THE ONGOING AQUATIC MONITORING PROGRAM

FOR THE GUNSTON COVE AREA

OF THE TIDAL FRESHWATER POTOMAC RIVER

2012

FINAL REPORT
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by

R. Christian Jones
Professor
Department of Environmental Science and Policy
Director
Potomac Environmental Research and Education Center
George Mason University
Project Director

&

Kim de Mutsert
Assistant Professor
Department of Environmental Science and Policy
George Mason University
Co-Principal Investigator

to

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

INTRODUCTION

This section reports the results of the on-going aquatic monitoring program for Gunston Cove conducted by the Potomac Environmental Research and Education Center at George Mason University and Fairfax County's Environmental Monitoring Branch. This study is a continuation of work originated in 1984 at the request of the County's Environmental Quality Advisory Committee and the Department of Public Works. The original study design utilized 12 stations in Gunston Cove, the Potomac mainstem, and Dogue Creek. Due to budget limitations and data indicating that spatial heterogeneity was not severe, the study has evolved such that only two stations are sampled, but the sampling frequency has been maintained at semimonthly during the growing season. This sampling regime provides reliable data given the temporal variability of planktonic and other biological communities and is a better match to other biological sampling programs on the tidal Potomac including those conducted by the Maryland Department of Natural Resources and the District of Columbia. 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 Elaine Schaeffer, Michael Mueller, and Shahran Moshsenin for their advice and cooperation during the study. 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. Thanks go to Alex Graziano, Natalia Ainsfield, Beverly Bachman, Alex Graziano, Lara Isdell, Saiful Islam, Julie McGivern, Mahdi Mojarrad, Kristyn Moskey, Chris Ruck, Amanda Sills, Catherine Schlick, Tunde Adebola, Peter Jacobs and Joris van der Ham. Claire Buchanan served as a voluntary consultant on plankton identification. Roslyn Cress and Joanne Anderson 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.

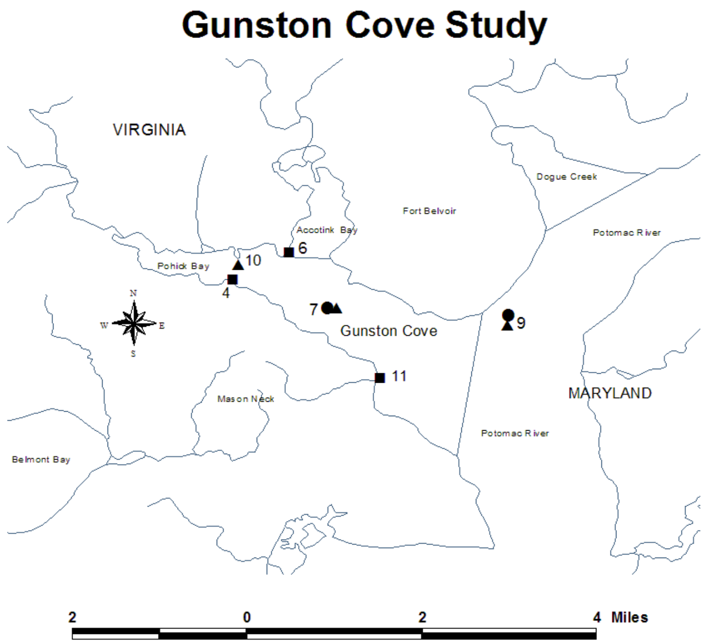


Figure 1a. Gunston Cove area of the Tidal Potomac River showing sampling stations. Circles (●) represent Plankton/Profile stations, triangles (▲) represent Fish Trawl stations, and squares (■) represent Fish Seine stations.

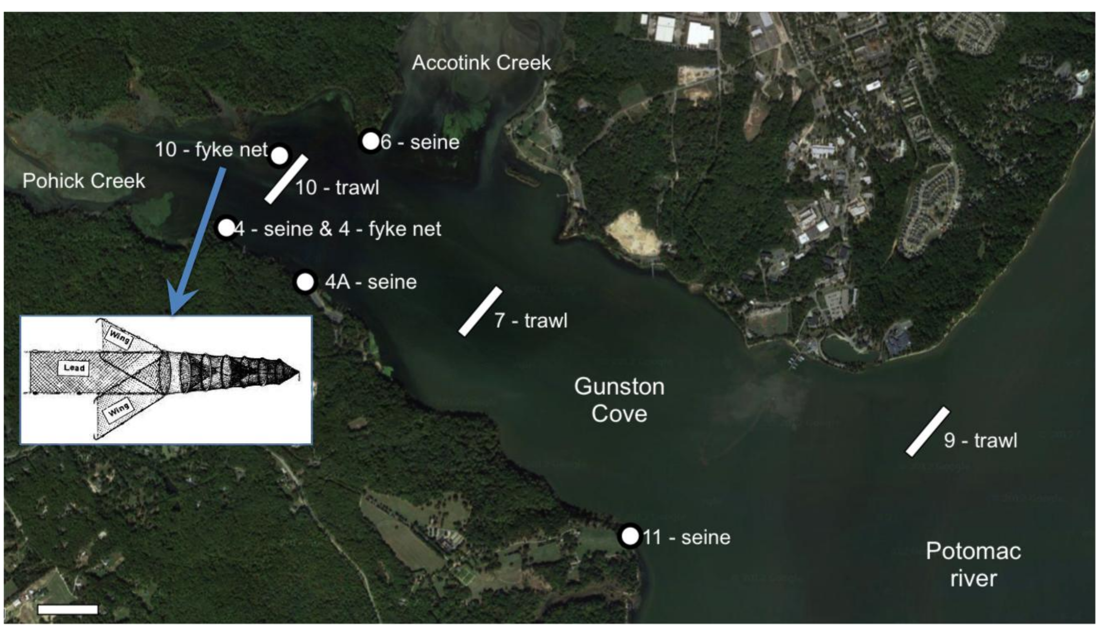


Figure 1b. Fish sampling stations including location and image of the fyke nets.

Table 1
Sampling Dates and Weather Data for 2012

	Type of Sampling					Avg Daily Temp (^oC)		Precipitation (cm)	
Date	G	F	T	S	Y	1-Day	3-Day	1-Day	3-Day
April 19		F*				16.1	17.0	T	0.15
April 23			T	S		7.8	13.3	0.25	3.89
April 24	G	F				11.7	10.2	0	3.48
May 7			T	S		18.3	20.4	0	0.03
May 8	G	F				20.0	19.3	0.08	0.09
May 22			T	S		23.3	22.0	0.03	0.13
May 23	G					23.3	22.8	0.79	0.89
June 4			T	S		20.6	20.4	0	T
June 5	G	F				18.3	19.8	T	T
June 19	G	F				26.1	22.2	0	0.71
June 22			T	S	Y	30.0	30.6	T	T
June 28			F*			28.3	25.4	0	0
July 9			T	S	Y	27.2	31.3	0.66	2.41
July 10	G	F				27.2	28.9	1.52	3.94
July 23			T	S	Y	28.3	24.4	T	0.55
July 24	G					28.9	27.2	T	T
August 6			T	S	Y	30.0	30.7	0.05	0.13
August 7	G	F				28.9	30.0	T	0.14
August 20			T	S	F	24.4	24.4	T	1.33
August 21	G					24.4	24.1	1.50	2.43
August 22		F*				25.0	24.6	0.89	2.40
Sept 10			T	S	Y	20.6	22.8	0	1.24
Sept 11	G	F				20.0	20.7	0	0
Sept 25		F*				18.3	17.6	0	0

Type of Sampling: 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.
*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, and dissolved oxygen were conducted at each station using a YSI 6600 datasonde with temperature, conductivity, dissolved oxygen and pH probes. 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 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 preserved immediately with formalin to a concentration of 5-10%. Rose bengal formalin with club soda pretreatment was used for macrozooplankton, but for ichthyoplankton only clear formalin was used. 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. In 2011 triplicate petite ponar samples were collected at the cove (Station 7) and river (Station 9) sites on three dates (May 23, June 21, and July 19).

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 fluroometrically 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:

$$\text{Chlorophyll } a\ (\mu g/L) = F_s R_s (R_b - R_a)/(R_s - 1)$$

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:

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

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 samples were sieved through a 333 µm sieve to remove formalin and then reconstituted in ethanol. Larval fish were picked from the reconstituted sample with the aid of a stereo dissecting microscope. Identification of ichthyoplankton was made to family and further to genus and species where possible. If the number of animals in the sample exceeded several hundred, then the sample was split with a plankton splitter and the resulting counts were multiplied by the subsampling factor. The works 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:

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

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, 4A, 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, but most tows curved up to 90º from the initial heading and many turned enough to head in the opposite direction. 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 July and August. Due to this permanent recovery of the SAV cover in this location we have adjusted our sampling regime in 2012 by adding fyke nets.

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. 4A was added to the sampling stations since 2007 because extensive SAV growth interferes with sampling station 4 in late summer. Sampling near station 4 was continued with a fyke net (station 4-fyke; Figure 1B).

Due to the permanent recovery of the SAV cover in station 4 and station 10, we have adjusted our sampling regime in 2012. Fyke nets were set in station 4-fyke and station 10-fyke starting in June (Figure 1B). 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 had 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). The fyke nets are now a standard addition to our sampling routine, and will be set each fish sampling trip in 2013. Setting fyke nets when seining and trawling is still possible will allow for gear comparison.

After the catch from various gear types was hauled in, the fishes were measured for standard length and total length to the nearest 0.5 cm. 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. Total length is the distance from the tip of the snout to the tip of the longer lobe of the caudal fin, measured by straightening the longer lobe toward the midline.

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. The VIMS SAV program was not successful in obtaining reliable images of the Gunston Cove area in 2011, but was able to get imagery in 2012.

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

Data for each parameter were entered into spreadsheets (Excel or SigmaPlot) for graphing of temporal and spatial patterns. 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 2012 air temperature was substantially above average for most of the year. All months from March through August were at least 1.0°C greater than normal (Table 2). July was the warmest month and was 1.3°C above normal. There were 42 days with maximum temperature above 32.2°C (90°F) during 2012 compared with 4 in 2004, 18 in 2005, 29 in 2006, 33 in 2007, 31 in 2008, 16 days in 2009, 62 in 2010, and 42 in 2011. Precipitation was below normal from March through August, but well above normal in September and October. The largest rainfall in this fall period was in late October when Hurricane Sandy passed near the area.

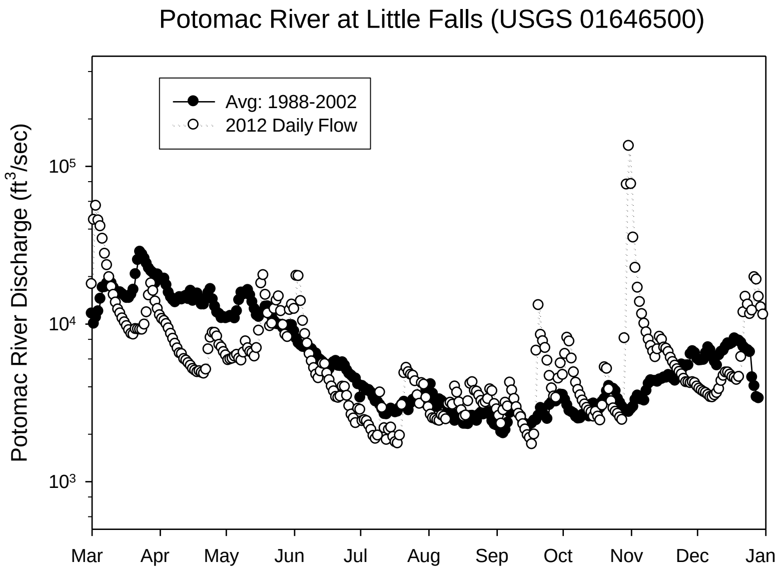
Table 2. Meteorological Data for 2012. National Airport. Monthly Summary.

MONTH	Air Temp (°C)		Precipitation (cm)	
March	13.8	(8.1)	2.6	(9.1)
April	14.6	(13.4)	4.9	(7.0)
May	21.9	(18.7)	8.3	(9.7)
June	24.6	(23.6)	6.0	(8.0)
July	28.9	(26.2)	7.1	(9.3)
August	27.2	(25.2)	7.1	(8.7)
September	22.3	(21.4)	10.9	(9.6)
October	16.1	(14.9)	14.8	(8.2)
November	8.1	(9.3)	1.5	(7.7)
December	7.6	(4.2)	7.7	(7.8)

Note: 2012 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. (+) 2012 month > 2x Long Term Avg. (-) 2012 month < ½ Long Term Avg.

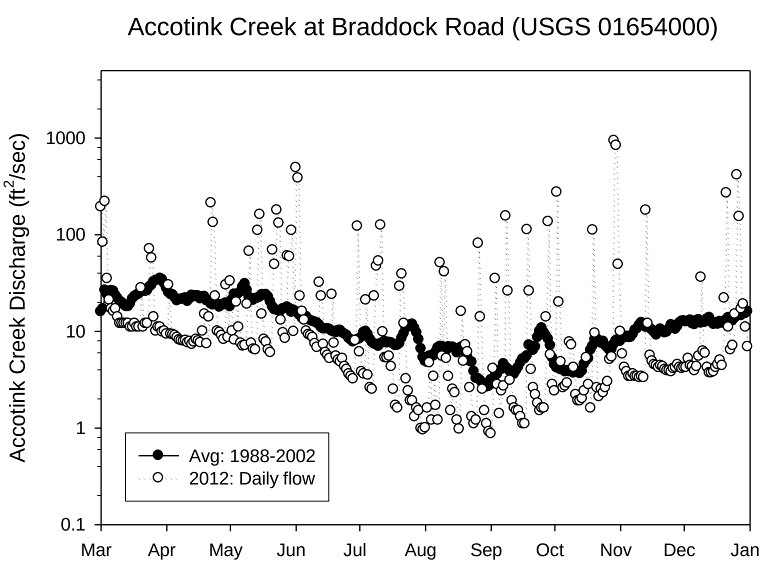
	Potomac River at Little Falls (cfs)		Accotink Creek at Braddock Rd (cfs)	
	2012	Long Term Average	2012	Long Term Average
January	16743	13700	30.8	31
February	9869	16600	24.9	35
March	14298	23600	31.9	42
April	7171 (-)	20400	21.7	36
May	9514	15000	39.4	34
June	6152	9030	41.9	28
July	2986	4820	13.6	22
August	3137	4550	8.7 (-)	22
September	4084	5040	18.5	27
October	10538	5930	74.6 (+)	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 2012 was generally below average from February through September, being particularly low in April and July (Table 2, Figure 2). The higher flows in October were the product of Hurricane Sandy. Accotink Creek flows were slightly below average for most of the year. During May and June, they were actually above normal owing to numerous rainfall events. August was well below normal and October well above normal.



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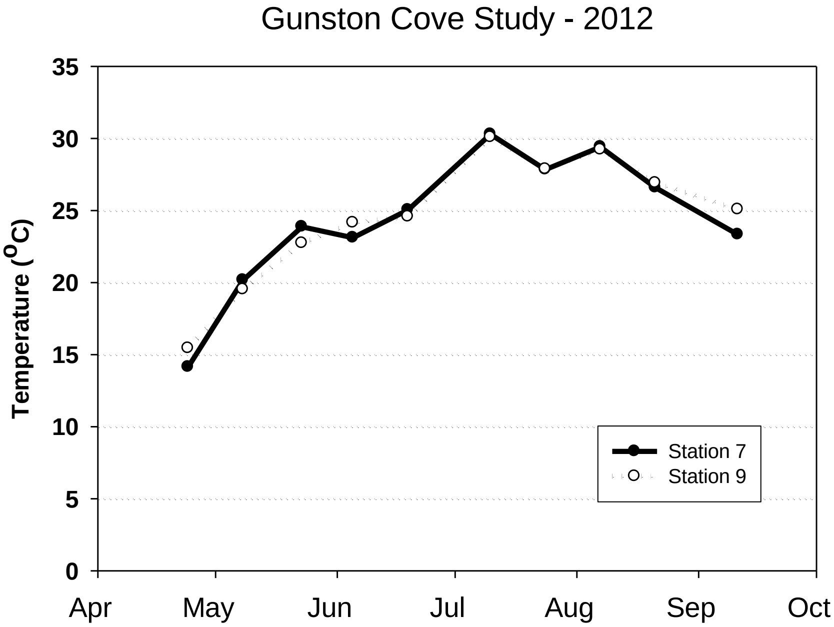
Figure 3. Mean Daily Discharge: Accotink Creek at Braddock Road (USGS Data).

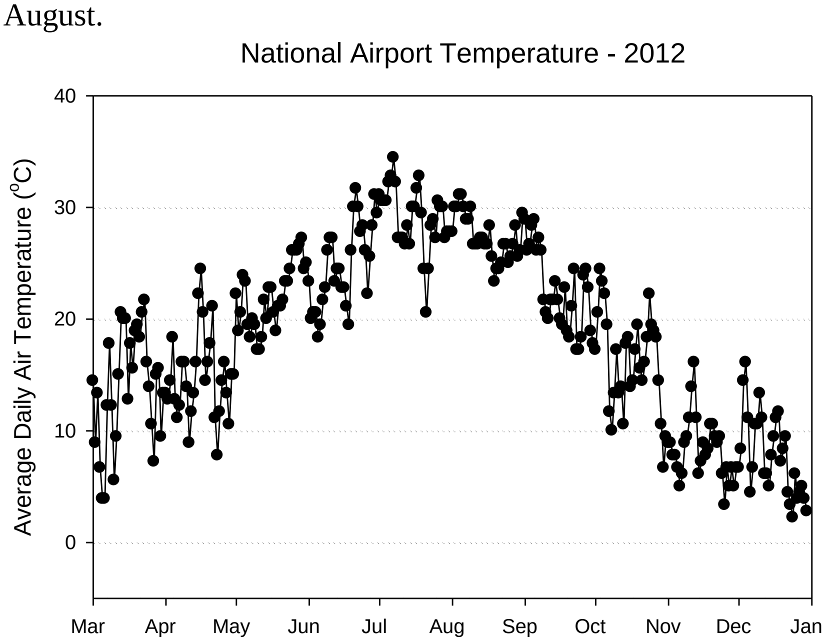
B. Physico-chemical Parameters – 2012



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.

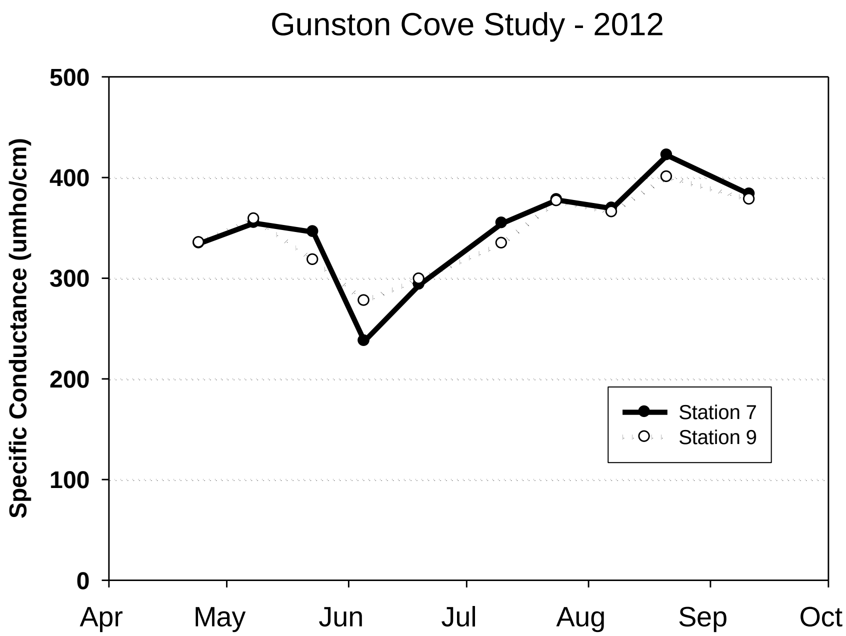
Figure 4. Water Temperature (°C). GMU Field Data. Month tick is at first day of month.

In 2012, water temperature followed the typical seasonal pattern at both sites (Figure 4). Both sites showed a steady increase during the spring and early summer with both sites reaching 30°C in early July. For most of the summer, the two stations showed similar water temperatures between 25° and 30° C. Water temperature declined in late August and September. Average daily air temperature peaked above 30°C from late June through early August.



Mean daily air temperature (Figure 5) was a good predictor of water temperature (Figure 4).

