	2	2	2	1	1	0
1999	4	0	0	1	2	2	2	2	2	2	1	1	1
1999	6	0	0	1	2	2	2	2	2	2	1	1	1
1999	11	0	0	1	2	2	2	2	2	2	1	1	0
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	0
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	1	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	0
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	2	2	1	0
1994	4	0	0	0	0	1	1	0	0	1	1	0	0
1994	6	0	0	1	0	1	1	0	0	1	1	0	0
1994	11	0	0	1	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

Year	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
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	1	2	0	0
1986	6	1	1	0	1	1	1	0	0	2	1	0	0
1986	11	1	1	0	1	1	1	0	0	2	2	0	0
1985	4	0	0	0	0	0	0	0	1	1	1	2	0
1985	6	0	0	0	0	0	0	0	1	1	1	2	0
1985	11	0	0	0	0	0	0	0	1	1	1	2	0

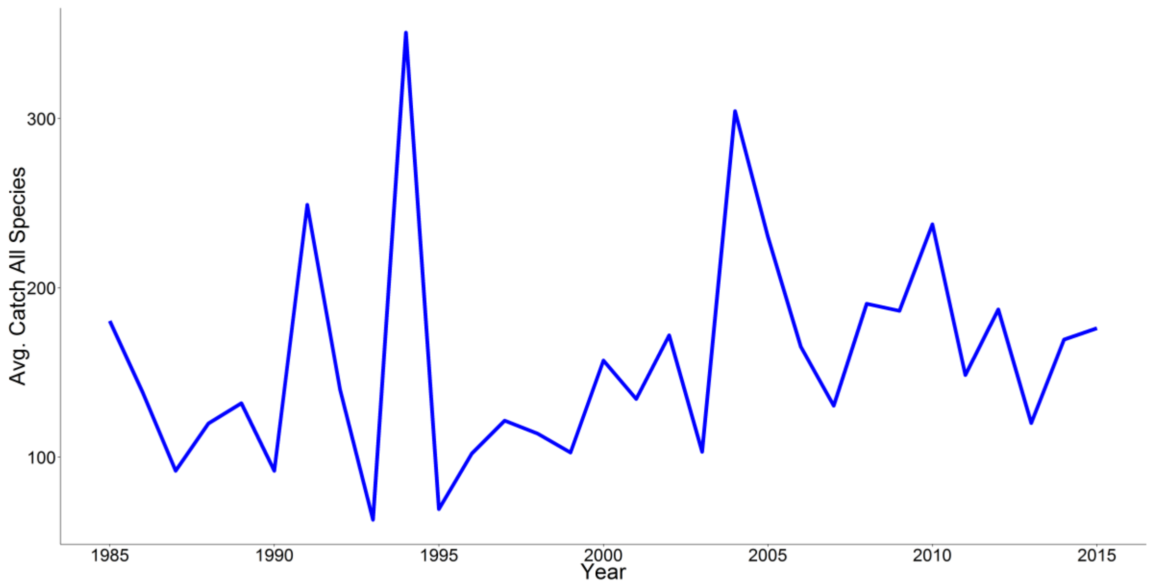


Figure 157. Seines. Annual Average over Stations 4, 4A, 6, and 11. All Species. 1985-2015.

Over the course of the survey mean annual seine catch rates of White Perch have exhibited a gradual decline (Figures 158). 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, 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, but also White Perch (Figure 63). Additional abundant species in the fyke nets in 2015 were Inland Silverside and Eastern Silvery Minnow. The state shift of the ecosystem to a SAV dominated system has resulted in a shift in the nekton community from open-water species to SAV-associated species.

The 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, and may be better at avoiding our gear amongst the SAV than Banded Killifish.