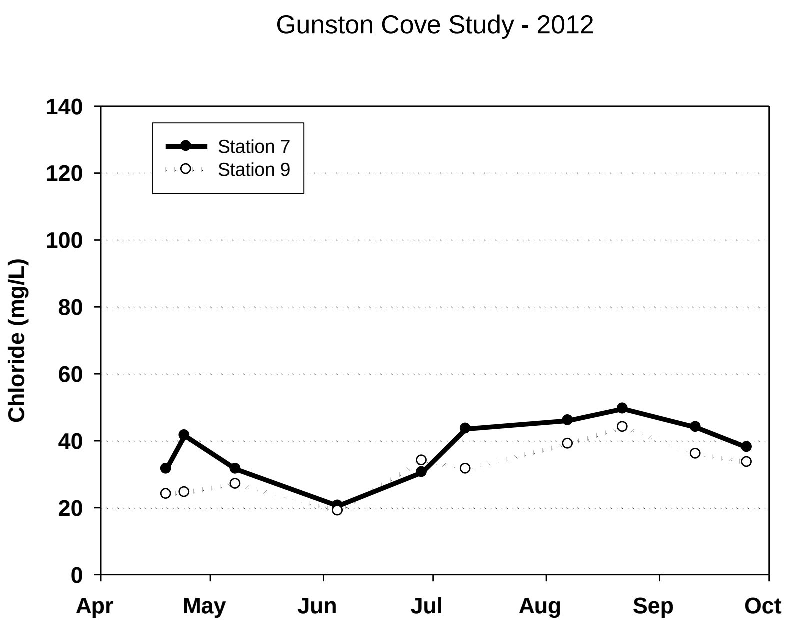
Figure 5. Average Daily Air Temperature (°C) at Reagan National Airport.



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.

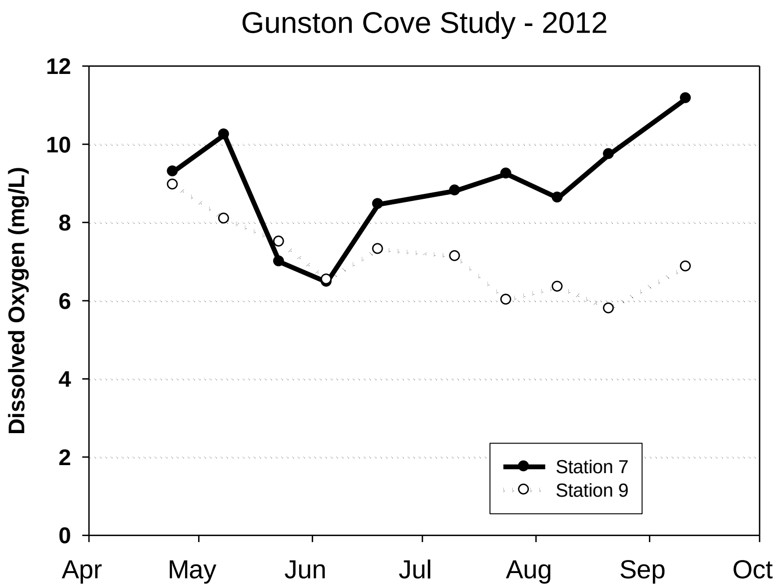
Figure 6. Specific Conductance (uS/cm). GMU Field Data. Month tick is at first day of month.

During most of 2012, specific conductance (Figure 6) exhibited similar patterns in the cove (Station 7) and the river (Station 9). During late May and early June specific conductance decreased markedly due to elevated spring flows (Figure 2), but by late June values were on an increasing pattern that continued through August. Chloride exhibited a similar pattern (Figure 7), but cove values maintained slightly higher values than the river site over the entire year.



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.

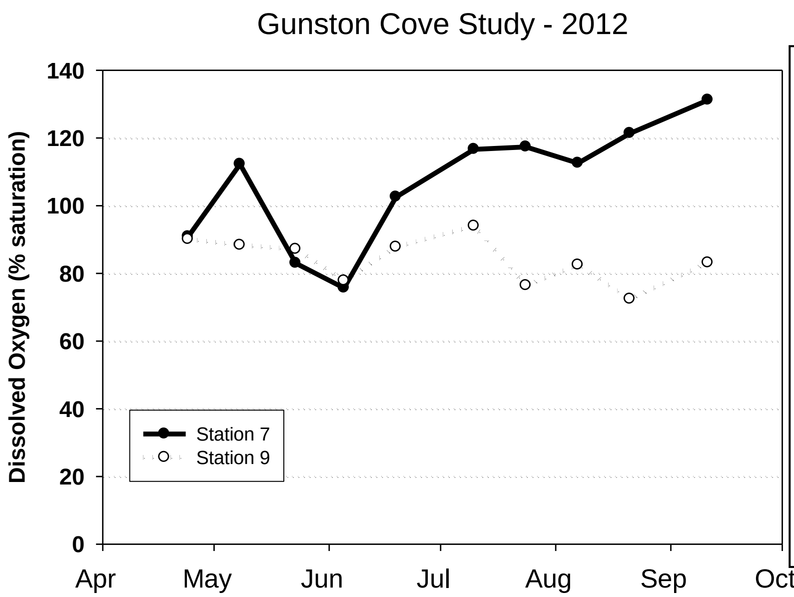
Figure 7. Chloride (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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.

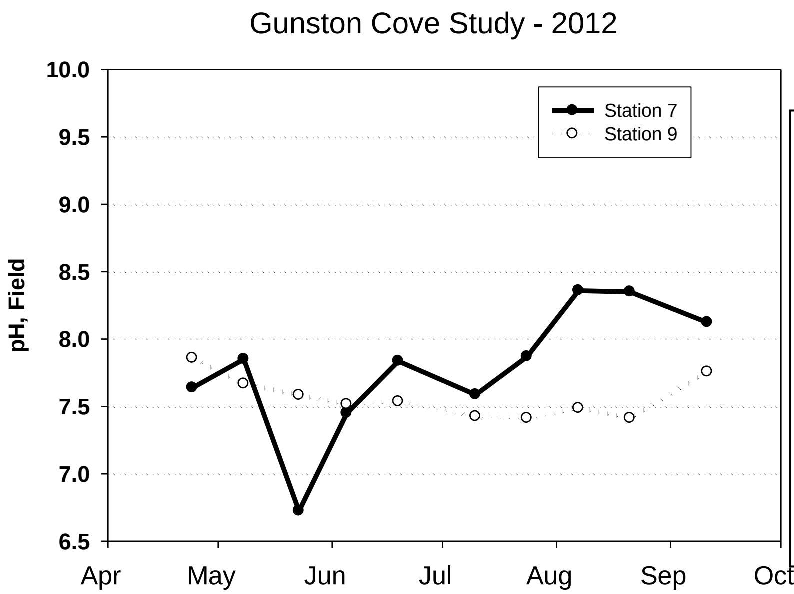
Figure 8. Dissolved Oxygen (mg/L). GMU Field Data. Month tick is at first day of month.

From April through early June dissolved oxygen values were similar at both river and cove sites showing a general decline related to temperature (Figure 8). Beginning in late June and continuing through the rest of the year, the two sites steadily diverged. At the cove site dissolved oxygen steadily increased from late June through September while in the river values were steady or slightly decreasing. In the cove dissolved oxygen was generally above 100% during this period indicating a general surplus of photosynthesis over respiration (Figure 9). In the river values were generally equal less than 100% indicating lower photosynthesis and an excess of respiration.



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

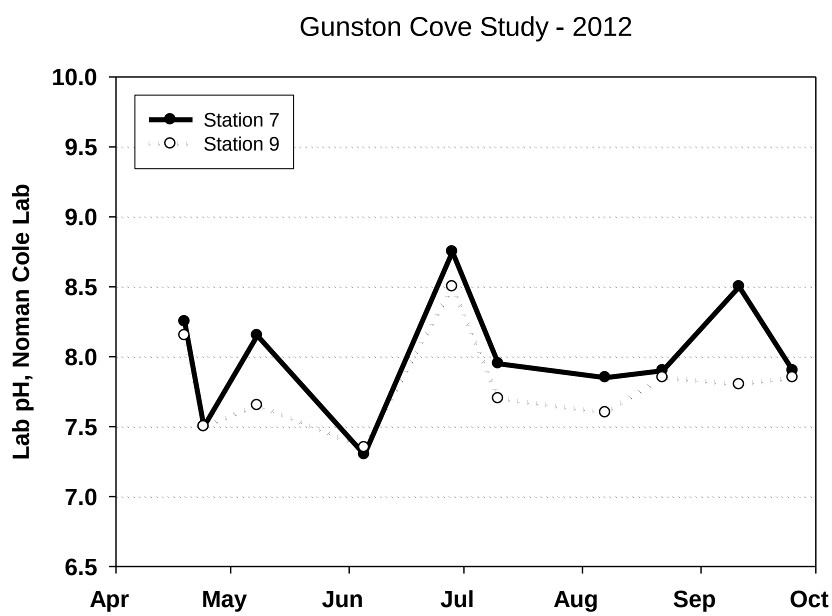
Figure 9. Dissolved Oxygen (% saturation). GMU Field Data. Month tick is at first day of month.



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.

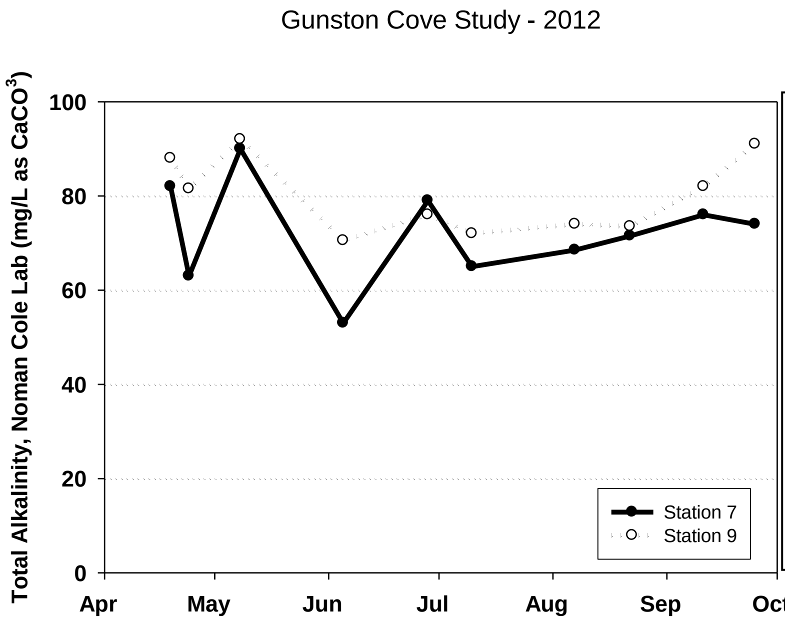
Figure 10. pH. GMU Field Data. Month tick is at first day of month.

Field pH was generally similar at the two sites from April through early July, but began to diverge in late July as values at the Gunston Cove station rose and river values remained constant (Figure 10). This difference is to be expected given the more intensive photosynthesis in the cove indicated by the dissolved oxygen data. The late May drop at the Gunston Cove site was unusual and not easily explained. Lab pH was more variable over time, but more uniform between the two stations (Figure 11). Sustained pH's above 9 are expected to promote sediment P release; these were not attained in 2012.



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.

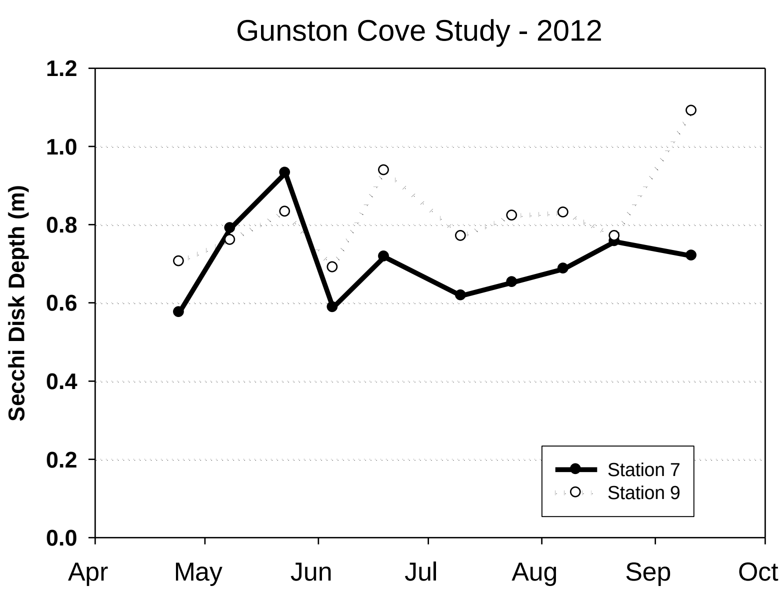


Total alkalinity measures the amount of bicarbonate and carbonate dissolved in the water. In freshwater this corresponds to the ability of the water to absorb hydrogen ions (acid) and still maintain a near neutral pH. Alkalinity in the tidal freshwater Potomac generally falls into the moderate range 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.

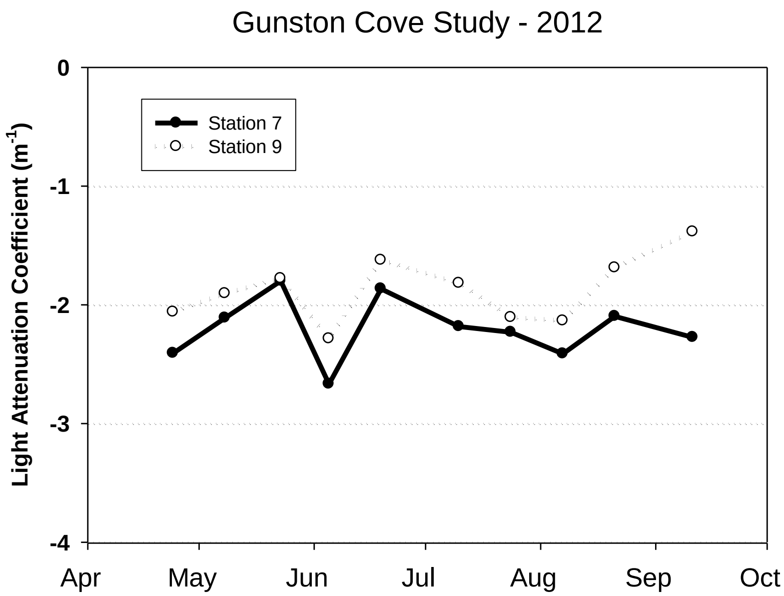
Total alkalinity was generally slightly higher in the river than in the cove (Figure 12). Values did not show any clear seasonal pattern.

Water clarity as reflected by Secchi disk depth was higher in the cove briefly in spring, but for most of the year was about 20 cm greater in the river (Figure 13). Even at the somewhat reduced levels, water clarity in the cove was reasonably good compared with pre-2000 values.



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

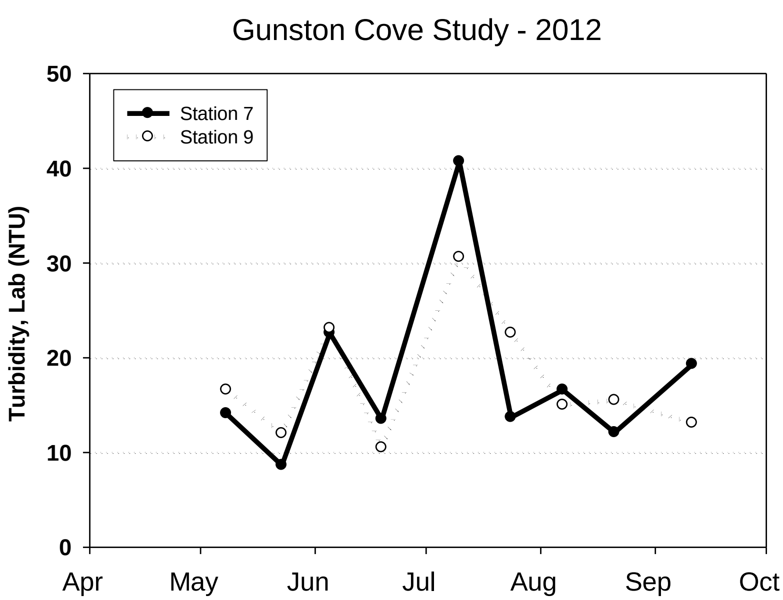
Figure 13. Secchi Disk Depth (m). GMU Field Data. Month tick is at first day of month.



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

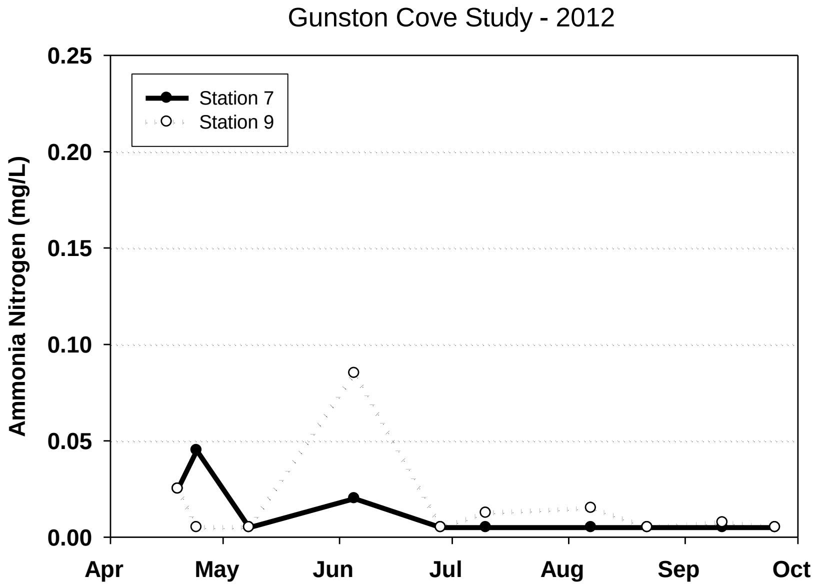
Figure 14. Light Attenuation Coefficient (m^{-1}). GMU Field Data. Month tick is at first day of month.

Light attenuation coefficient data 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 generally slightly greater (more negative) in the cove than in the river. Turbidity was similar at both sites reaching a peak in early July (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.

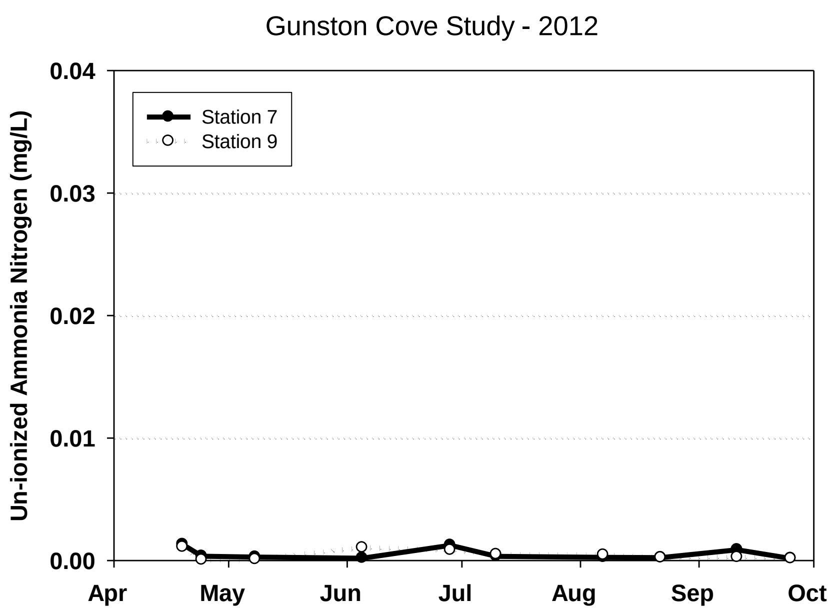
Figure 15. Turbidity (NTU). GMU Lab Data. Month tick is at first day of month.



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.

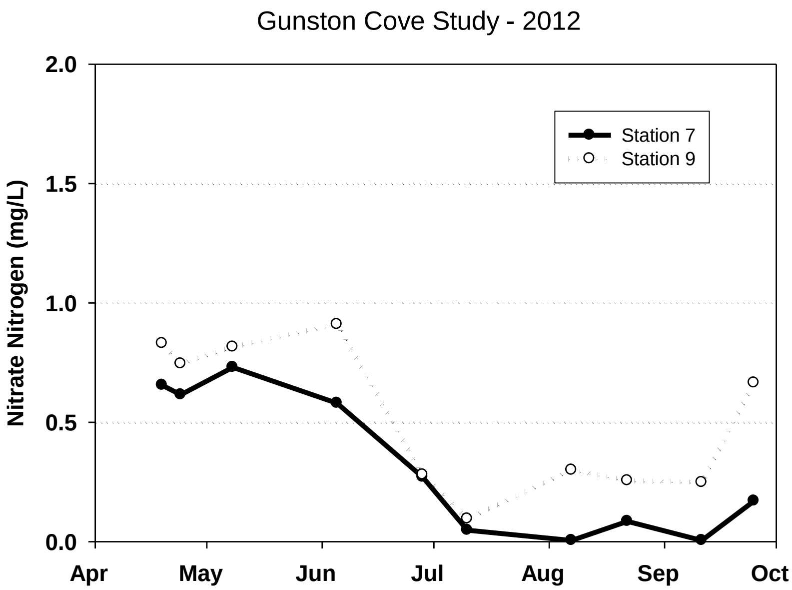
Figure 16. Ammonia Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.

Ammonia nitrogen was consistently very low (<0.05 mg/L) in the cove for the entire study period (Figure 16). River values were also very low during most of the year except in early June which approached 0.10 mg/L. 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.

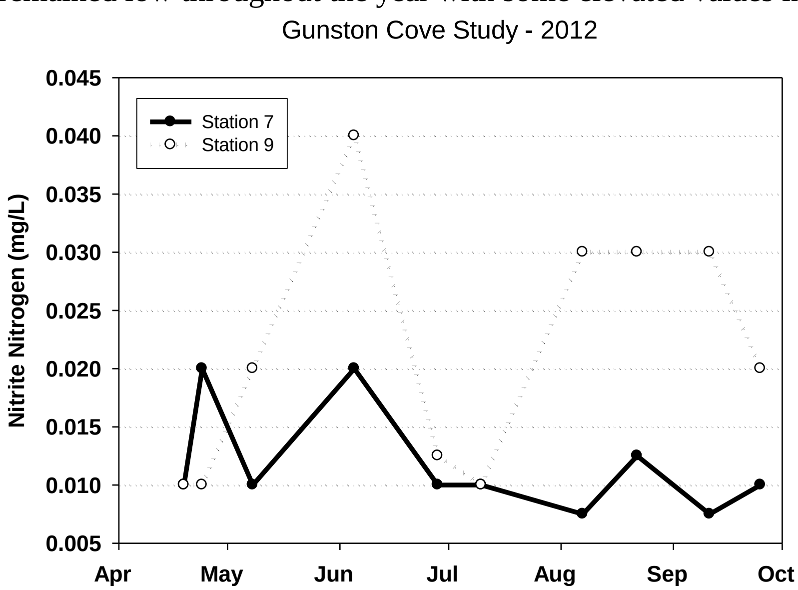
Figure 17. Un-ionized Ammonia Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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.

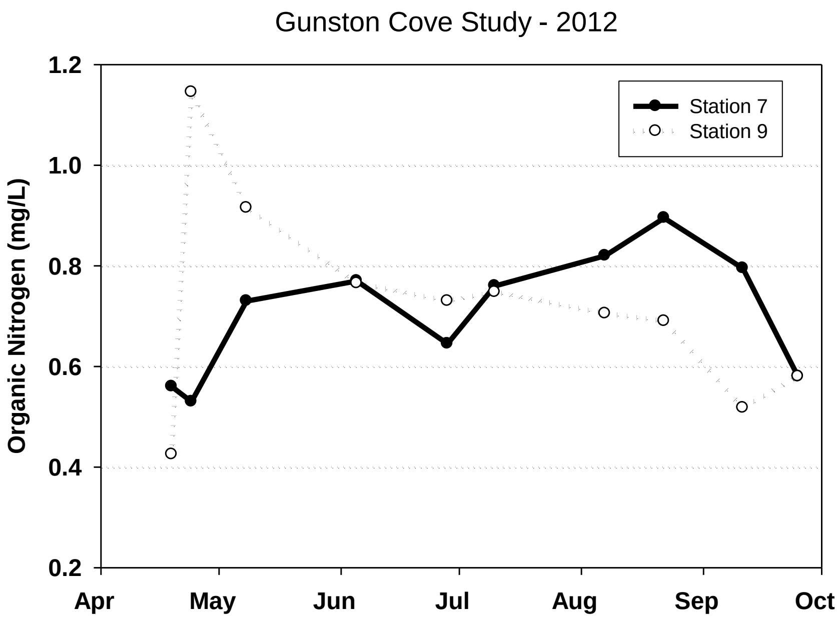
Figure 18. Nitrate Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.

Nitrate nitrogen levels followed similar trends in cove and river throughout the year with river values generally about 0.2 mg/L higher (Figure 18). Nitrate levels were elevated from April to early June and exhibited a strong decline during late June and July to very low values which were maintained through the rest of the year. This decline corresponded to the upswing in phytoplankton and was probably due to algal uptake. Higher values gradually returned to the river in August and were starting to increase in the cove in September. Nitrite nitrogen remained low throughout the year with some elevated values in the river (Figure 19).



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.

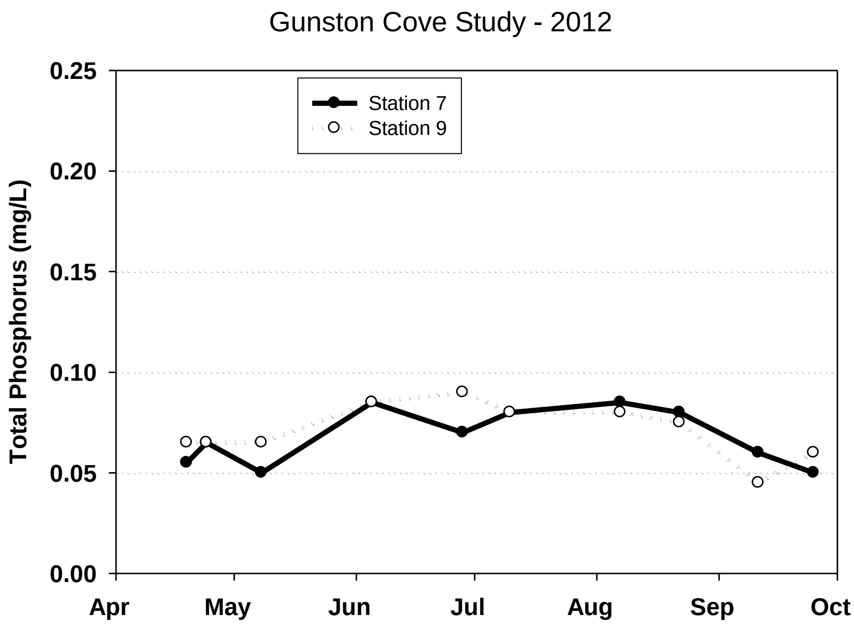
Figure 19. Nitrite Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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.

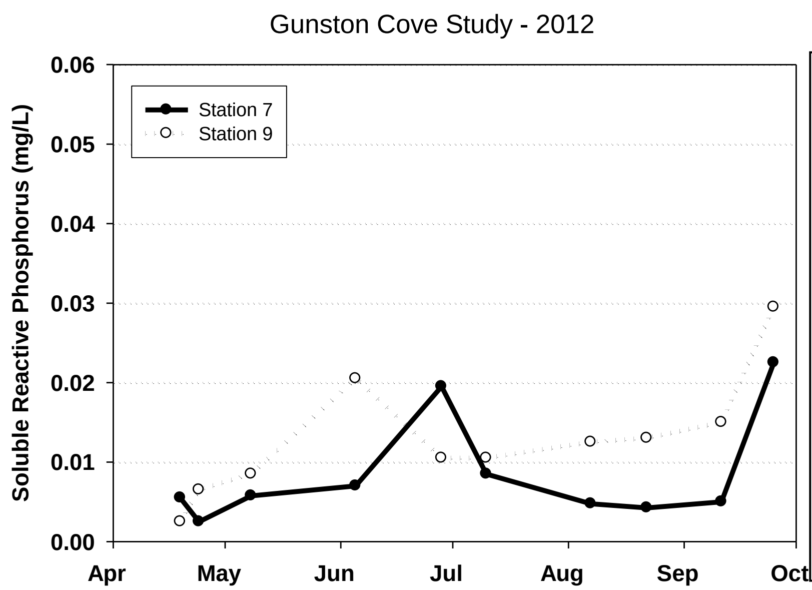
Organic nitrogen was generally higher in the river in spring and declined steadily during the remainder of the study period (Figure 20). In the cove values started lower in the spring and gradually increased through August.



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.

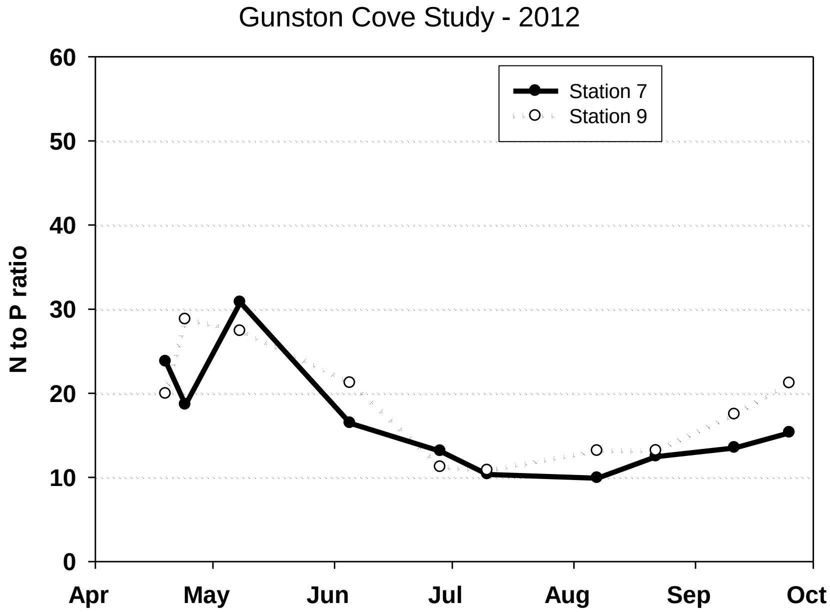
Figure 21. Total Phosphorus (mg/L). Fairfax County Lab Data. Month tick is at first day of month.

Total phosphorus was similar at both sites on almost all dates and did not show much seasonal variation (Figure 21). In early September cove values were substantially higher. Soluble reactive phosphorus was consistently higher in the river than in the cove (Figure 22). In the cove values were generally less than 0.01 mg/L, while in the river values were generally above that level. The only exception was late June when values were reversed.



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.

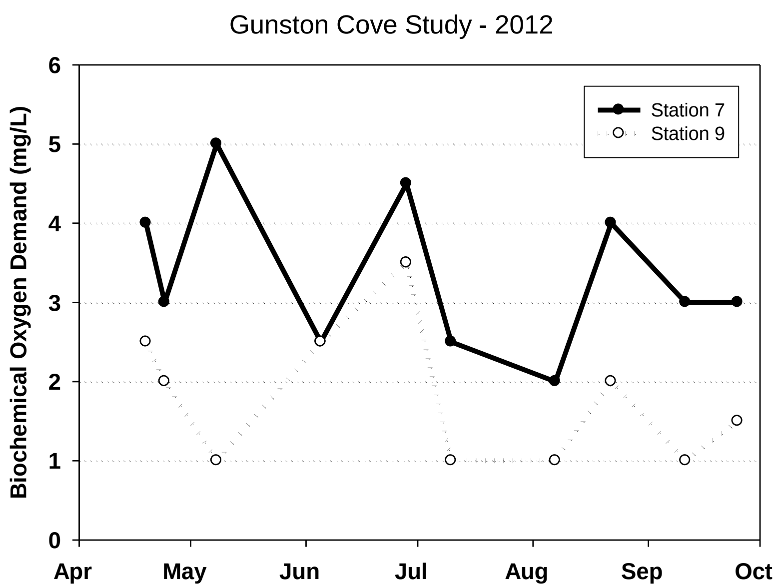
Figure 22. Soluble Reactive Phosphorus (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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

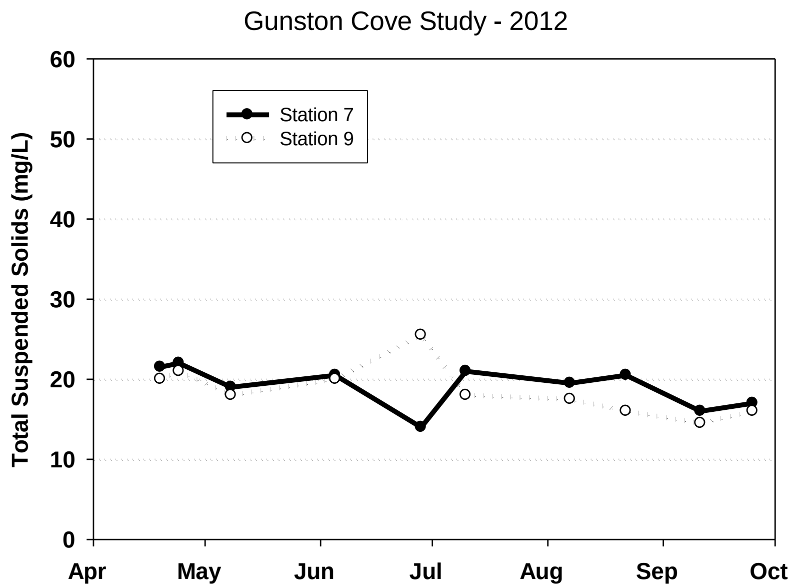
Figure 23. N/P Ratio (by mass). Fairfax County Lab Data. Month tick is at first day of month.

N/P ratio exhibited a clear seasonal pattern that was similar at both sites (Figure 23). High readings in April and early May declined steadily through July to about 10 and remained low through August and September. These late summer readings remained just above 7.2 the point at which algae shift from P to N limitation. Biochemical oxygen demand (BOD) was consistently higher in the cove than in the river (Figure 24). While quite variable, cove values were generally 2-5 mg/L whereas most river values were generally 1-3 mg/L.



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.

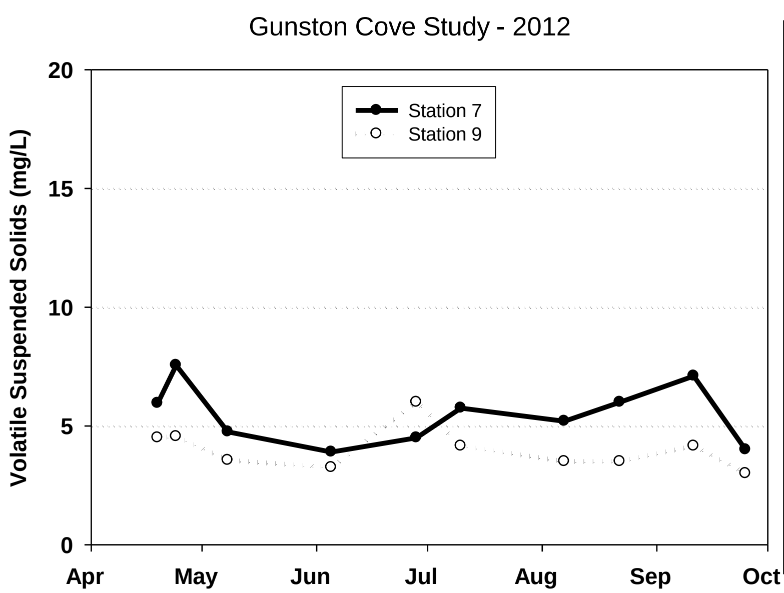
Figure 24. Biochemical Oxygen Demand (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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.

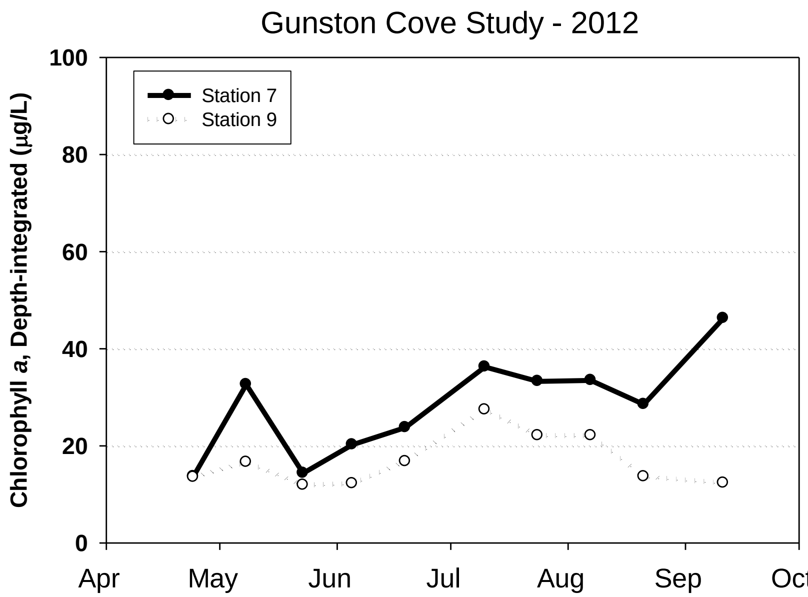
Total suspended solids was generally in the range 15-25 mg/L at both stations (Figure 25). There was essentially no seasonal pattern. Volatile suspended solids was generally somewhat higher in the cove than in the river with little seasonal pattern (Figure 26).



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.

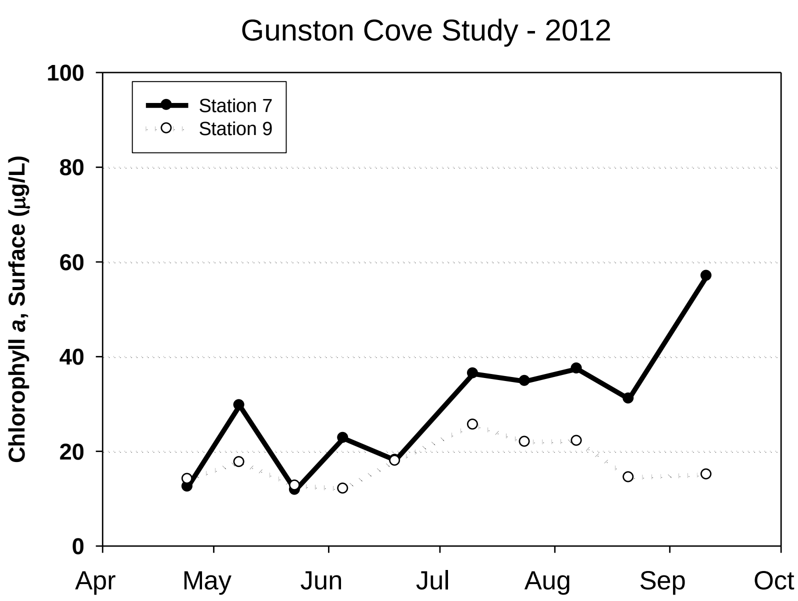
C. Phytoplankton -2011



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* exhibited a clear seasonal pattern at both sites with values increasing in June and early July and remaining elevated through late July and August (Figure 27). In the cove values increased from about 10 ug/L in the spring to about 35 ug/L for the summer months ending the year at about 50 ug/L in September. In the river, chlorophyll *a* levels were about 10 ug/L in spring increasing to about 20-30 ug/L in July and early August. 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.

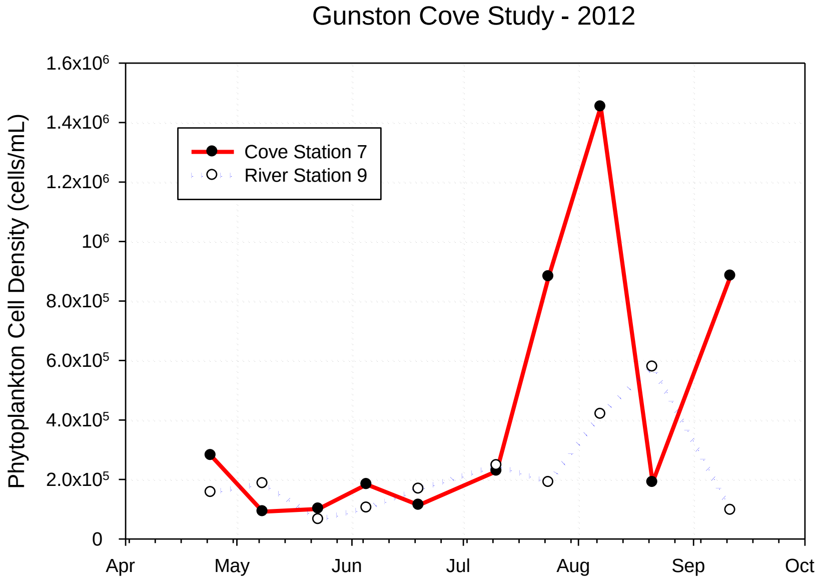


Figure 29. Phytoplankton Density (cells/mL).

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.

Phytoplankton density was generally low from April through early July in both cove and river (Figure 29). In the cove, density increased strongly in late July reaching a peak in early August. A decline in late August was followed by another increase in early September. In the river a more gradual increase in cell density was observed with a peak in late August. Total biovolume indicated two maxima at both stations (Figure 30). Cove biovolume reached a peak of nearly 1.0 x 10^8 um^3/mL in April and a second lower peak of about 0.7 x 10^8 um^3/mL on late July. In the river the early May maximum was nearly 2.0 x 10^8 um^3/mL, while the early August peak was somewhat smaller.