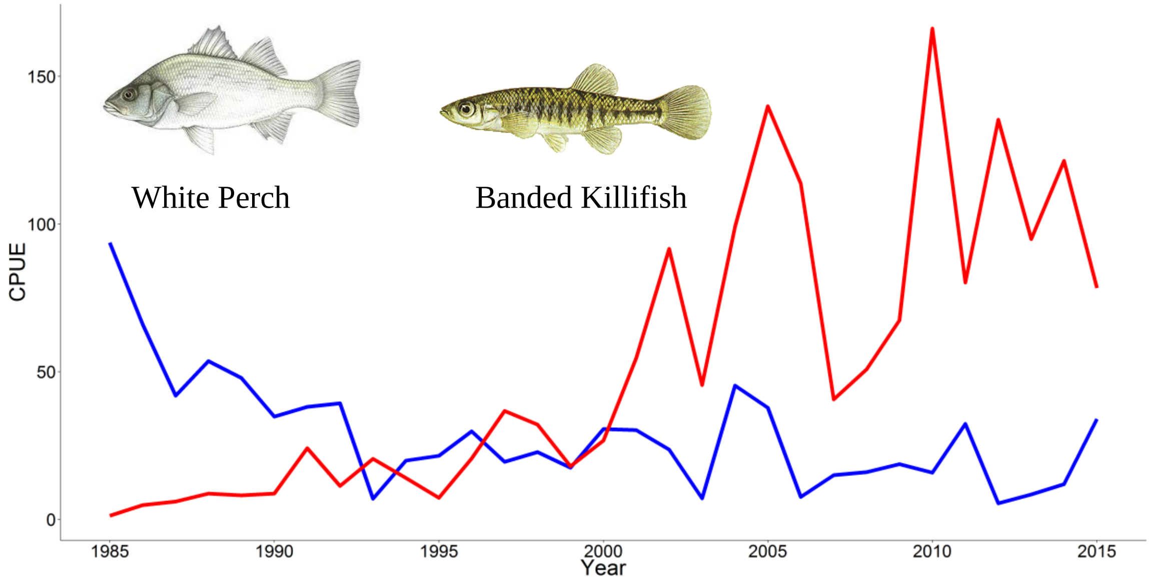


Figure 158. Seines. Annual Average Stations 4, 6, and 11. White Perch (blue) and Banded Killifish (red). 1985-2015.

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 158). Mean catches from both species in 2015 may indicate a stabilization of these diverging trends.

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. Although especially Blueback Herring has been collected in Gunston Cove in 2015, the numbers are not large enough to consider this a recovery. 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 Anadromous Report, could signal the start of the recovery of these species.

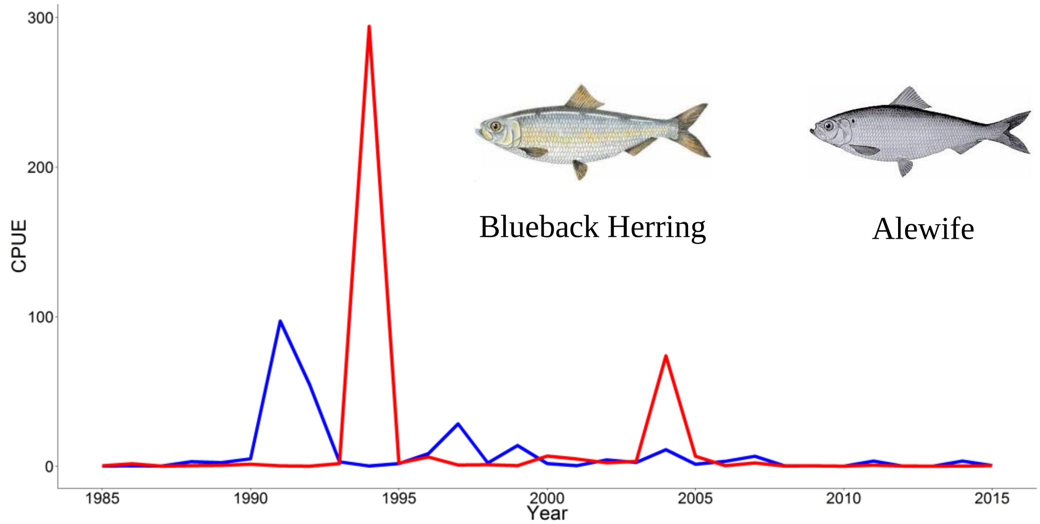


Figure 159. Seines. Annual Average over 4, 4A, 6, and 11 Stations. Blueback Herring (blue) and Alewife (red). 1985-2015.