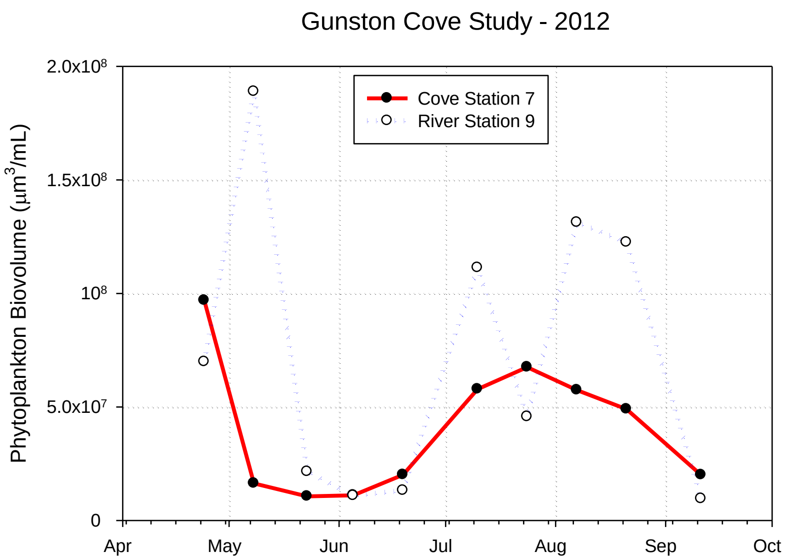
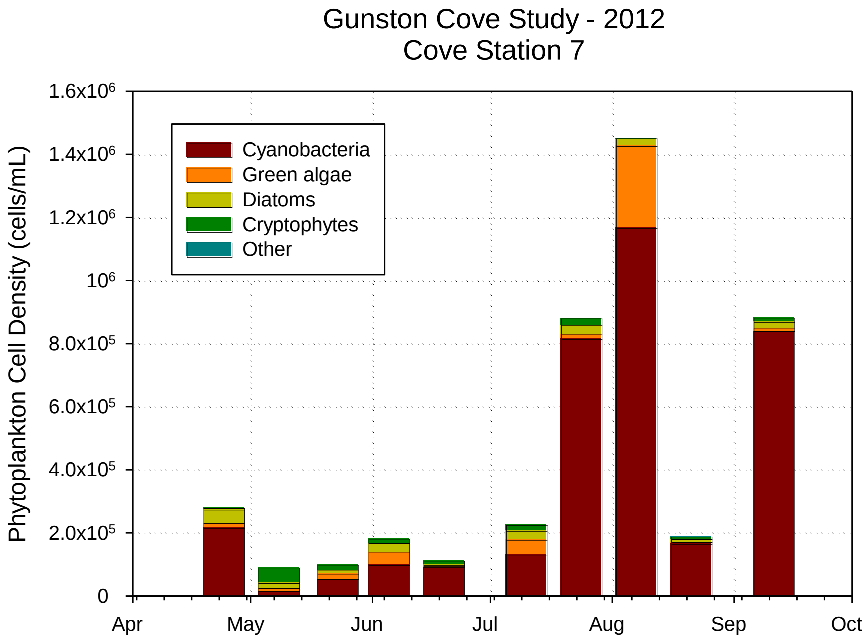


Figure 30. Phytoplankton Biovolume (um^3/mL).

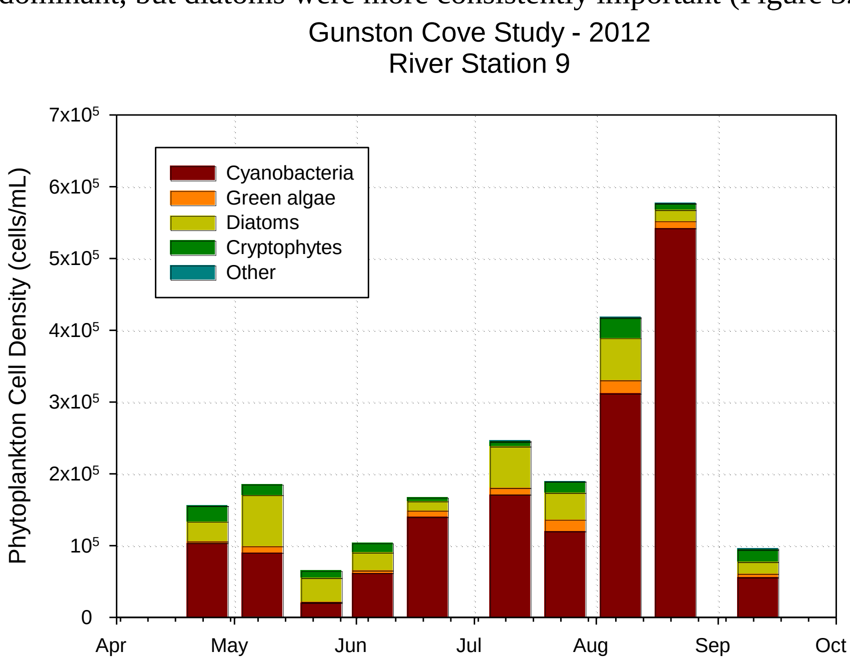
The volume of individual cells of each species is determined by approximating the cells of each species to an appropriate geometric shape (e.g. sphere, cylinder, cone, cube, etc.) and then making the measurements of the appropriate dimensions under the microscope. Total phytoplankton biovolume (shown 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. In this case **Cyano** refers to cyanobacteria (or "blue-green algae"), **Greens** refers to green algae, **Diatoms** is self-explanatory, **Cryptos** refers to cryptophytes, and **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.

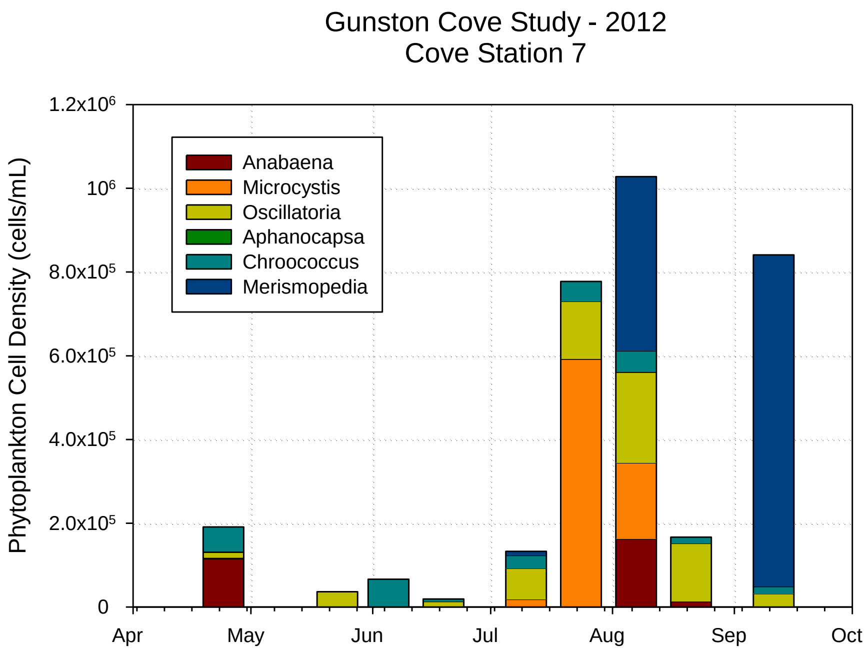
Figure 31. Phytoplankton Density by Major Group (cells/mL). Gunston Cove.

Phytoplankton density in the cove was fairly evenly divided among the major groups in spring, but in July cyanobacteria began to dominate and by July and August and into September they were overwhelmingly dominant (Figure 31). During this period diatoms were a distant second except in early August when green algae were important. In the river cyanobacterial were still dominant, but diatoms were more consistently important (Figure 32).



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.

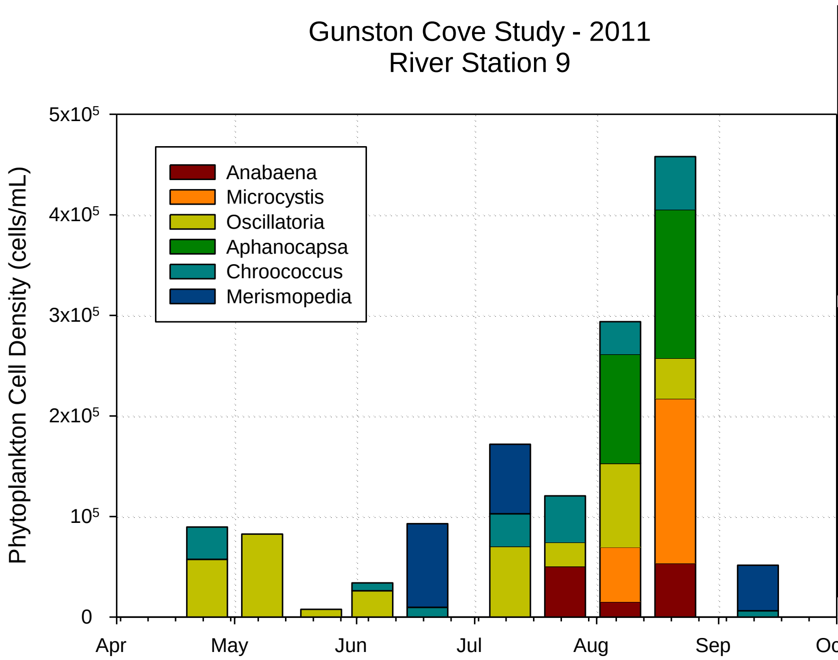
Figure 32. Phytoplankton Density by Major Group (cells/mL). River.

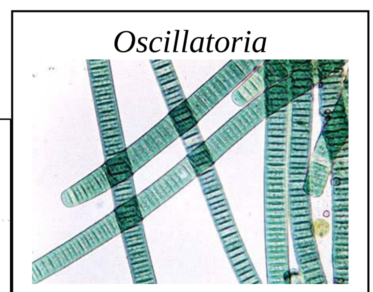


The dominant cyanobacteria on a numerical basis were:
Aphanocapsa -- small sphere
Oscillatoria – a filament with cylindrical cells
Microcystis – an irregular colony of spherical cells
Anabaena – a filament with bead-like cells & heterocysts
Merismopedia -- a flat plate of cells in a rectangular arrangement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

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

In the cove the low spring levels were dominated early by *Anabaena*. *Oscillatoria* and *Microcystis* were most important during July with several genera important in early August (Figure 33). In early September *Merismopedia* was clearly most abundant. In the river *Oscillatoria* was numerically dominant for most of the spring and early summer (Figure 34). *Microcystis* and Aphanocapsa were co-dominant during August.





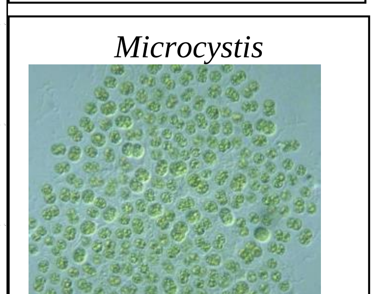
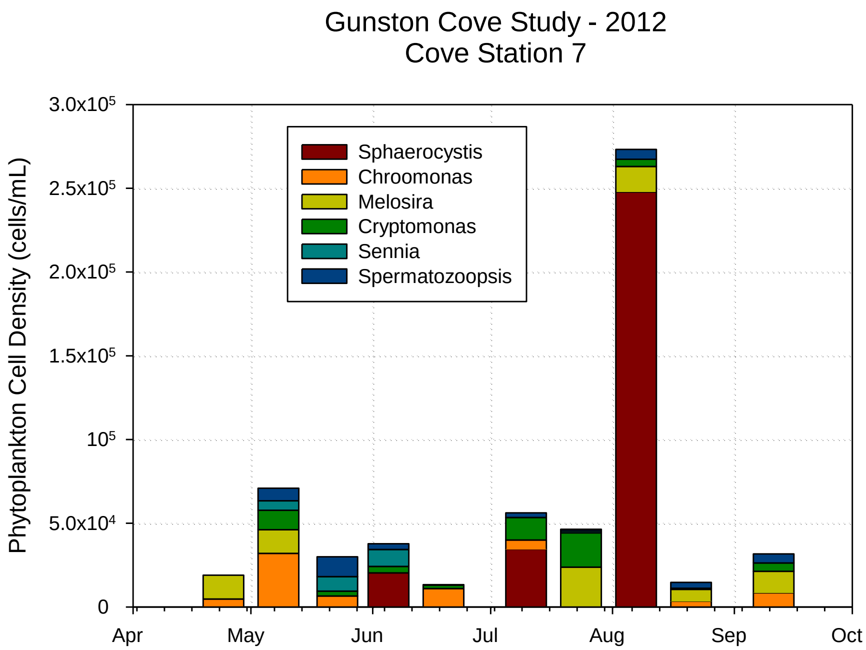


Figure 34. Phytoplankton Density by Dominant Cyanobacteria (cells/mL). River.



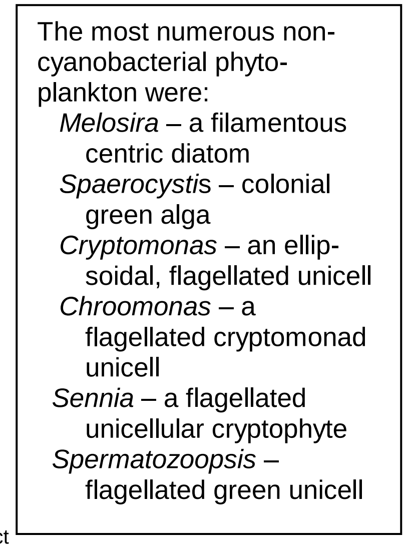
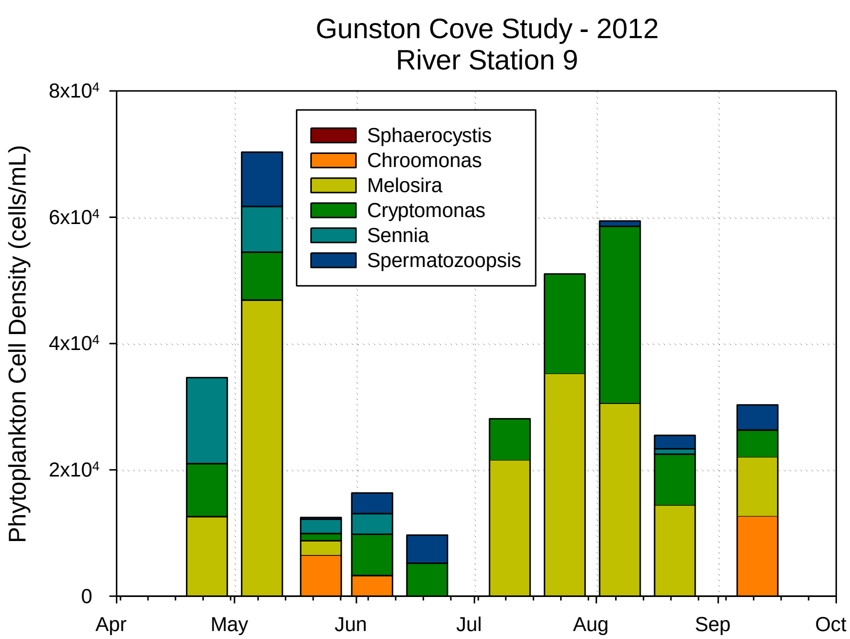
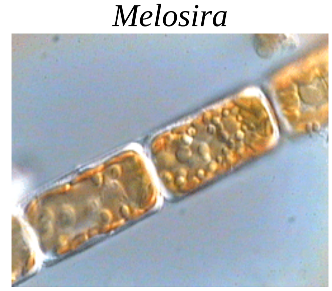


Figure 35. Phytoplankton Density (#/mL) by Dominant Noncyanobacterial Taxa. Gunston Cove.

In the cove *Melosira* was the most numerous eukaryotic taxon in spring and early summer (Figure 35). Sphaerocystis was very abundant in early August. In the river *Melosira* led dominance on most dates, especially in spring and mid to late summer. *Cryptomonas* was abundant on many dates (Figure 36).

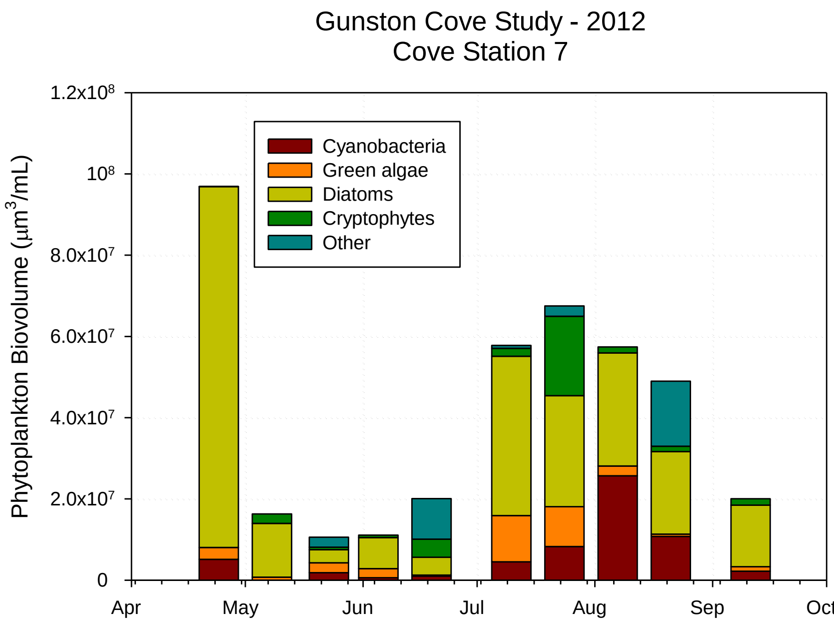


Melosira



Cryptomonas

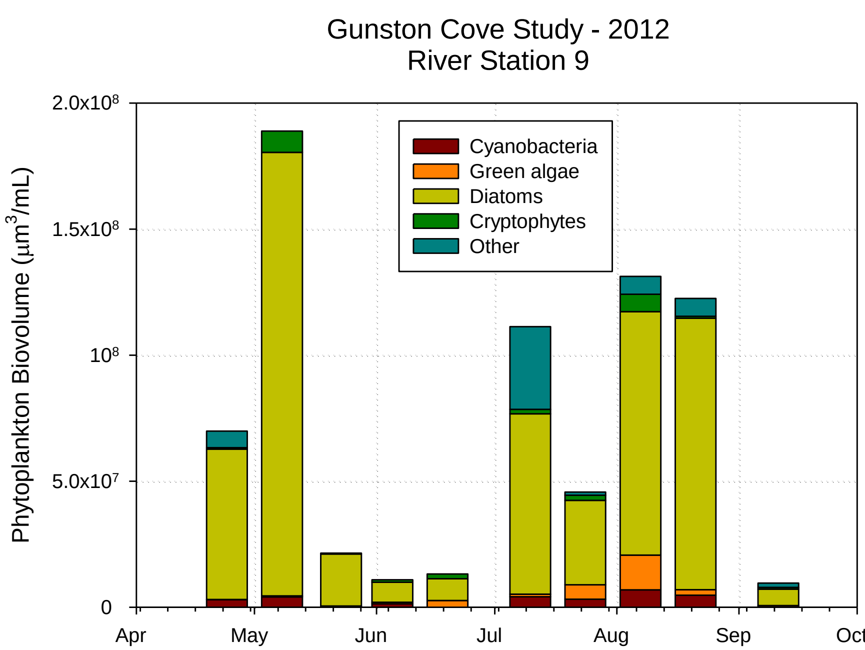
Figure 36. Phytoplankton Density (#/mL) by Dominant Taxa. River.



Total phytoplankton biovolume can be broken down into groups:
- **Cyano** – cyanobacteria ("blue-green" algae)
- **Greens** – green algae
- **Diatoms** – includes both centric and pinnate
- **Cryptos** – cryptophytes
- **Other** – includes euglenoids, crysophytes, and dinoflagellates

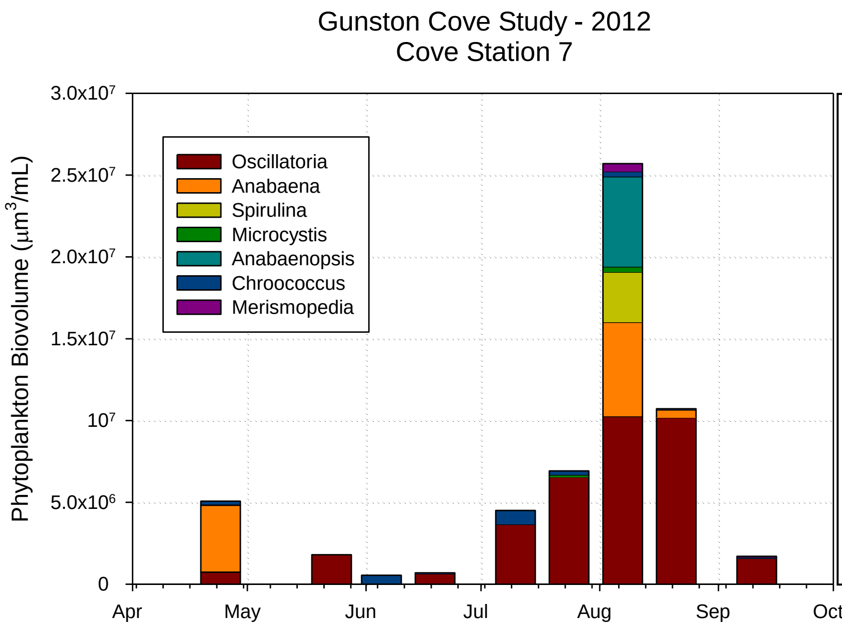
Figure 37. Phytoplankton Biovolume (um^3/mL) by Major Groups. Gunston Cove.

In the cove diatoms were dominant in biovolume in most samples (Figure 37). In particular, they were responsible for the very high values in April and were generally the most abundant group in summer. Cyanobacteria were subdominant in summer. In the river, diatoms were again the overwhelming dominants during most of the year and were especially responsible for the spring peak (Figure 38).



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, although in 2011, the two regions had similar levels.

Figure 38. Phytoplankton Biovolume (um^3/mL) by Major Groups. River.

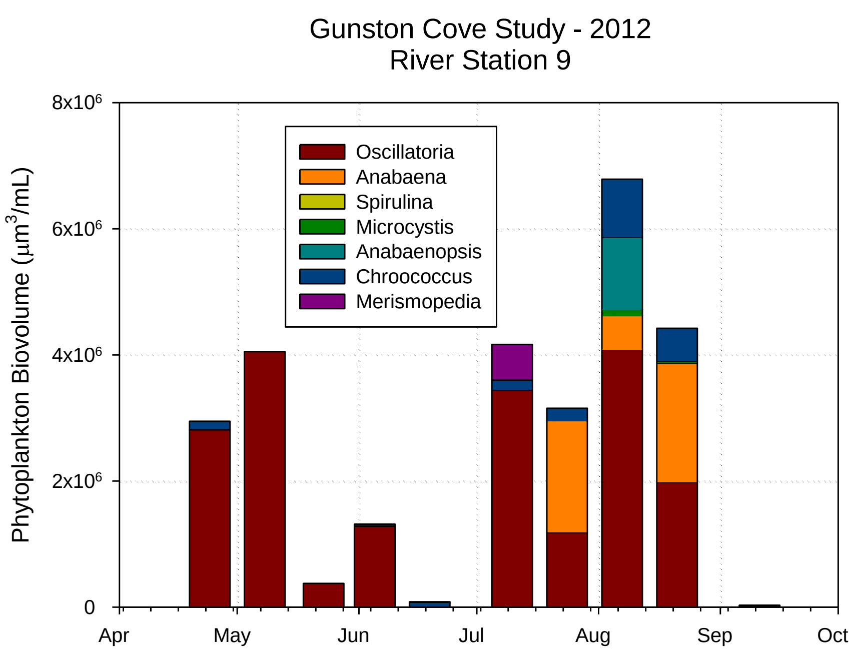


Cyanobacteria are generally most common in late summer and that is when they normally make the largest contribution to phytoplankton biovolume. Important taxa for biovolume which were not on the top list for cell density are:

- *Spirulina*– a coiled filament of cylindrical cells
- *Anabaenopsis* – a filament of spherical cells with terminal heterocysts

Figure 39. Phytoplankton Biovolume (um^3/mL) by Cyanobacteria Taxa. Gunston Cove.

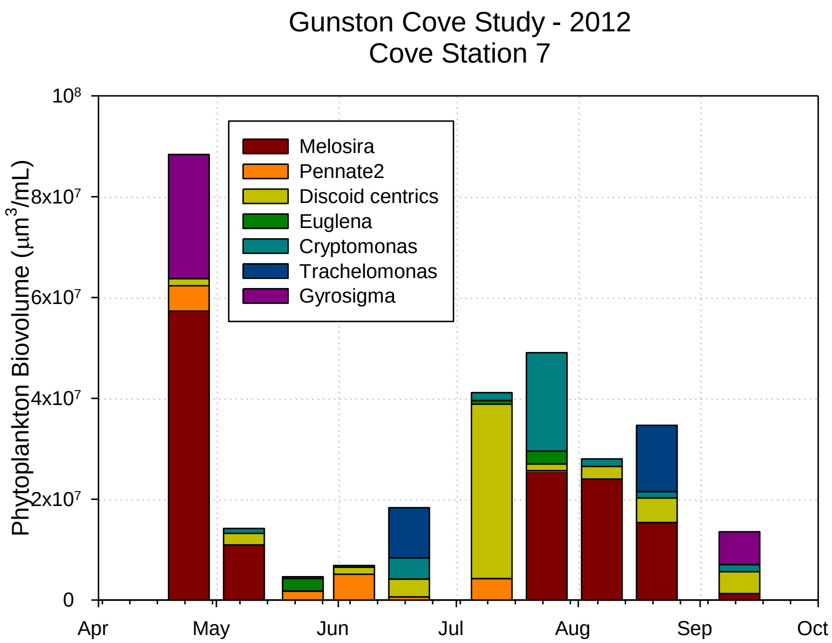
In the cove *Oscillatoria* was the dominant cyanobacterium in terms of biovolume for most of the year (Figure 39). *Anabaena* made a strong showing in late April and again early August. *Anabaenopsis* and *Spirulina* were important in July and August. In the river *Oscillatoria* was generally most important, but *Anabaena* was important in the late summer and (Figure 40).



Anabaena

Chroococcus

Figure 40. Phytoplankton Biovolume (um^3/mL) by Cyanobacterial Taxa. River.



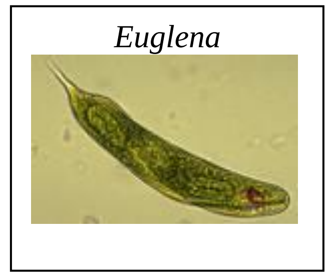
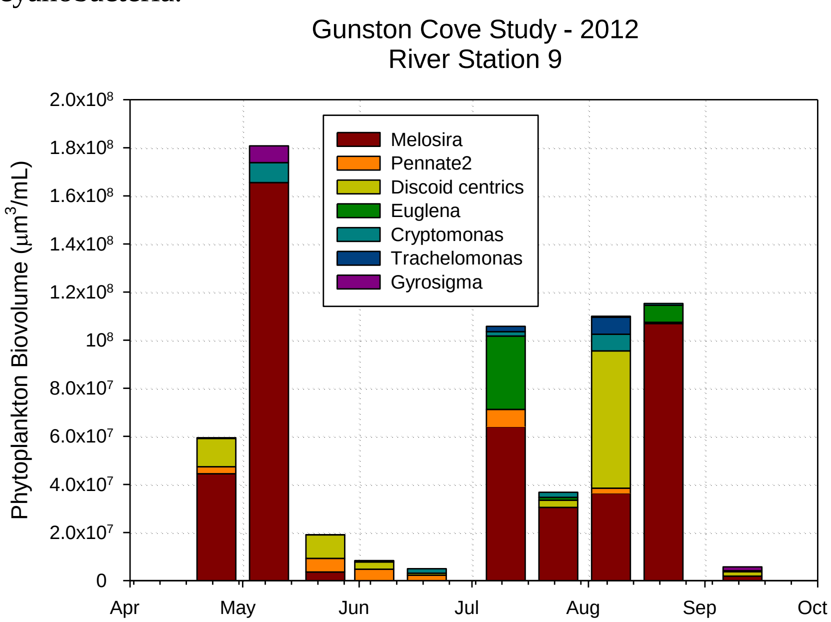
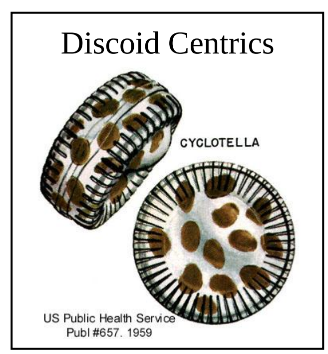


Figure 41. Phytoplankton Biovolume (um^3/mL) by Dominant Noncyanobacterial Taxa. Gunston Cove.

Melosira was the most important component of noncyanobacterial biovolume in the cove for much of the year and in particular during the spring peak and again in late July and August (Figure 41). Discoid centrics were very abundant in early July. In the river, *Melosira* was even more omnipresent with other taxa having scattered periods of abundance (Figure 42). Like other diatoms, *Melosira* is considered to be a healthy part of the aquatic food web serving as food for many consumers like zooplankton without the toxic properties of many cyanobacteria.





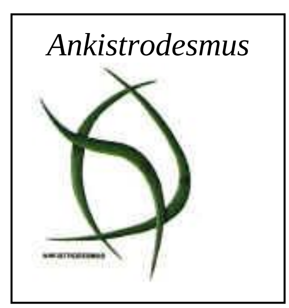
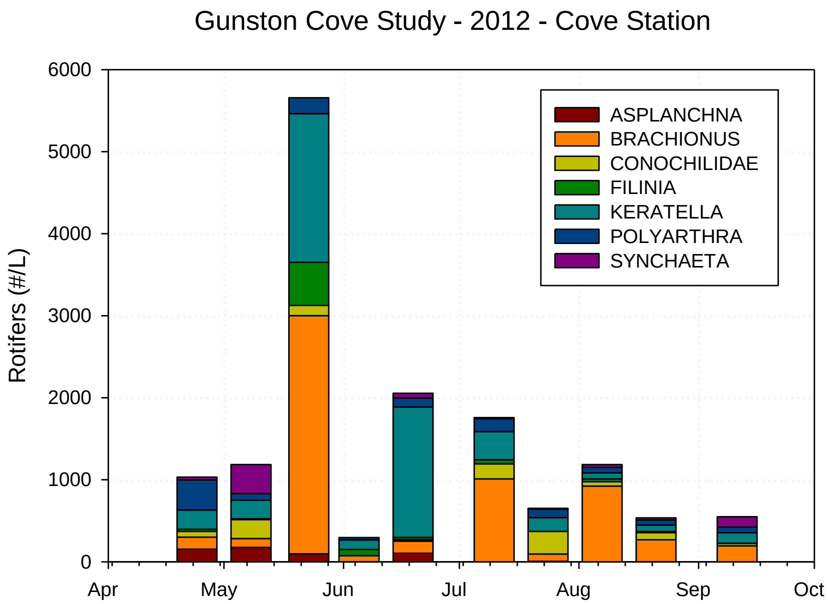
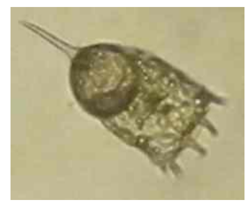


Figure 42. Phytoplankton Biovolume (um^3/mL) by Dominant Taxon. River.

D. Zooplankton – 2012



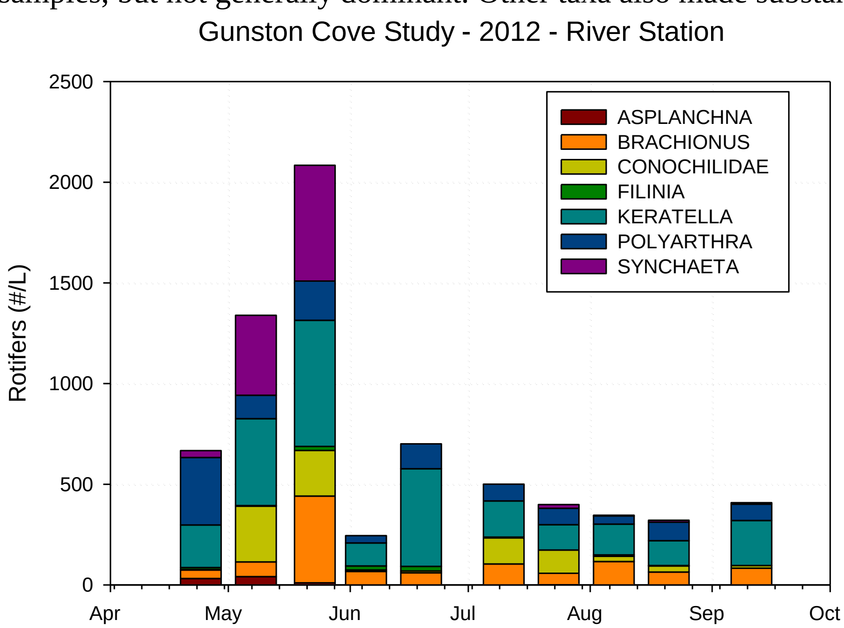
Brachionus (Sta 7, RCJ)



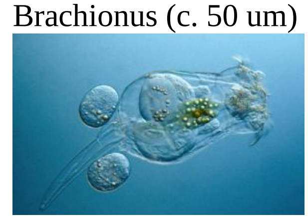
Keratella (Sta 7, RCJ)

Figure 43. Rotifer Density by Dominant Taxa (#/L). Cove.

In the cove, rotifers increased in May from just over 1000/L to about 5500/L (Figure 43). A strong decline was observed in early June followed by a rebound to about 2000/L in late June with levels slowly declining through the summer. *Brachionus* was the most important genus for most of the year. In spring and early summer *Keratella* was very abundant. On many dates there were a number of other rotifer species of significance. In the river rotifers demonstrated a similar seasonal pattern at lower abundance levels (Figure 44). *Keratella* was important on almost all dates with *Synchaeta* being abundant in May. *Brachionus* was present in all samples, but not generally dominant. Other taxa also made substantial contributions.



Brachionus (c. 50 um)



Conochilidae

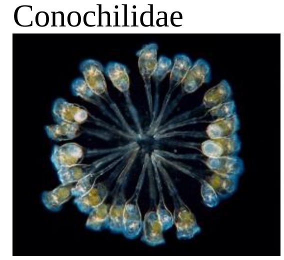
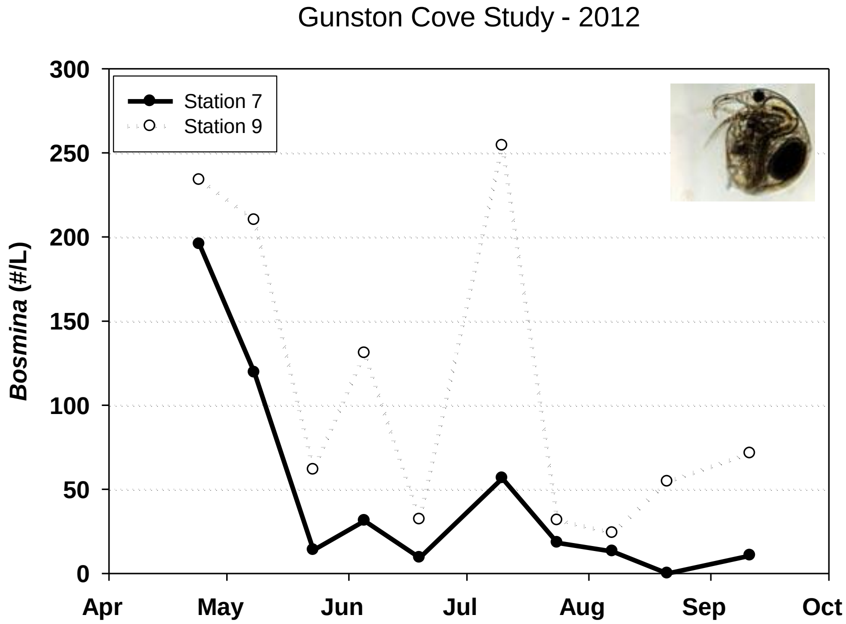


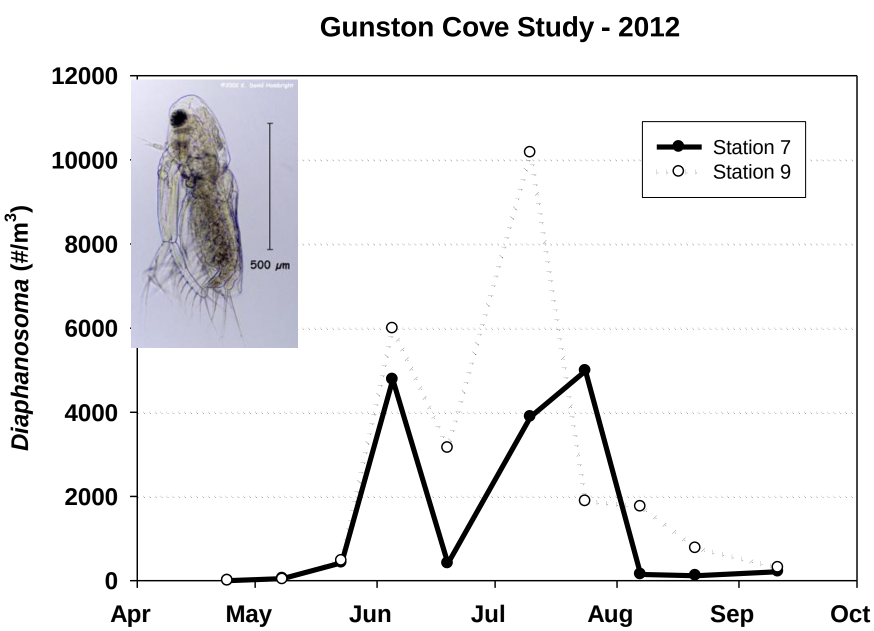
Figure 44. Rotifer Density by Dominant Taxa (#/L). River.



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.

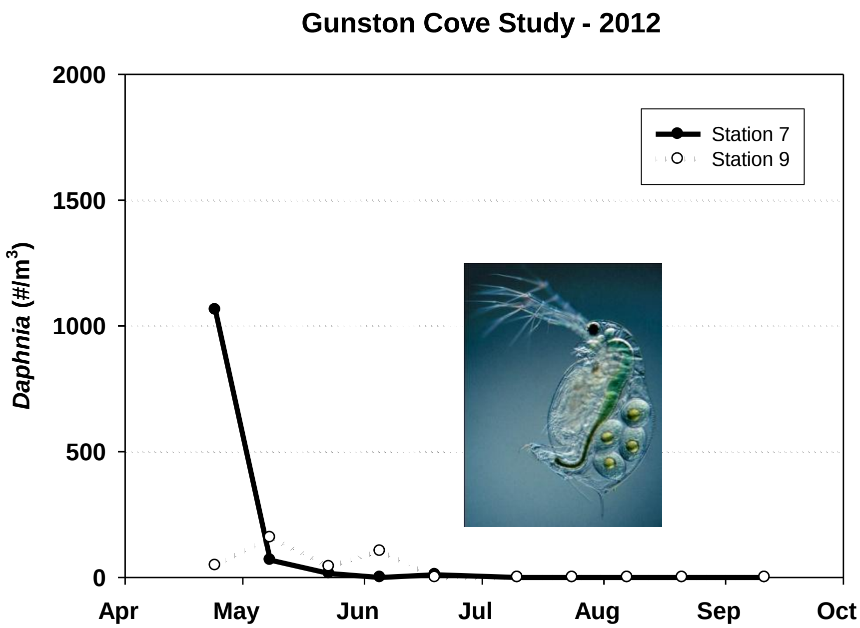
Figure 45. *Bosmina* Density by Station (#/L).

In 2012 the small cladoceran *Bosmina* was most abundant in the cove in spring reaching a maximum of about 200/L in late May steadily declining thereafter (Figure 45). In the river *Bosmina* was also found at high levels of near 250/L in late April which recurred in early July. *Diaphanosoma*, typically the most abundant larger cladoceran in Gunston Cove, exhibited two peaks at both sites (Figure 46). The early June peak reached similar values at both sites (5000/m^3 to 18,000/m^3). The second peak was more pronounced at the river site attaining 10,000/m^3 whereas in the cove this July peak reached only 5000/m^3.



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

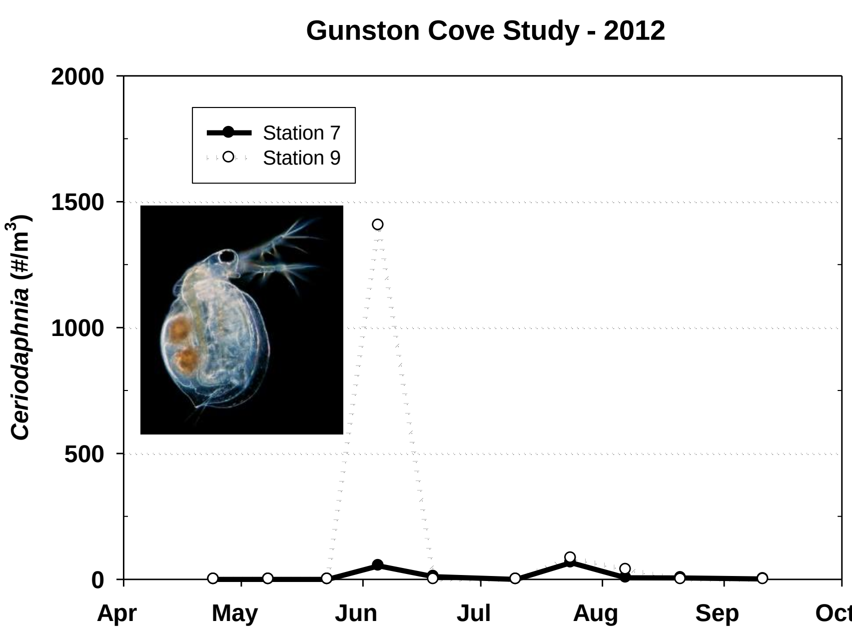
Figure 46. *Diaphanosoma* Density by Station (#/m^3).



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.

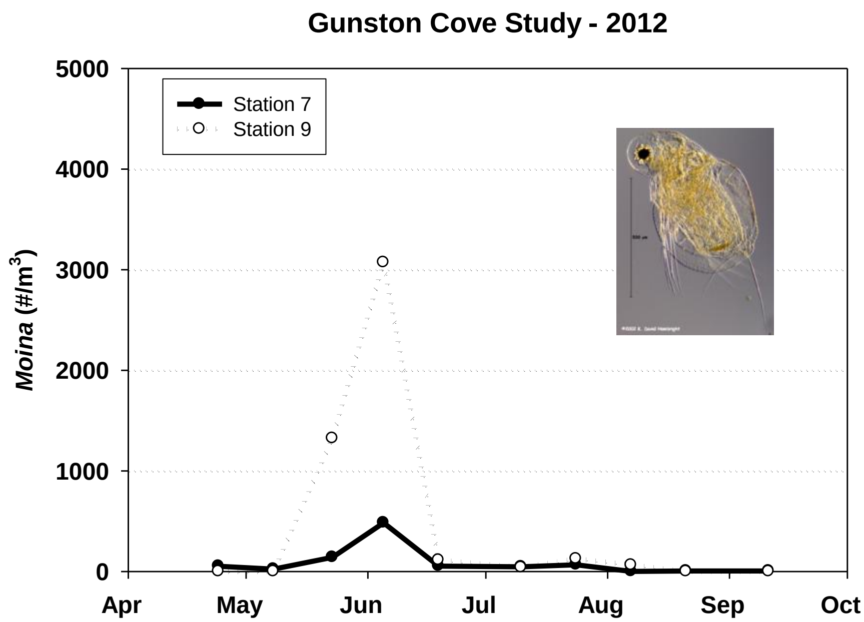
Figure 47. *Daphnia* Density by Station (#/m^3).