Owing to their affinity for marginal and littoral zone habitats, Spottail Shiner and Inland Silverside were consistently captured at moderate abundances throughout the course of the survey (Figure 160). Although a few high abundance years (1985, 1991, 1998, 2000, and 2004) have occurred, a general declining trend in catches since 2000 was present (Figure 160). While the fyke nets did capture a high proportion of Spottail Shiner in 2014, only one was collected in 2015. Unlike last year, Inland Silverside had a higher abundance in the fyke nets. With the variable record within the SAV-beds as represented by the fyke net catches, and a high proportion of Spottail Shiner the trawl collections in 2015, 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.

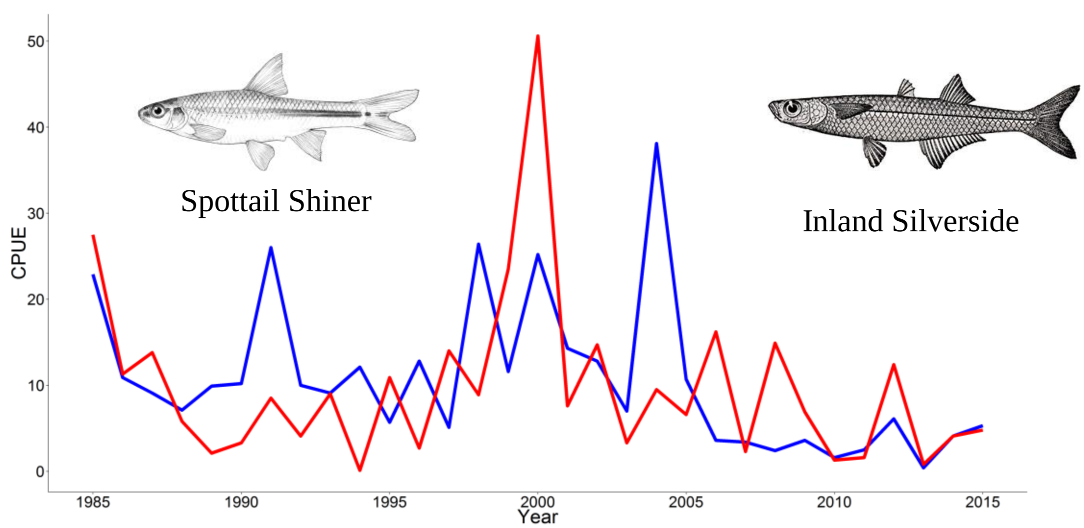


Figure 160. Seines. Annual Average over 4, 4A, 6, and 11 Stations. Spottail Shiner (blue) and Inland Silverside (red). 1985-2015.

Long-term Species Composition Changes

The species composition and community structure is 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. The 2012 report included results of a community analysis that showed in more detail how community composition changes in relation to increases in SAV cover. 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 collected Brown Bullhead in the fyke nets in 2014, but not in 2015. 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 Blueback Herring and Alewife (the two river herring species) in the trawl samples in 2015 could be an indication of the start of a recovery since a moratorium on fishing was imposed in 2012. The large estimated size of the spawning populations of Blueback Herring and Alewife in Accotink Creek and Pohick Creek, as reported in the Anadromous Report, could be the start of increasing numbers in years to come.

Summary

The sampled ichthyoplankton was dominated by clupeids, most of which were *Dorosoma* sp. (Gizzard Shad), but a relatively high density of river herring (Alewife and Blueback Herring) was present as well. *Morone* larvae (White Perch and Striped Bass) were found in low densities, which is unusual, although it does not mean the population has decreased as we found high abundances of juveniles and adults in 2015. A non-Clupeid species that was found in relatively high densities in the ichthyoplankton samples was Inland Silverside. Other taxa were found in low numbers similar to previous years. The highest density of fish larvae occurred in mid-May, which is slightly earlier than usual (typically the peak is late May). This peak was driven by a high density of Clupeid larvae.

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 that was included in the report in 2012.

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. Since 2013, fyke nets have been set at all sampling dates from May to September.