Daphnia was common mainly in April and May and was most abundant in the cove reaching 1100/m^3 (Figure 47). *Ceriodaphnia* was present mainly in June in the river reaching about 1400/m^3 (Figure 48).



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.

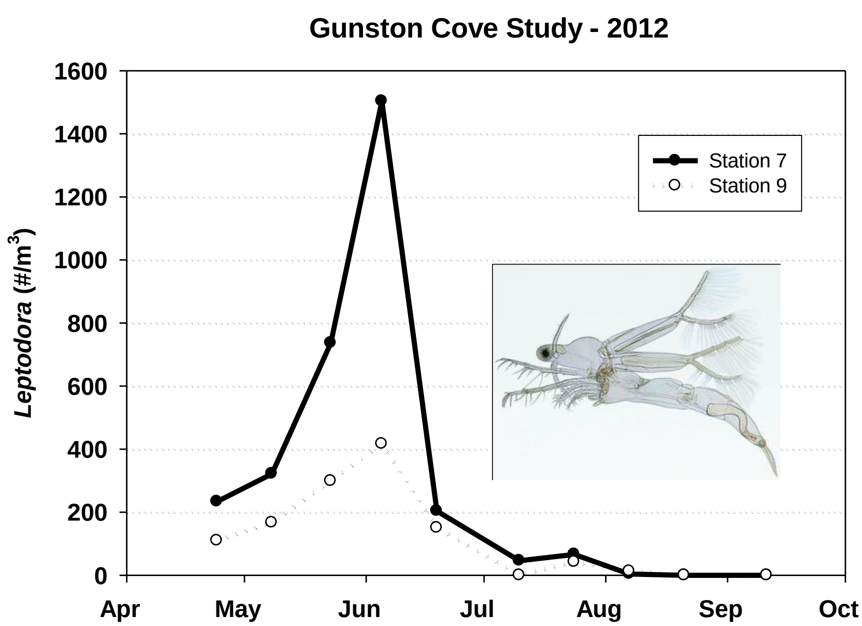
Figure 48. *Ceriodaphnia* Density by Station (#/m^3).



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.

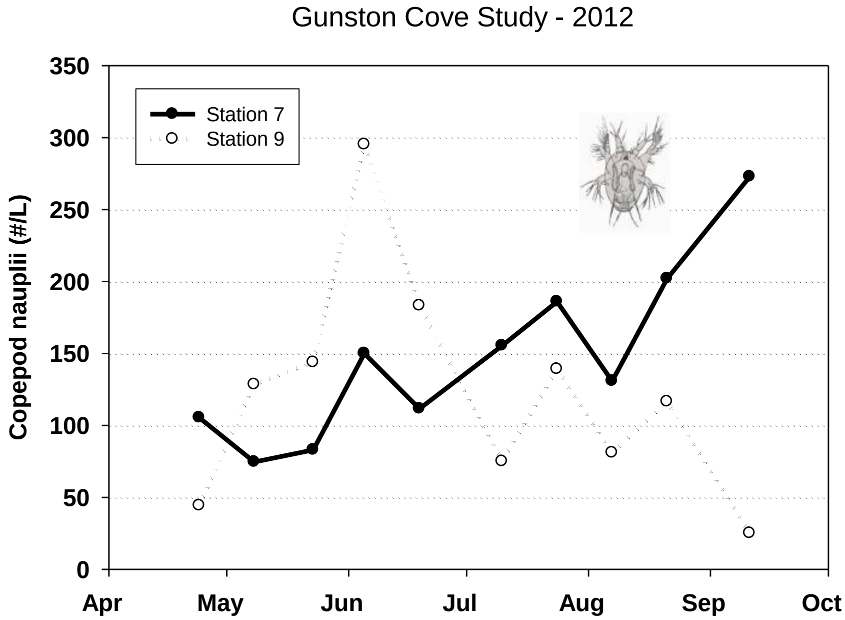
Figure 49. *Moina* Density by Station (#/m^3).

Moina was found almost exclusively in early June at relatively high levels of 3000/m^3 in the river and lower levels of about 500/m^3 in the cove (Figure 49). *Leptodora*, the large cladoceran predator, was consistently present in May and June in both cove and river (Figure 50). In the cove the peak was in early June at 1400/m^3. In the river an early June peak of about 400/m^3 was observed.



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.

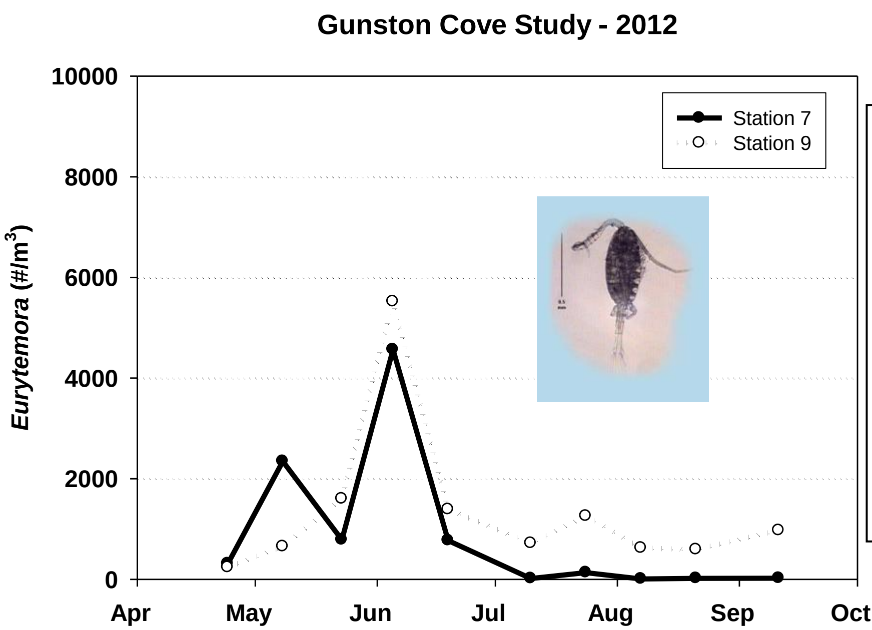
Figure 50. *Leptodora* Density by Station (#/m^3).



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.

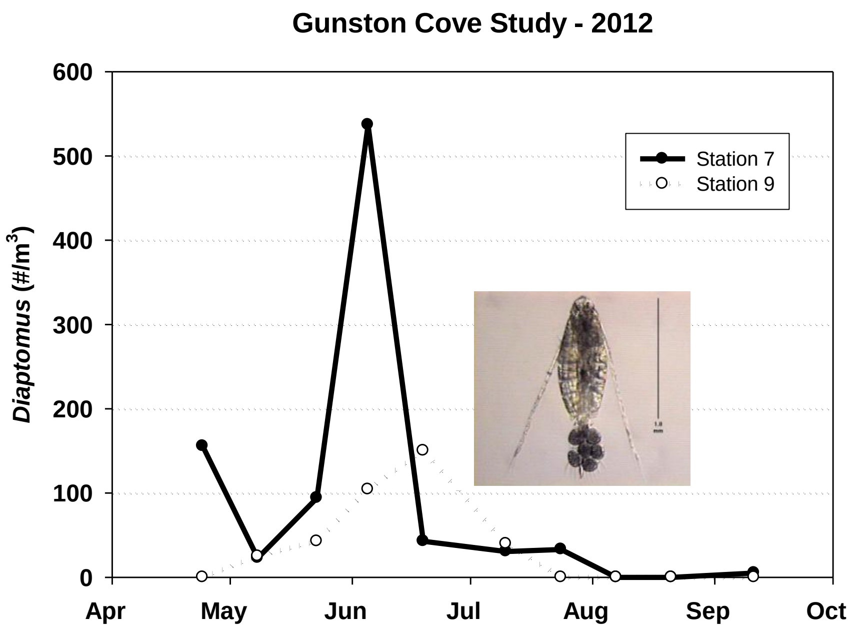
Figure 51. Copepod Nauplii Density by Station (#/L).

In the cove copepod nauplii increased steadily from levels of about 100/L in early May reaching nearly 300/L in September (Figure 51). In the river, nauplii increased consistently from April through early June peaking at about 300/L and then generally declined through the remainder of the year. *Eurytemora* exhibited highest densities early June (Figure 52). Maximum values were about 5000/m^3 at both sites. *Eurytemora* declined to very low levels by early June in the cove, but remained near 1000/m^3 in the river for the remainder of the year.



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*.

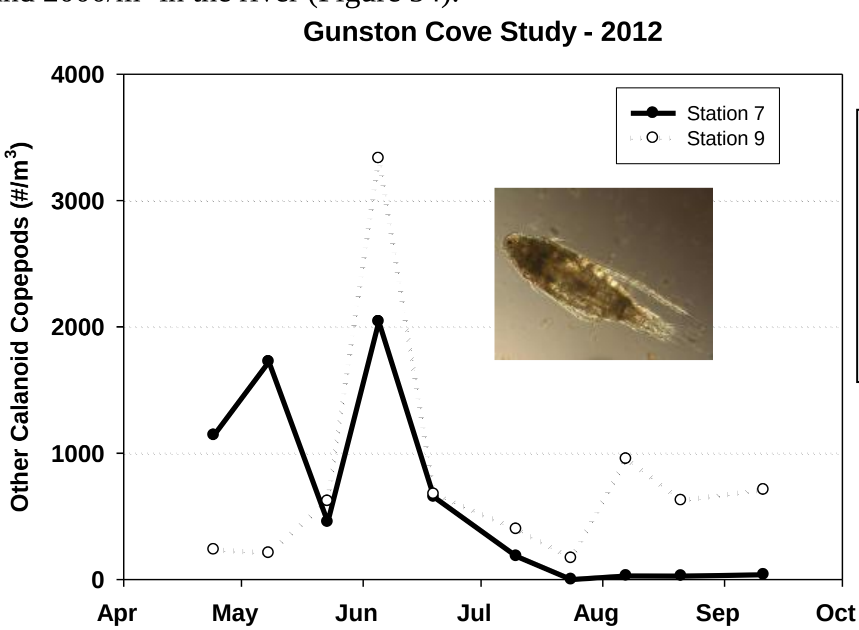
Figure 52. *Eurytemora* Density by Station (#/m^3).



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

Diaptomus was reached a maximum in the cove in early June at just over 500/m^3 (Figure 53). In the river the increase was more gradual reaching a peak in late June at about 150/m^3. Other calanoid copepods were quite abundant in spring reaching a peak of over 3000/m^3 in the cove and 2000/m^3 in the river (Figure 54).



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

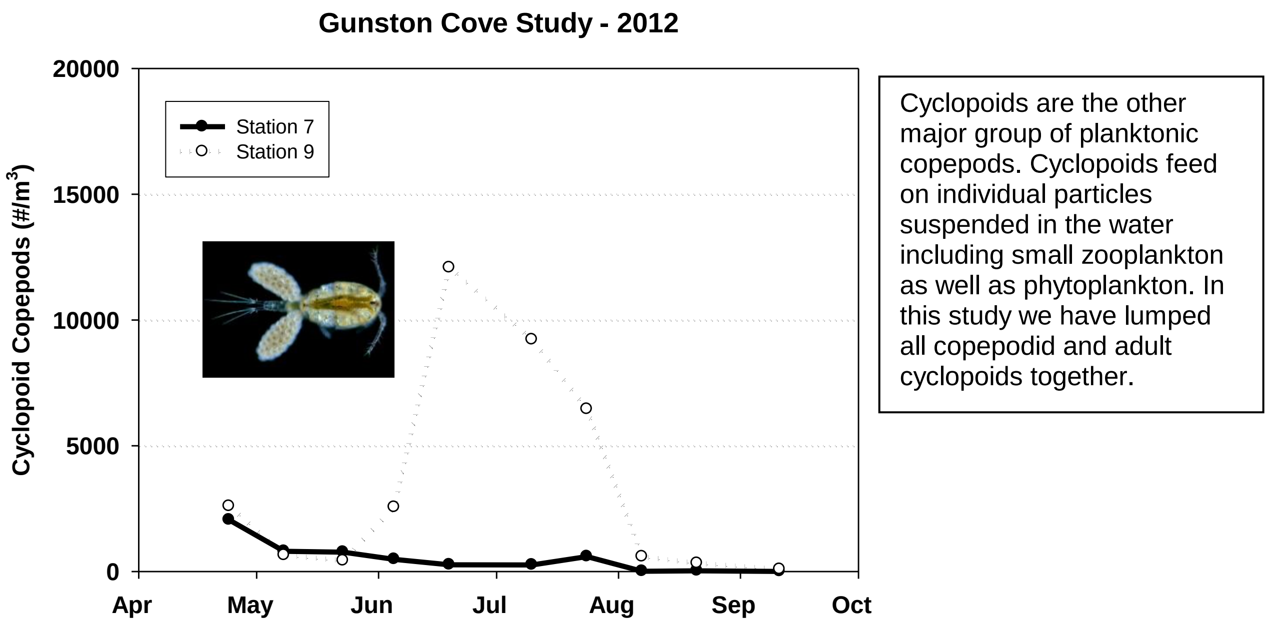


Figure 55. Cyclopoid Copepods by Station (#/m^3).

Cyclopoid copepods were very scarce in the cove in 2012, but quite abundant in the river (Figure 55). A peak value was attained in the river in late June of about 12,000/m^3.

E. Ichthyoplankton – 2012

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 sunfish 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 2012, we collected 14 samples (7 at Station 7 and 7 at Station 9) during the months April through July and obtained a total of 13250 larvae (Table 4). The fish larvae are often difficult to distinguish at the species level, thus some of the counts are only to the genus level. The dominant species was *Dorosoma sp*. with 56.9% of the catch. Most, if not all of these, were probably gizzard shad, since threadfin shad have been extremely rare in our collections of juvenile and adult fishes. Alewife were second in rank (21.9 %). White perch and *Alosa sp*. were common too (*Alosa sp.* is most likely alewife too), comprising 10.5% and 7.9% of total collections respectively. Other species were only collected in very low numbers (Table 4).

Table 4. The larval fishes collected in Gunston Cove and the Potomac River in 2012

Taxon	Common Name	Station 7	Station 9	Total	% of Total
Alosa mediocris	hickory shad	14	47	61	<1.0
Alosa pseudoharengus	alewife	426	2476	2902	21.9
Alosa sapidissima	American shad	17	40	57	<1.0
Centrarchidae	sunfish	3	0	3	<0.1
Clupeidae	herring or shad	483	562	1045	7.9
Dorosoma sp.	gizzard shad	1299	6242	7541	56.9
Lepomis sp.	sunfish	10	10	20	<1.0
Menidia sp.	silverside	14	6	20	<1.0
Menidia beryllina	inland silverside	17	110	127	<1.0
Micropterus salmoides	largemouth bass	2	1	3	<0.1
Morone sp.	perch or bass	0	27	27	<1.0
Morone americana	white perch	340	1049	1389	10.5
Morone saxatilis	striped bass	16	30	46	<1.0
Notemigonus crysoleucas	golden shiner	0	6	6	<0.1
Perca flavescens	yellow perch	3	0	3	<0.1
		2644	10606	13250	100

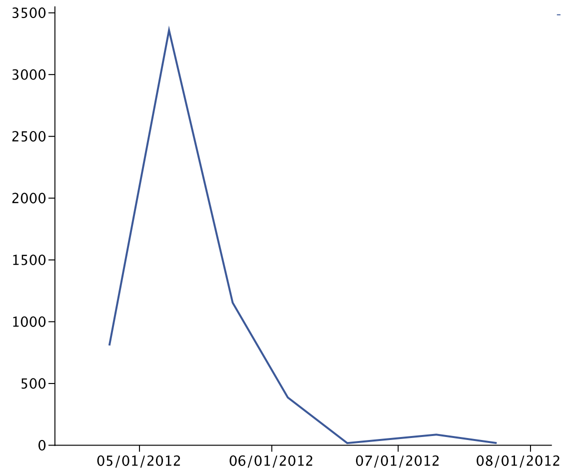


Figure 56. Clupeid larvae, mean abundance.

Clupeid larvae in Figure 56 include hickory shad, alewife, American shad, gizzard shad, threadfin shad and blueback herring (hard to distinguish from alewife larvae, and likely among the *Alosa* sp. group). 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 early May (Figure 56). Almost all individual larval species had their highest abundance in May. White perch larvae attained maximum numbers in late April, which dominated the pattern of the other larvae combined (Figure 57).

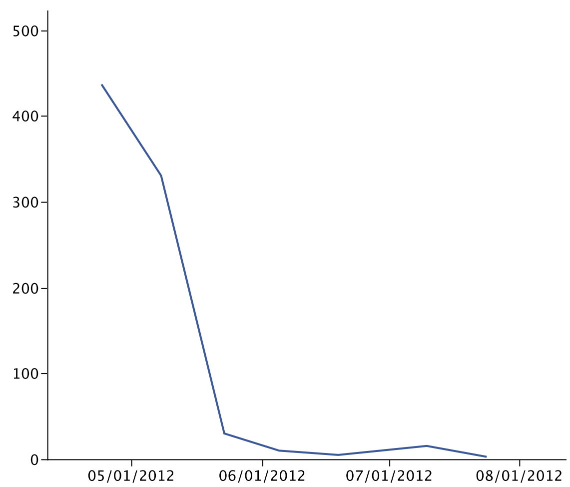


Figure 57. All other larvae, mean abundance.

F. Adult and juvenile fishes – 2012

Trawls

Trawl sampling was conducted between April 23 and June 22 at station 10, and between April 23 and September 10 at station 7 and 9. These three fixed stations have been sampled continuously since the inception of the survey. A total of 2994 fishes comprising 28 species representing 12 families were collected (Table 5). The majority (87.6%, numerically) of the fish collected were represented by 3 species: white perch (70.7%), bay anchovy (10.8%), and spottail shiner (6.1%). Other abundant species (annual total >1%) included: blue catfish (2.4%), bluegill (2%), redear sunfish (1.5%), and pumpkinseed (1.1%). Other species were observed sporadically and at low abundances (Tables 5 and 6).

Table 5. Adult and Juvenile Fish Collected by Trawling. Gunston Cove Study - 2012

Atherinidae	*Menidia beryllina*	inland silverside	13
Catostomidae	*Carpiodes cyprinus*	quillback	1
	Erimyzon oblongus	creek chubsucker	1
Centrarchidae	*Lepomis auritus*	redbreast sunfish	2
	Lepomis gibbosus	pumpkinseed	33
	Lepomis machrochirus	bluegill	60
	Lepomis microlophus	redear sunfish	44
	Lepomis sp.	Sunfish	10
	Micropterus salmoides	large-mouth bass	13
	Pomoxis nigromaculatus	black crappie	17
Clupeidae	*Alosa sapidissima*	American shad	1
	Alosa sp.	herring or shad	4
	Dorosoma cepedianum	gizzard shad	8
Cyprinidae	*Carassius auratus*	goldfish	18
	Cyprinus carpio	carp	2
	Hybognathus regius	Eastern silvery minnow	1
	Notemigonus crysoleucas	golden shiner	4
	Notropis hudsonius	spottail shiner	184
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	10
Engraulidae	*Anchoa mitchilli*	bay anchovy	323
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	9
	Ictalurus punctatus	channel catfish	6
	Ictaurus furcatus	blue catfish	73
Percichthyidae	*Morone americana*	white perch	2116
	Morone saxatilis	striped bass	2
Percidae	*Etheostoma olmstedi*	tessellated darter	8
	Perca flavescens	yellow perch	26
Sciaenidae	*Micropogonias undulatus*	Atlantic croaker	4
Soleidae	*Trinectes maculatus*	hogchoker	1
		Total	2994

Table 6. Adult and Juvenile Fish Collected by Trawling. Gunston Cove Study - 2012

			4/23	5/07	5/22	6/04	6/22	7/09	7/23	8/06	8/20	9/10
Atherinidae	*Menidia beryllina*	inland silverside	0	0	0	0	13	0	0	0	0	0
Catostomidae	*Carpiodes cyprinus*	quillback	0	0	0	0	0	1	0	0	0	0
	Erimyzon oblongus	creek chubsucker	0	0	0	0	0	0	1	0	0	0
Centrarchidae	*Lepomis auritus*	redbreast sunfish	0	2	0	0	0	0	0	0	0	0
	Lepomis gibbosus	pumpkinseed	0	0	4	2	0	15	4	2	2	4
	Lepomis machrochirus	bluegill	9	14	23	0	2	0	4	4	0	4
	Lepomis microlophus	redear sunfish	0	1	5	0	3	7	1	12	5	10
	Lepomis sp.	Sunfish	0	0	0	0	10	0	0	0	0	0
	Micropterus salmoides	largemouth bass	2	1	0	0	9	0	1	0	0	0
	Pomoxis nigromaculatus	black crappie	0	5	1	0	2	4	3	1	0	1
Clupeidae	*Alosa sapidissima*	American shad	0	0	0	0	0	0	0	0	1	0
	Alosa sp.	Herring or shad	1	0	2	0	0	1	0	0	0	0
	Dorosoma cepedianum	gizzard shad	0	0	0	0	0	4	1	3	0	0
Cyprinidae	*Carassius auratus*	goldfish	1	0	0	0	16	0	0	0	0	1
	Cyprinus carpio	carp	0	0	0	0	0	0	0	2	0	0
	Hybognathus regius	Eastern silvery minnow	1	0	0	0	0	0	0	0	0	0
	Notemigonus crysoleucas	golden shiner	0	0	2	0	1	0	1	0	0	0
	Notropis hudsonius	spottail shiner	3	15	57	9	78	10	6	4	2	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	0	0	0	0	9	1	0	0	0	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	0	0	0	1	3	1	83	235
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	0	0	0	0	1	4	2	2	0	0
	Ictalurus punctatus	channel catfish	2	0	1	3	0	0	0	0	0	0
	Ictaurus furcatus	blue catfish	0	0	0	5	29	11	3	10	6	9
Percichthyidae	*Morone americana*	white perch	6	59	133	328	764	175	135	376	85	55
	Morone saxatilis	striped bass	0	0	0	0	0	2	0	0	0	0
Percidae	*Etheostoma olmstedi*	tesselated darter	0	0	4	1	3	0	0	0	0	0
	Perca flavescens	yellow perch	2	1	22	1	0	0	0	0	0	0
Sciaenidae	*Micropogonias undulatus*	Atlantic croaker	0	0	0	3	1	0	0	0	0	0
Soleidae	*Trinectes maculatus*	hogchoker	0	0	0	0	0	0	0	0	1	0
		Total	27	98	254	352	941	236	165	417	185	319

The dominant migratory species, white perch, was ubiquitous occurring at all stations on every sampling date (Tables 5 and 6). In the spring adult white perch were primarily caught in the nets while later in the summer juveniles dominated. Bay anchovy has reoccurred in our catches again, and is most abundant in September.