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. 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 did see higher numbers of juvenile Blueback Herring and Alewife in trawls in 2015. 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: 1994-2015

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 1994-2015 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 continued to decline in 2015 and that Secchi depth reached an all-time high. These values reflect the sustained partial recovery of Gunston Cove from eutrophication.

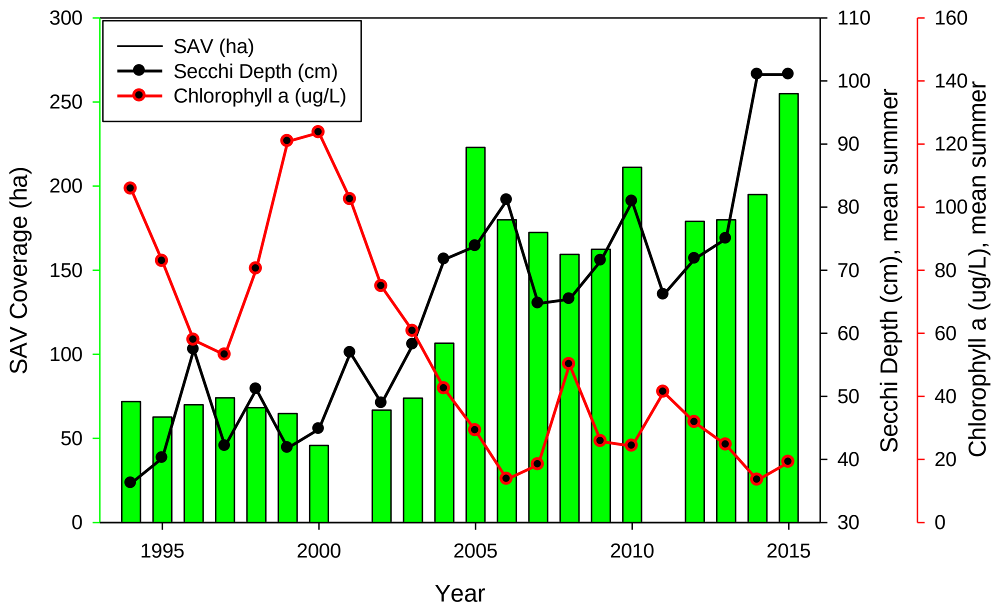


Figure 163. Inner Cove SAV Coverage. Graphed with average summer (June-September) Depth-integrated Chlorophyll a (µg/L) and Secchi Depth (cm) measured at Station 7 in Gunston Cove. (2014 and 2015 values are estimates).

H. Benthic macroinvertebrates

Benthic invertebrates have been monitored in a consistent fashion for the last 7 years. Those data are assembled below (Table 26) 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. Isopods have been commonly found in the river since 2010 and sporadically in the cove. 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 26. Benthic macroinvertebrates: annual averages (#/petite ponar)

	Station 7 (#/petite ponar)			Station 9 (#/petite ponar)		
Taxon	2009-13 Avg	2014	2015	2009-13 Avg	2014	2015
Oligochaeta	46.2	26.1	45.1	69.6	9.7	98.2
Amphipoda	1.6	1.7	4.4	23.5	32.6	33.9
Chironomidae	39.5	2.3	3.7	1.3	0.4	5.3
Corbicula	0.1	--	0.9	8.4	--	3.9
Gastropoda	0.4	--	11.9	5.2	--	12.4
Isopoda	0.02	0.1	0.7	1.9	1.7	6.4
Turbellaria	0.1	0.0	0.7	0.7	2.9	6.3
Hirundinea	0.4	0.2	0.6	0.2	1.2	0.1
Total	88.7	30.4*	68.2	111.1	48.5*	217.1

For 2009-10, n=8 per station; for 2011-12, n=6 per station; for 2013 and 2015, 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 2015

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 far 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 most recent 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 hoop 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 hoop 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 2015 sampling are presented below. A summary of historical results was provided in the 2007 annual report for this project; we now provide a summary of the data from 2008-2015 which shows the magnitude of change observed in 2015 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 hoop 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 2015 in Pohick Creek and Accotink Creek.