In total numbers and species richness of fish, station 7 dominated the other stations with 2177 individuals from 23 species. Stations 9 and 10 had 605 individuals from 9 species and 212 individuals from 15 species, respectively (Table 6). Station 10 had half the amount of units of effort (sampling dates) than station 7 and 9 due to SAV cover, which is partially responsible for the low number. However, per unit of effort, station 10 still has the lowest catch.

Table 7. Adult and Juvenile Fish Collected by Trawling. Gunston Cove Study - 2012

		Station	7	9	10
Atherinidae	*Menidia beryllina*	inland silverside	2	0	11
Catostomidae	*Carpiodes cyprinus*	quillback	1	0	0
	Erimyzon oblongus	creek chubsucker	1	0	0
Centrarchidae	*Lepomis auritus*	redbreast sunfish	0	0	2
	Lepomis gibbosus	pumpkinseed	29	1	3
	Lepomis machrochirus	bluegill	27	0	33
	Lepomis microlophus	redear sunfish	37	0	7
	Lepomis sp.	sunfish	0	0	10
	Micropterus salmoides	largemouth bass	3	1	9
	Pomoxis nigromaculatus	black crappie	16	0	1
Clupeidae	*Alosa sapidissima*	American shad	1	0	0
	Alosa sp.	herring or shad	4	0	0
	Dorosoma cepedianum	gizzard shad	8	0	0
Cyprinidae	*Carassius auratus*	goldfish	1	0	17
	Cyprinus carpio	carp	2	0	0
	Hybognathus regius	eastern silvery minnow	0	1	0
	Notemigonus crysoleucas	golden shiner	2	0	2
	Notropis hudsonius	spottail shiner	162	7	15
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	1	0	9
Engraulidae	*Anchoa mitchilli*	bay anchovy	6	317	0
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	9	0	0
	Ictalurus punctatus	channel catfish	2	3	1
	Ictaurus furcatus	blue catfish	0	73	0
Percichthyidae	*Morone americana*	white perch	1850	201	65
	Morone saxatilis	striped bass	2	0	0
Percidae	*Etheostoma olmstedi*	tessellated darter	4	0	4
	Perca flavescens	yellow perch	3	0	23
Sciaenidae	*Micropogonias undulatus*	Atlantic croaker	4	0	0
Soleidae	*Trinectes maculatus*	hogchoker	0	1	0
		Total	2177	605	212

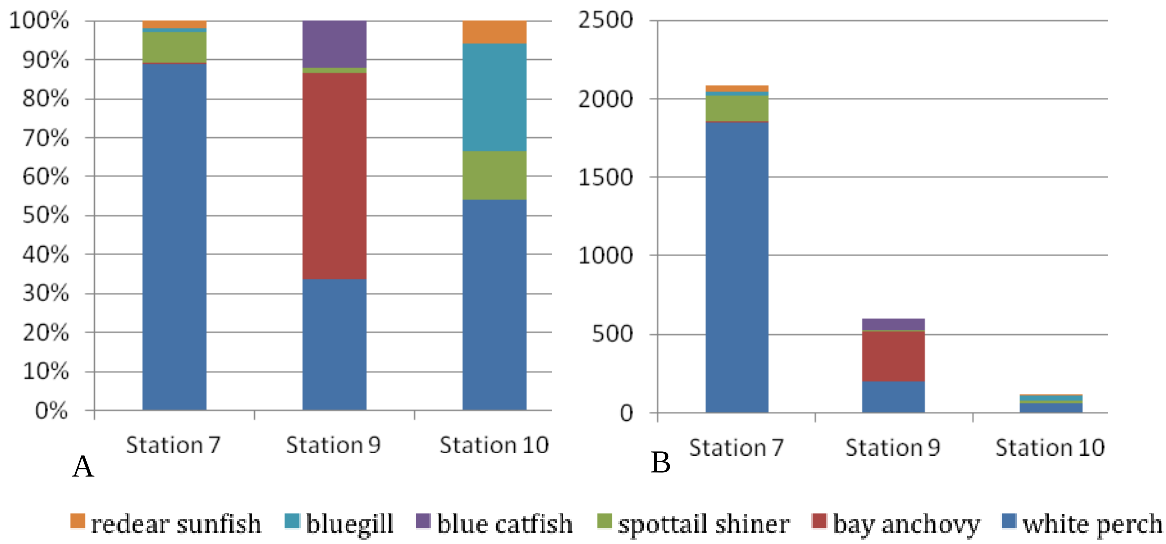


Figure 58A and B. Adult and Juvenile Fishes Collected by Trawling. Dominant Species by Station.

The six most abundant species varied in representation across stations (Figure 58A and B). 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 reason for the high total catch of station 7. Blue catfish were exclusively observed at station 9. Blue catfish are primarily a mainstem species and have not been featured prominently at stations within the cove. Clupeids were not as abundant as in previous years and, just like in 2011, the individual species could not be counted among the six most abundant species. Bay anchovy was amongst the most abundant species after being absent from catches in 2011. The high numbers were due to a high catch of Bay anchovy the last day of the season in station 9. Station 7 was overall the most productive site, with a total abundance more than 3 times higher than the other two stations. The low total abundance at station 10 is partially due to the fact that trawling at station 10 stopped at the end of June because of extensive SAV cover, while trawling at 7 and 9 continued until September 2012.

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.

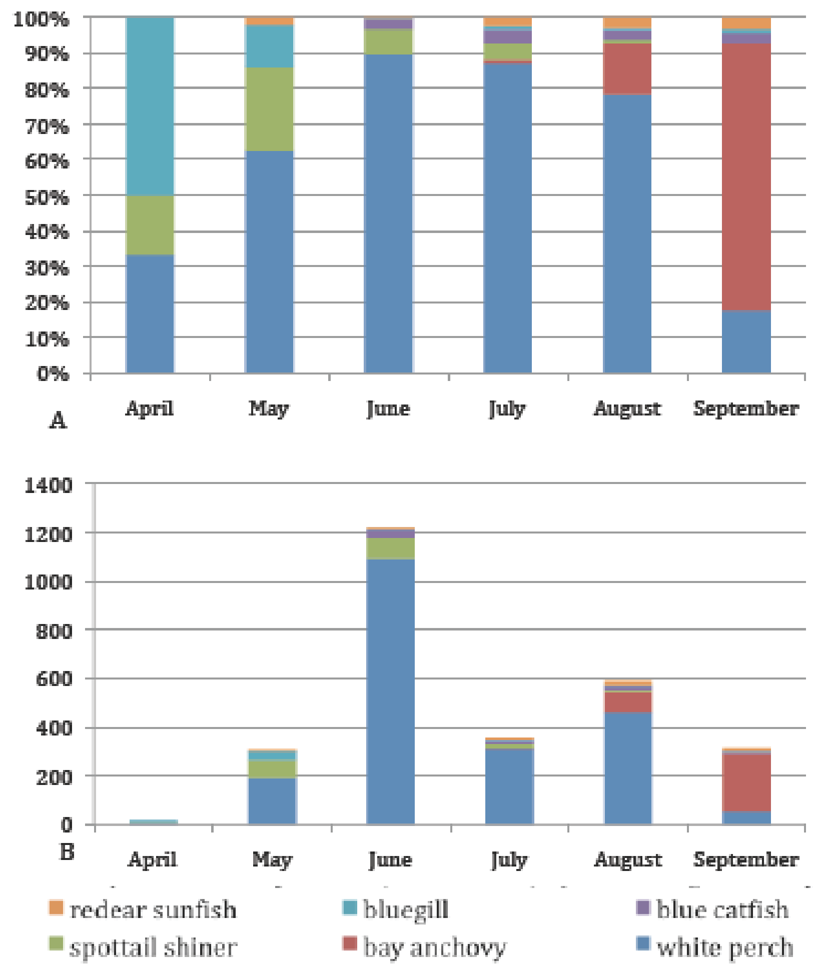


Figure 59A and B. Adult and Juvenile Fishes Collected by Trawling. Dominant Species by Month.

White perch was the most common species, and was present throughout the season (Figure 59A and B). The relative abundance of spottail shiner was high early in the season and tapered of toward the end of the season, as can be more clearly seen on a scale of relative abundance (Figure 59A). Bay anchovy shows an opposite trend, with highest abundance at the end of the season. Other common species were sunfish species and blue catfish. In 2012, the most productive month was June, which was dominated by a large cohort of juvenile white perch.

Blueback herring (*Alosa aestivalis*) and Alewife (*Alosa pseudo-harengus*) 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.

Seines

Seine sampling was conducted approximately semi-monthly at 4 stations between 23 April and 10 September. As planned, only one sampling trip per month was performed in April and September. We stopped seining at station 4 on July 23 due to dense SAV growth.

Stations 4, 6, and 11 have been sampled continuously since 1985. Station 4A was added in 2007 to have a continuous seine record when dense SAV impedes seining in 4. Station 4A is a routine station now, also when seining at 4 is possible. This allows fro comparison between 4 and 4A.

A total of 35 seine samples were conducted, comprising 6742 fishes and 27 species (Table 8). The dominant species in seine catches was banded killifish (72.2%), followed by inland silverside (6.6%). Several other species occurred at high abundances (>100 total) including: bluegill, eastern silvery minnow, golden shiner, spottail shiner and white perch. Other species occurred at medium or low abundances (Table 8). Continuing a recent trend since 2007 were moderate catches of (primarily juvenile) largemouth bass. The relative abundance of banded killifish is higher than before, which can be due to the extensive SAV cover now an established presence in the cove.

Table 8. Adult and Juvenile Fish Collected by Seining. Gunston Cove Study - 2012

Atherinidae	*Menidia beryllina*	inland silverside	445
Belonidae	*Strongylura marina*	Atlantic needlefish	22
Catostomidae	*Carpiodes cyprinus*	quillback	78
	Erimyzon oblongus	creek chubsucker	9
Centrarchidae	*Lepomis auritus*	redbreast sunfish	5
	Lepomis gibbosus	pumpkinseed	44
	Lepomis machrochirus	bluegill	131
	Lepomis microlophus	redear sunfish	56
	Lepomis sp.	sunfish	1
	Micropterus salmoides	largemouth bass	32
	Pomoxis nigromaculatus	black crappie	3
Clupeidae	*Alosa pseudoharengus*	alewife	5
	Alosa sapidissima	American shad	1
	Alosa sp.	herring or shad	80
	Dorosoma cepedianum	gizzard shad	2
Cyprinidae	*Carassius auratus*	goldfish	79
	Hybognathus regius	eastern silvery minnow	133
	Notemigonus crysoleucas	golden shiner	108
	Notropis hudsonius	spottail shiner	220
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	4870
	Fundulus heteroclitus	mummichog	10
Engraulidae	*Anchoa mitchilli*	bay anchovy	1
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	1
Lepisosteidae	*Lepisosteus osseus*	longnose gar	1
Percichthyidae	*Morone americana*	white perch	194
	Morone saxatilis	striped bass	36
Percidae	*Etheostoma olmstedi*	tesselated darter	94
	Perca flavescens	yellow perch	2
Poeciliidae	*Gambusia holbrooki*	mosquitofish	79
		Total	6742

Seasonal catch patterns were variable with may representing the most productive period, due to the very high abundance of banded killifish during that month (Table 9). Peaks in abundance tended to be short represented by two sampling trips, and for most species these pulses represented cohorts of young-of-the-year. Other peaks in catch constituted pulses of juveniles that recently recruited to shallow habitats accessible by the seine (e.g., gizzard shad, blueback herring, white perch, and striped bass). The high abundance early in the season may be due to the mild 2011/2012 winter. For the numerically dominant banded killifish, catches averaged 487 per sampling round.

The high abundance of banded killifish in station 4 and 4A heavily dominated the distribution of the abundance over sampling sites. Abundance varied from n=3010 fish at station 4 to n=789 at station 11 (Table 10). In previous years, highest abundance was found in Station 11 and lowest at Station 4/4A, so the increased abundance of banded killifish is also causing a spatial shift in productivity in Gunston Cove. Species richness also increased further into the Cove, and varied from 14 species in station 11 to 21 species in station 4. Most species had highest abundance at station 4 and 4A, except for inland silverside, eastern silvery minnow, white perch and striped bass, which were most abundant at station 11.

Of the 6 dominant species ranked by catch rate, banded killifish was most abundant (Figure 60A and B). Other dominant species in 2012 included bluegill, eastern silvery minnow, white perch, spottail shiner and inland silverside. These species were not the most dominant last year, which indicates a shift in community structure. Banded killifish abundances dominated at every station except station 11, where the species are most evenly distributed.

The most productive period for seine sampling occurred in May, which is a month earlier than usual (Figure 61A and B). As mentioned before, this can be an effect of a mild winter. Banded killifish occurred in every month peaking in May, with very low abundance in September. The community structure in September is completely different than the rest of the year because of this, with highest abundances from eastern silvery minnow, inland silverside and white perch.

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 individuals 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 - 2012

			4/23	5/07	5/22	6/04	6/22	7/09	7/23	8/06	8/20	9/10
Atherinidae	*Menidia beryllina*	inland silverside	19	58	87	5	73	124	6	4	1	68
Belonidae	*Strongylura marina*	Atlantic needlefish	0	0	14	1	4	1	0	0	2	0
Catostomidae	*Carpiodes cyprinus*	quillback	0	0	0	40	22	1	0	15	0	0
	Erimyzon oblongus	creek chubsucker	0	7	0	1	1	0	0	0	0	0
Centrarchidae	*Lepomis auritus*	redbreast sunfish	1	0	0	0	0	3	1	0	0	0
	Lepomis gibbosus	pumpkinseed	22	14	3	0	2	0	1	0	1	1
	Lepomis machrochirus	bluegill	14	58	3	0	0	6	17	21	8	4
	Lepomis microlophus	redear sunfish	37	2	5	3	4	0	1	2	0	2
	Lepomis sp.	sunfish	0	0	0	0	0	1	0	0	0	0
	Micropterus salmoides	large-mouth bass	0	7	0	1	7	4	8	0	4	1
	Pomoxis nigromaculatus	black crappie	2	1	0	0	0	0	0	0	0	0
Clupeidae	*Alosa pseudoharengus*	alewife	0	0	0	3	0	2	0	0	0	0
	Alosa sapidissima	American shad	0	0	0	0	0	0	1	0	0	0
	Alosa sp.	herring or shad	79	0	0	0	0	0	0	1	0	0
	Dorosoma cepedianum	gizzard shad	0	1	0	1	0	0	0	0	0	0
Cyprinidae	*Carassius auratus*	goldfish	0	0	0	0	52	24	2	1	0	0
	Hybognathus regius	Eastern silvery minnow	1	35	3	2	4	2	0	1	3	82
	Notemigonus crysoleucas	golden shiner	84	8	0	9	0	0	0	2	1	4
	Notropis hudsonius	spottail shiner	11	4	0	134	64	0	2	0	0	5
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	968	1749	1242	196	195	68	262	68	105	17
	Fundulus heteroclitus	mummichog	0	0	3	0	0	6	1	0	0	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	0	0	0	0	0	1	0	0
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	0	1	0	0	0	0	0	0	0	0
Lepisosteidae	*Lepisosteus osseus*	longnose gar	0	0	0	0	1	0	0	0	0	0
Percichthyidae	*Morone americana*	white perch	11	2	4	24	25	4	29	35	8	52
	Morone saxatilis	striped bass	0	0	0	31	0	0	0	2	2	1
Percidae	*Etheostoma olmstedi*	tesselated darter	13	19	2	54	5	1	0	0	0	0
	Perca flavescens	yellow perch	0	1	0	1	0	0	0	0	0	0
Poeciliidae	*Gambusia holbrooki*	mosquitofish	1	3	1	0	0	3	19	2	0	50
		Total	1263	1970	1367	506	459	250	350	155	135	287

Table 10. Adult and Juvenile Fish Collected by Seining. Gunston Cove Study - 2012

			4	4A	6	11
Atherinidae	*Menidia beryllina*	inland silverside	110	7	11	317
Belonidae	*Strongylura marina*	Atlantic needlefish	7	14	0	1
Catostomidae	*Carpiodes cyprinus*	quillback	61	0	0	17
	Erimyzon oblongus	creek chubsucker	1	8	0	0
Centrarchidae	*Lepomis auritus*	redbreast sunfish	0	0	5	0
	Lepomis gibbosus	pumpkinseed	4	35	5	0
	Lepomis machrochirus	bluegill	21	57	53	0
	Lepomis microlophus	redear sunfish	7	43	6	0
	Lepomis sp.	sunfish	0	1	0	0
	Micropterus salmoides	large-mouth bass	13	14	5	0
	Pomoxis nigromaculatus	black crappie	1	2	0	0
Clupeidae	*Alosa pseudoharengus*	alewife	0	0	0	5
	Alosa sapidissima	American shad	0	0	0	1
	Alosa sp.	herring or shad	1	0	78	1
	Dorosoma cepedianum	gizzard shad	0	0	0	2
Cyprinidae	*Carassius auratus*	goldfish	0	71	8	0
	Hybognathus regius	Eastern silvery minnow	5	1	3	124
	Notemigonus crysoleucas	golden shiner	57	24	7	20
	Notropis hudsonius	spottail shiner	202	9	1	8
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	2328	1517	900	125
	Fundulus heteroclitus	mummichog	1	0	9	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	0	1
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	1	0	0	0
Lepisosteidae	*Lepisosteus osseus*	longnose gar	1	0	0	0
Percichthyidae	*Morone americana*	white perch	58	1	4	131
	Morone saxatilis	striped bass	0	0	0	36
Percidae	*Etheostoma olmstedi*	tesselated darter	70	23	1	0
	Perca flavescens	yellow perch	1	1	0	0
Poeciliidae	*Gambusia holbrooki*	mosquitofish	60	4	15	0
		Total	3010	1832	1111	789

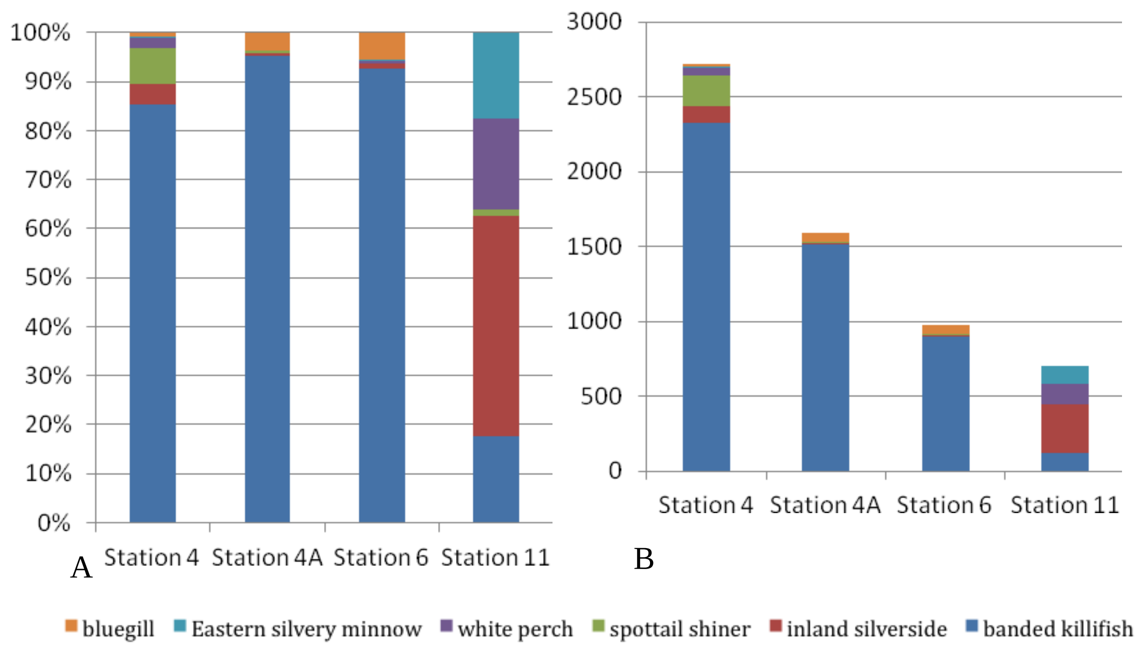


Figure 60. Adult and Juvenile Fishes Collected by Seining. Dominant Species by Station.