Methods

We conducted weekly sampling trips from March 20th to May 25th in 2015. 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 hoopnet 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 hoopnet remained in the same location. On one day each week, we sampled ichthyoplankton by holding two conical plankton net 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.

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) (Table 1).

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 blue back 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. For this report, we will include a summary of abundance of all clupeids we collected from 2008-2015.

The larval stages of two *Dorosoma* species are also extremely difficult to distinguish. However, only gizzard shad comes this far upstream, while treadfin 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 hoop net was deployed once each week in the morning and retrieved the following morning (see Figure 1). All fish in the hoop 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 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/240 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. Hoop net deployed in Pohick creek. The top of the hoop 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 2015 spanned a total of 10 weeks, during which we collected 40 ichthyoplankton samples, and ten adult (hoopnet) samples. We collected an unprecedented number of adult clupeids since the consistent hoopnet collection method started in 2008. The 2015 collections are three years after the establishment of a moratorium on river herring. 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 a high number of hickory shad specimens in Pohick Creek.

The abundance of *Alosa* larvae was a lower than last year (119 versus 266 last year). However, there were more unidentified clupeids (too mangled to identify), with 577 unidentified clupeids versus 125 last year, which could be *Alosa* (the other option would be *Dorosoma*; gizzard shad). We also collected 92 identified gizzard shad larvae. We discovered again that the *Alosa* larvae consisted of blueback herring and hickory shad larvae in addition to Alewife larvae (Table 1).

Table 1. Larval and adult abundances of clupeids collected in both creeks in 2015.

	Pohick Creek		Accotink Creek	
Clupeid species	# larvae	# adults	# larvae	# adults
Alewife	43	635	52	372
Blueback Herring	2	962	12	3
Hickory Shad	8	209	2	0
Gizzard Shad	25	130	67	67
Unknown Clupeid	502	1	75	0

Same as we found last year, *Dorosoma cepedianum* (gizzard shad) larvae are not the most abundant anymore.

We measured creek discharge at the same locations and times where ichthyoplankton samples were taken. Discharge was much more variable this year in Accotink Creek than Pohick Creek and ranged from 0.05 to 5.50 $m^3 s^{-1}$, while Pohick Creek ranged from 1.32 to 3.85 $m^3 s^{-1}$ (Figure 2). On average and as in previous years, the discharge in Accotink Creek was lower than in Pohick Creek, with 1.21 $m^3 s^{-1}$ in Accotink Creek and 1.86 $m^3 s^{-1}$ in Pohick Creek. During the 70 day sampling period (which coincides with the river herring spawning period), the total discharge was estimated to be on the order of 7 and 11 million cubic meters for Accotink and Pohick creeks, respectively (Table 2).

Larval density of alewife exhibited a peak in Accotink Creek in early May (Figure 3a). larval densities in Pohick creek were lower and showed two small peaks in early April and in early May. Given the observed mean densities of larvae and the total discharge, the total production of alewife larvae was estimated at close to 2 and 1 million for Accotink and Pohick creeks, respectively (Table 2). Blueback herring larval density was lower leading to total larval production estimates of 240 and 160 thousand for Accotink and Pohick creeks, respectively.