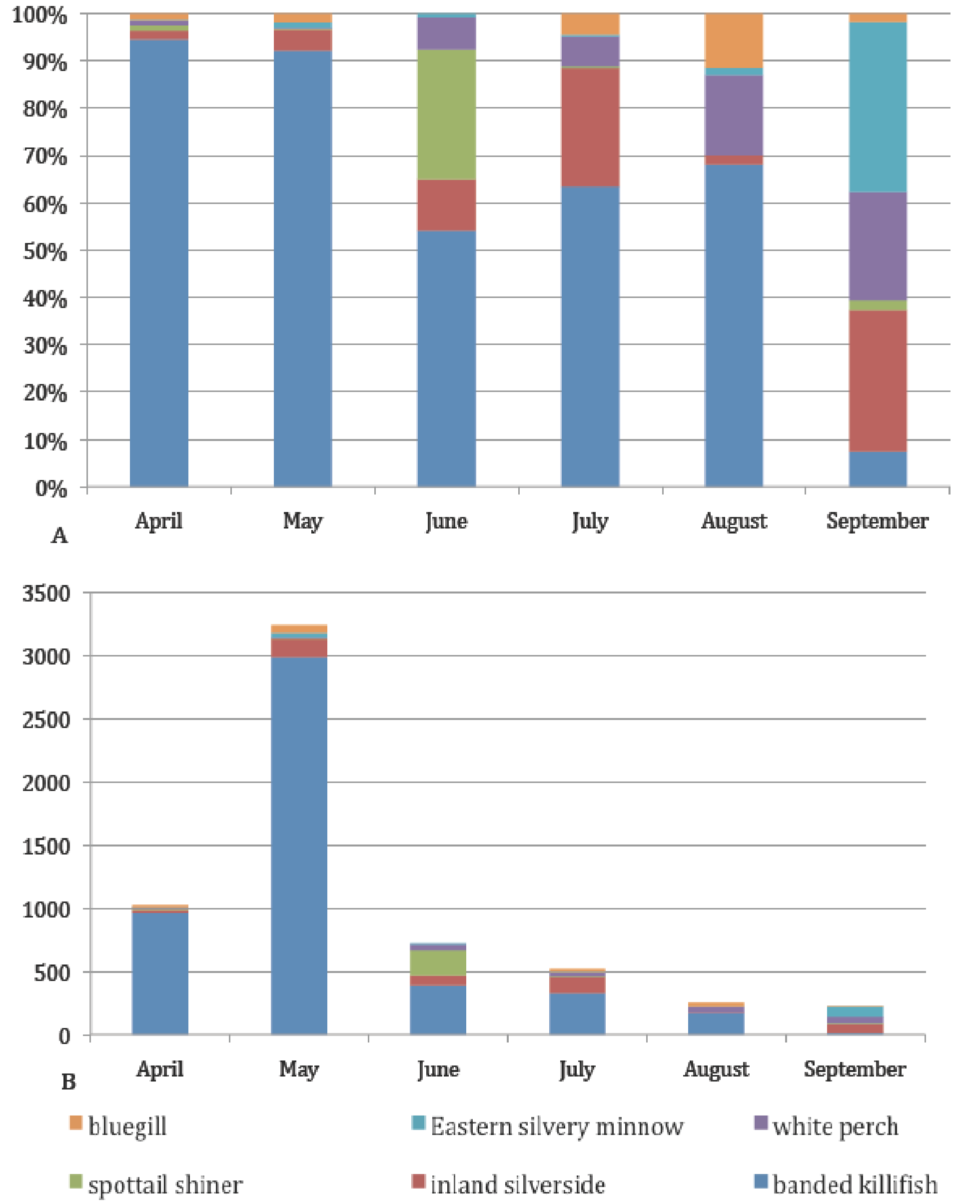


Figure 61A and B. Adult and Juvenile Fish Collected by Seining. Dominant Species by Month.

Fyke nets

We added fyke nets to the sampling regime in June 2012 to better represent the fish community present within SAV beds. We collected a total number of 1500 specimens of 14 species in the two fyke nets (Station 10F and Station 4F; Figure 1B; Table 11).

Table 11. Adult and Juvenile Fish Collected by fyke net. Gunston Cove Study - 2012

Catostomidae	*Carpiodes cyprinus*	quillback	1
	Erimyzon oblongus	creek chubsucker	2
Centrarchidae	*Lepomis auritus*	redbreast sunfish	2
	Lepomis gibbosus	pumpkinseed	91
	Lepomis machrochirus	bluegill	532
	Lepomis microlophus	redear sunfish	161
	Lepomis sp.	sunfish	285
	Micropterus salmoides	large-mouth bass	36
Cyprinidae	*Carassius auratus*	goldfish	53
	Hybognathus regius	Eastern silvery minnow	1
	Notropis hudsonius	spottail shiner	8
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	306
Percichthyidae	*Morone americana*	white perch	13
Percidae	*Etheostoma olmstedi*	tesselated darter	5
Poeciliidae	*Gambusia holbrooki*	mosquitofish	4
		Total	1500

Highest abundance in the fyke nets was found in August, when SAV cover is most extensive and dense (Table 12). While banded killifish was most abundant in May, all other species were most abundant in August.

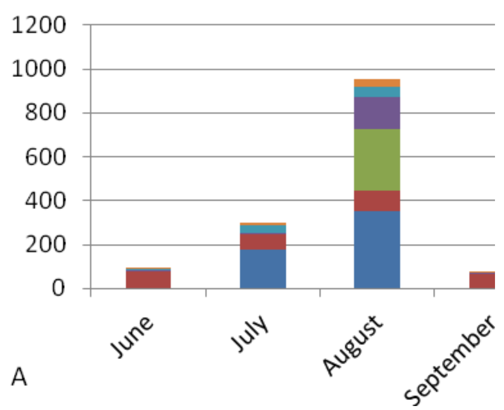
Table 12. Adult and Juvenile Fish Collected by fyke nets. Gunston Cove Study - 2012

			6/22	7/09	7/23	8/06	8/20	9/10
Catostomidae	*Carpiodes cyprinus*	quillback	0	0	0	1	0	0
	Erimyzon oblongus	creek chubsucker	1	0	0	1	0	0
Centrarchidae	*Lepomis auritus*	redbreast sunfish	0	0	0	2	0	0
	Lepomis gibbosus	pumpkinseed	5	28	7	50	1	0
	Lepomis machrochirus	bluegill	1	83	96	160	191	1
	Lepomis microlophus	redear sunfish	6	2	4	33	108	8
	Lepomis sp.	sunfish	0	0	0	285	0	0
	Micropterus salmoides	large-mouth bass	5	15	3	13	0	0
Cyprinidae	*Carassius auratus*	goldfish	6	5	7	29	4	2
	Hybognathus regius	Eastern silvery minnow	0	1	0	0	0	0
	Notropis hudsonius	spottail shiner	0	4	2	0	0	2
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	79	41	29	60	33	64
Percichthyidae	*Morone americana*	white perch	1	9	0	3	0	0
Percidae	*Etheostoma olmstedi*	tesselated darter	0	1	0	2	1	1
Poeciliidae	*Gambusia holbrooki*	mosquitofish	4	0	0	0	0	0
		Total	108	189	148	639	338	78

Unlike the seine collections, banded killifish was not the most abundant species collected with the fyke nets. The most abundant species were sunfish, specifically pumpkinseed, bluegill and redear sunfish (Table 13; *Lepomis sp.* indicates that we could not identify which of the three Lepomis species the specimen was, which occurred with small juveniles).

Table 13. Adult and Juvenile Fish Collected by fyke nets. Gunston Cove Study - 2012

			Station 10F	Station 4F
Catostomidae	*Carpiodes cyprinus*	quillback	1	0
	Erimyzon oblongus	creek chubsucker	1	1
Centrarchidae	*Lepomis auritus*	redbreast sunfish	0	2
	Lepomis gibbosus	pumpkinseed	38	53
	Lepomis machrochirus	bluegill	388	144
	Lepomis microlophus	redear sunfish	58	103
	Lepomis sp.	sunfish	0	285
	Micropterus salmoides	largemouth bass	6	30
Cyprinidae	*Carassius auratus*	goldfish	31	22
	Hybognathus regius	eastern silvery minnow	1	0
	Notropis hudsonius	spottail shiner	7	1
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	152	154
Percichthyidae	*Morone americana*	white perch	13	0
Percidae	*Etheostoma olmstedi*	tessellated darter	2	3
Poeciliidae	*Gambusia holbrooki*	mosquitofish	2	2
		Total	700	800



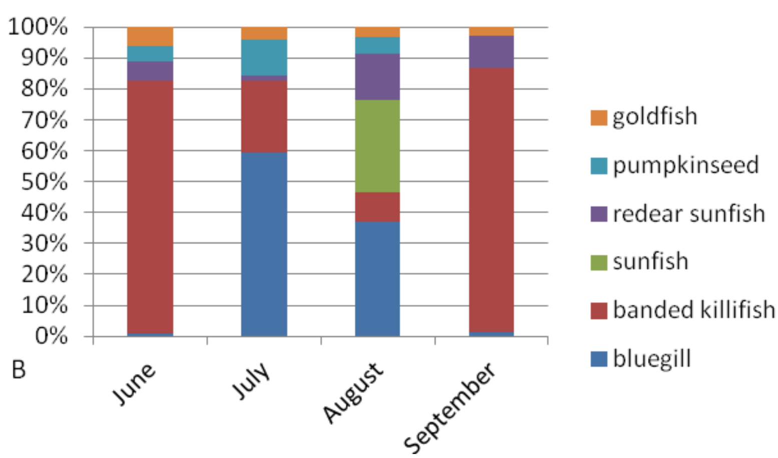


Figure 62A and B. Adult and Juvenile Fish Collected by fyke nets. Dominant Species by Month.

Abundance of dominant species by month (Figure 62A and B) reveals that banded killifish was present with similar abundance throughout the season (62A), but reach the highest relative abundance in June and September due to the low numbers of other species present in those months (62B). The high amount of unidentified sunfish in August (green bar) is indicative of a large cohort of very small juvenile sunfish from a recent spawning event. Considering the high abundance of bluegills in July, these small juveniles in August are most likely bluegills. The numbers per fyke net were very similar (Figure 63A and B). The community structure of the two fyke nets is very similar, the main difference being the higher number of unidentified sunfish in Station 4F. The dominant species in the fyke nets were the three sunfish species, banded killifish and goldfish. The fyke nets thereby mostly represents resident freshwater species.

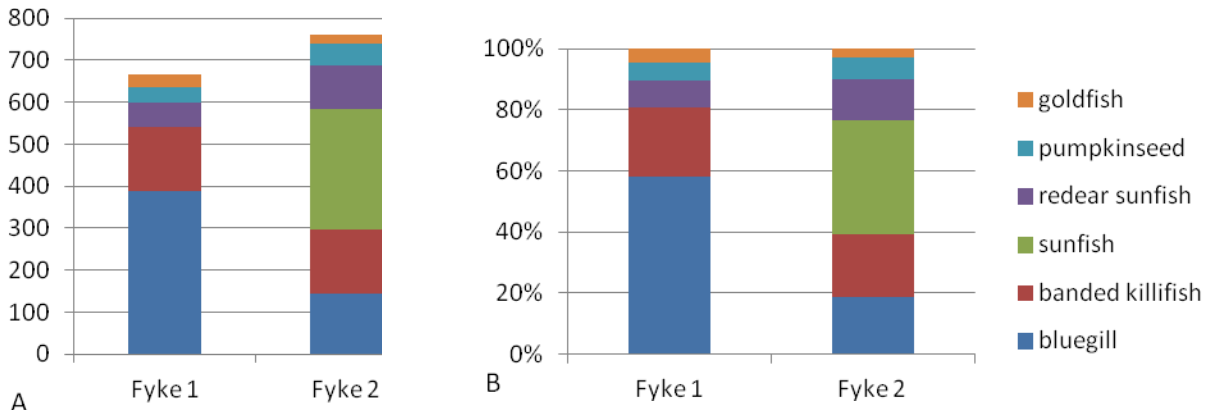


Figure 63A and B. Adult and Juvenile Fishes Collected by fyke nets. Dominant Species by Station (Fyke 1 is at station 10F and Fyke 2 at Station 4F).

F. Submersed Aquatic Vegetation – 2012

SAV data overflights by VIMS were successful again in 2012 following the lack of data for 2011. The map below (Figure 64) depicts the area covered by SAV that was detectable by aerial remote sensing. The areal coverage by bed for 2012 in Gunston Cove was B4: 178.4 ha, F4: 0.3 ha, G4: 0.4 ha; this yielded a total acreage of 179 ha for 2012. This was similar to values found since 2005.

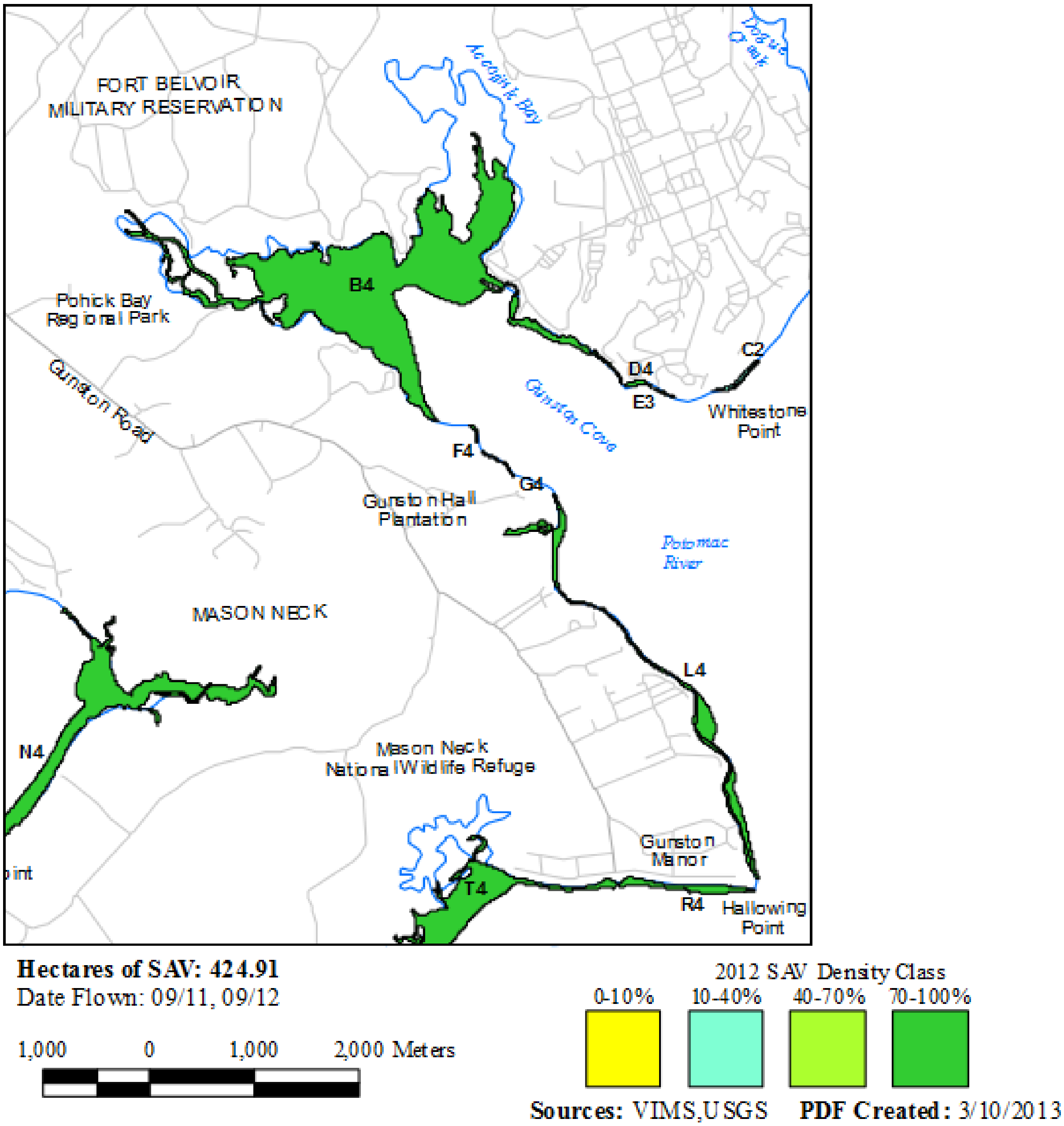


Figure 64. Distribution and density of Submersed Aquatic Vegetation (SAV) in the Gunston Cove area in 2012. VIMS (http://www.vims.edu/bio/sav/index.html).

H. Benthic Macroinvertebrates - 2012

Triplicate petite ponar samples were collected at the cove (Station 7) and river (Station 9) sites on three dates (May 23, June 19, July 24, and August 21). Oligochaetes were the most common invertebrates collected in these samples and were found at about twice the density at Station 9 than at Station 7 (Figure 65a). In the cove chironomid (midge) larvae made up the bulk of the remaining organisms and in 2012 were even more abundant than oligochaetes. In the river chironomids were a minor component of the community.

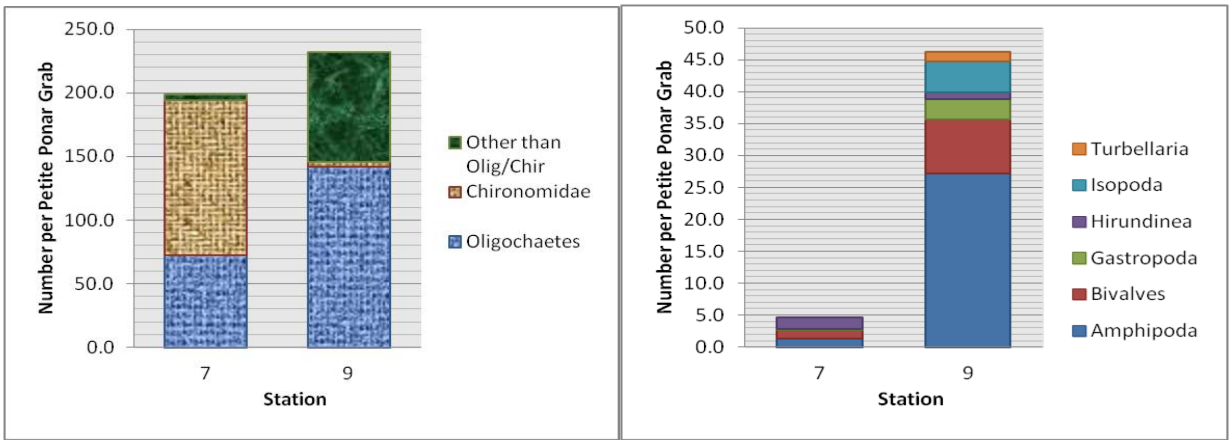


Figure 65. Average abundance of various benthic macroinvertebrate taxa in petite ponar samples collected on four dates in 2012. (a) dominant taxa. (b) "other" group from (a) broken out by taxa.

Other organisms were found at both sites, but were substantially more numerous and more diverse at Station 9. At the river site, amphipods (crustaceans commonly known as scuds) were found in substantial numbers. Bivalves, led by *Corbicula* (Asiatic clam), were also common. Members of the groups Gastropoda (snails), Hirundinea (leeches), Isopoda (aquatic sow bugs), and Turbellaria (flatworms) were also found. In the cove, amphipods, bivalves, and leeches were present, but never abundant.

Within the bivalves, unionid mussels were collected in addition to the *Corbicula*. Within the isopod group, there were two taxa: *Cyathura*, which made up about 90% of the isopods found and *Chiridotea*, which comprised the other 10%.

These results are consistent with previous collections although the higher density of oligochaetes in the channel is unusual. The composition of the benthic macroinvertebrate community at these two sites seems to mainly reflect 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 supportive of the other taxa found in the river. 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. However, the continued occurrence of taxa besides chironomids and oligochaetes in the cove is a positive indicator that conditions may be improving.