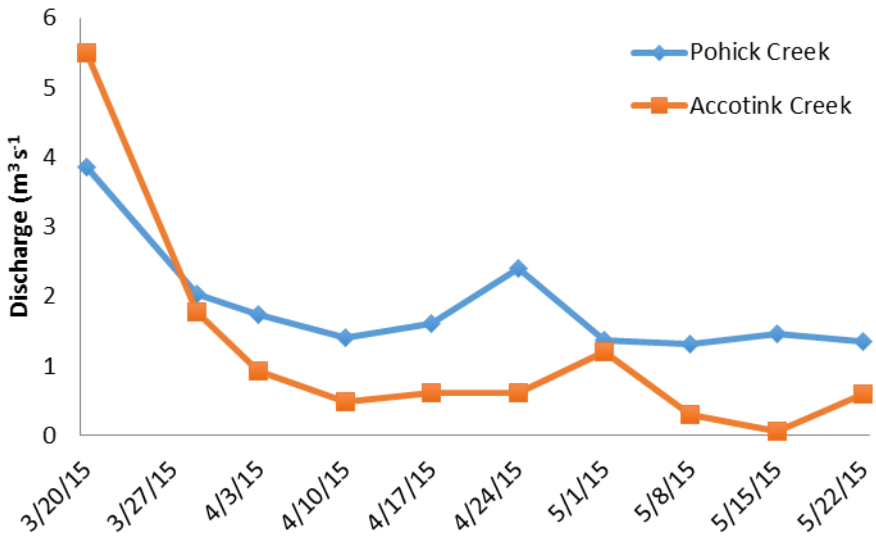

Figure 2. Discharge rate measured in Pohick and Accotink creeks during 2015.

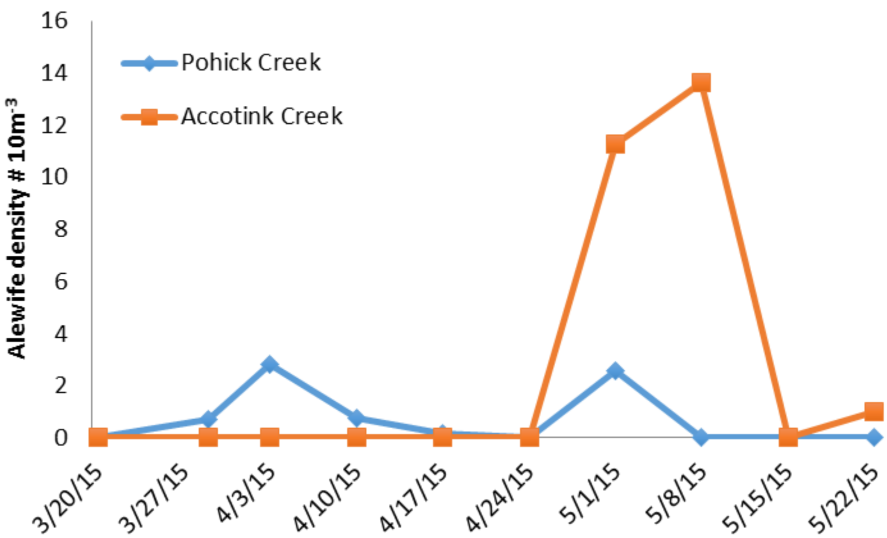

Figure 3a. Density of larval alewife in # 10 m^{-3} observed in Pohick Creek and Accotink Creek in 2015.

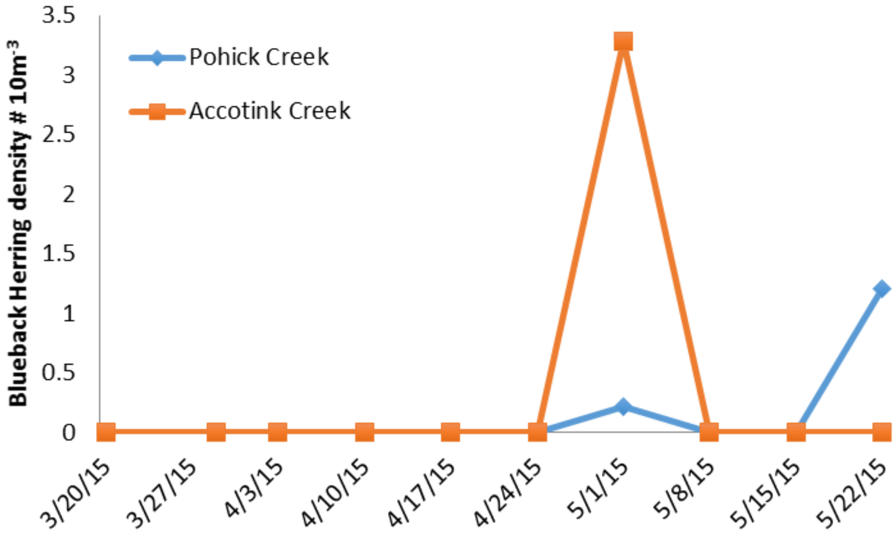

Figure 3b. Density of larval blueback herring in # 10 m^{-3} observed in Pohick Creek and Accotink Creek in 2015.

In the hoop net sets, an unprecedented high number of adults were captured in recent years for both alewife and blueback herring; 1007 and 965 respectively. Of those captured, 450 alewife and 76 blueback herring were sexed, providing us with sex ratios (Table 2). Skewed sex ratios in fish populations are common. The total abundance of spawning alewife was estimated to be 4445 in Pohick Creek during the period of sampling, and 2604 in Accotink Creek. The size of the spawning population of blueback herring is estimated to be 21 in Accotink Creek and 6734 in Pohick Creek this year. The contrast with the recent period of record can be seen in Table 3, which shows a summary of adult clupeid abundance collected in hoop nets from 2008-2015.

Table 2. Estimation of alewife and blueback herring fecundity and spawner abundance from Accotink and Pohick creeks during spring 2015.

	Accotink Creek	Pohick Creek
Mean discharge (m^3 s^{-1})	1.21	1.86
Total discharge, 3/20 to 5/22 (m^3)	7,318,080	11,249,280
Alewife		
Mean density of larval alewife (10 m^{-3})	2.59	0.70
Total larval production	1,895,383	787,450
Adult alewife mean standard length (mm)	245	227
Alewife fecundity	80,569	68,289
Sex ratio (proportion female)	0.1	0.25
Estimated number of female alewife	260	1111
Estimated total number of alewife	2604	4445
Blueback herring		
Mean density of larval blueback (10 m^{-3})	0.33	0.14
Total larval production	241,497	157,490
Blueback mean standard length (mm)	218	219
Blueback herring fecundity	62,149	62,832

Sex ratio (%F)	0.24*	0.24
Estimated # of female blueback herring	5	1616
Estimated total # of blueback herring	21	6734

*No female blueback herring were caught in Accotink Creek, therefore the same sex ratio as estimated for Pohick Creek was used.

Table 3. Total adult catch per year using hoopnets for 10 weeks during the spawning season of river herring of five the Clupeid species that occur in this area.

	Pohick Creek				Accotink Creek			
	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	33	2	0	0	7	4
2010	0	31	130	9	0	0	79	4
2011	5	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	27	6	52	21	0	1	8	28
2015	962	209	635	130	3	0	372	67

Discussion

We caught 1007 alewife and 965 blueback herring; we have positively identified blueback herring in this survey since 2011. We also collected 209 hickory shad. These numbers are all an order of magnitude higher than what we have observed since at least 2008. The estimated size of the spawning population of both blueback herring and alewife are in the thousands of fishes for the first time in years. The fact that the exceptionally high number of adults did not coincide with a corresponding increase in larvae, underscores the importance of collecting adults to estimate the size of the spawning population, instead of basing all estimates on the collection of larvae. Only the blueback herring spawning population in Accotink Creek was estimated to be small (21 individuals). 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 earlier in the season than Accotink Creek. It is possible that the blueback herring spawning season is actually taking place slightly later in Accotink Creek, rather than that the spawning population is smaller. Our sampling regime has been matched with the spawning season of alewife when the understanding was that blueback herring does not use this area to spawn (the first blueback herring were identified in 2011). Continuing sampling into the summer would resolve whether the size of the blueback herring spawning population in Accotink Creek is small, or if the peak of the spawning period is simply taking place later. A spawning population of blueback herring has at least firmly established in 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 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. 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 in 2015; some surveyors even reported declines (De Mutsert, personal communication). 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. This while the habitat in the Gunston Cove watershed is of suitable quality to support a larger spawning population now that reduced fishing pressure allows for more adults to return to their natal streams. Additional stressors could play a role in the variable success so far of the moratoria; while targeted catch of river herring is prohibited, river herring is still a portion of by-catch, notably of offshore midwater trawl fisheries (Bethoney et al. 2014). For the Gunston Cove watershed, 2015 certainly was a highly productive year. While it is too soon to tell whether this is a lasting effect of the moratorium, continued monitoring will determine whether the higher abundances will be maintained in subsequent years.

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