THE ONGOING AQUATIC MONITORING PROGRAM

FOR THE GUNSTON COVE AREA

OF THE TIDAL FRESHWATER POTOMAC RIVER

2011

FINAL REPORT
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by

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INTRODUCTION

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

The 1984 report entitled "An Ecological Study of Gunston Cove – 1984" (Kelso et al. 1985) contained a thorough discussion of the history and geography of the cove. The reader is referred to that document for further details.

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

The authors wish to thank the numerous individuals and organizations whose cooperation, hard work, and encouragement have made this project successful. We wish to thank the Fairfax County Department of Public Works and Environmental Services, Wastewater Planning and Monitoring Division, Environmental Monitoring Branch, particularly Elaine Schaeffer 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 Beverly Bachman, Alex Graziano, Lara Isdell, Saiful Islam, Naghma Malik, Julie McGivern, Chris Ruck, Shakiba Salehian, 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 (Figure 1). 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.

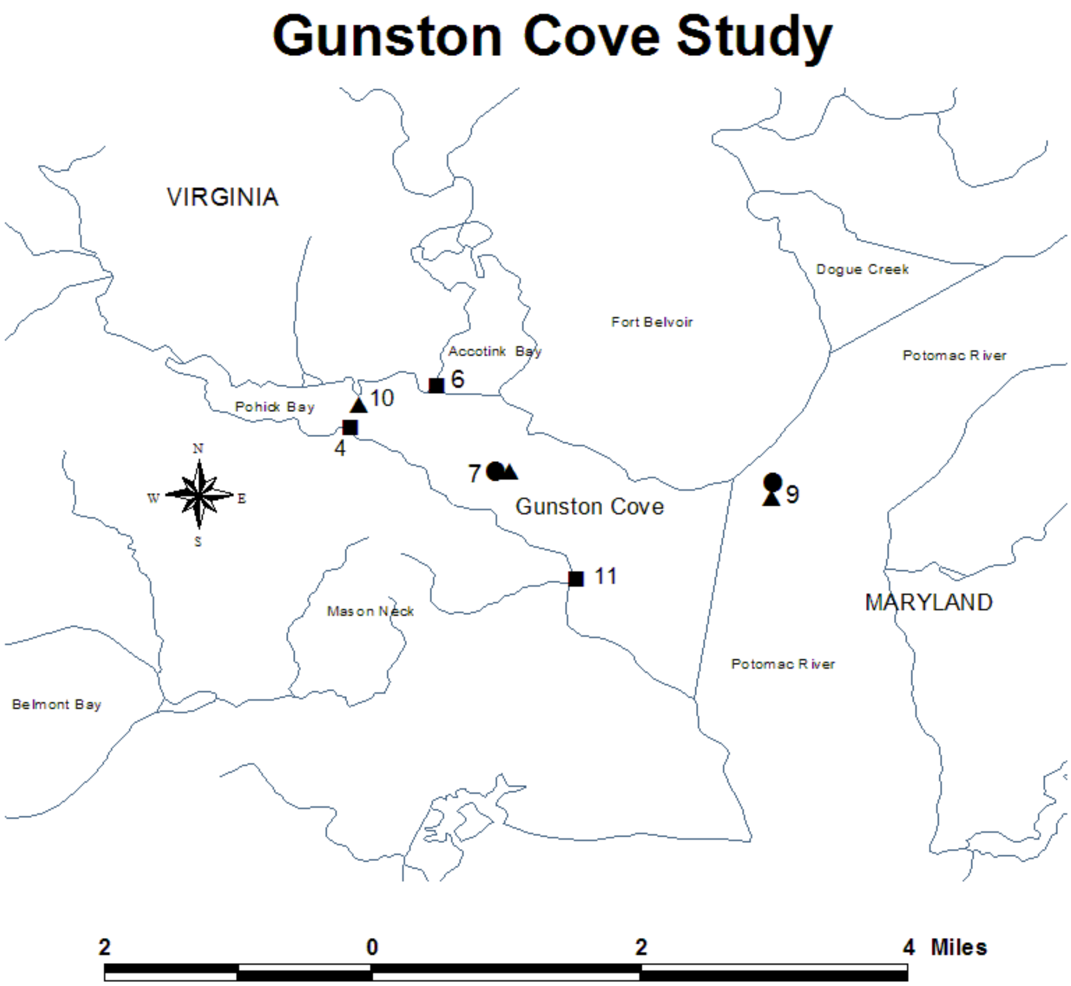


Figure 1. Gunston Cove area of the Tidal Potomac River showing sampling stations. Circles (●) represent Plankton/Profile stations, triangles (▲) represent Fish Trawl stations, and squares (■) represent Fish Seine stations.

Table 1
Sampling Dates and Weather Data for 2011

	Type of Sampling				Avg Daily Temp (^oC)		Precipitation (cm)	
Date	G	F	T	S	1-Day	3-Day	1-Day	3-Day
April 14		F*			15.0	14.6	0	1.27
April 19	G	F			16.7	15.9	0.03	0.03
April 26			T	S	23.3	22.2	0	1.89
May 3	G	F			22.2	18.1	0.05	0.09
May 10			T	S	17.8	17.6	0	0.01
May 17	G				20.0	20.7	0.03	0.52
May 20			T	S	17.8	18.5	0.01	0.83
May 23				S	23.3	22.0	0.05	0.06
June 3			T	S	22.2	26.3	0	0.41
June 7	G	F			26.1	25.2	0	0.01
June 14		F*			21.7	23.9	0.01	0.19
June 17			T	S	24.4	23.5	0.51	2.62
June 21	G				26.1	25.4	0.03	0.91
June 30			T	S	25.6	27.6	0	0.01
July 5	G	F			28.3	28.0	0.01	2.24
July 18			T	S	28.3	26.9	0	0
July 19	G				31.1	28.9	0.61	0.61
July 27	B				30.0	30.0	0	0.51
July 29			T	S	33.3	31.3	0	0
August 2	G	F			30.0	31.1	0	0
August 9	B	N			30.0	30.0	0	1.70
August 12			T	S	26.7	27.6	0	0
August 16	G				26.7	25.6	0	3.49
August 17		F*			27.2	26.3	0	T
August 26			T	S	26.7	25.6	0.03	1.09
Sept 6	G	F			18.9	23.1	2.29	5.74
Sept 20	G	F*			20.0	18.3	0.41	0.41
Sept 23			T	S	21.1	21.7	2.46	2.53
Oct 5				S	17.8	14.6	0	0.03

Type of Sampling: G: GMU profiles and plankton, B: bloom sampling, F: nutrient and lab water quality by Fairfax County Laboratory, N: nutrients only, T: fish collected by trawling, S: fish collected by seining.
*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:

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

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

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

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

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

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

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

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:

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

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

C. Adult and Juvenile Fish

Fishes were sampled by trawling at Stations 7, 9, and 10 (Figure 1). 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 August. This trend started in 2010 and will likely continue. In 2012, fyke nets will be added to the sampling design to ensure continued sampling in station 10.

Shoreline fishes were sampled by seining at 4 stations: 4, 4A, 6, and 11 (Figure 1). The seine was 45-50 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. In 2012, fyke nets will be added to the sampling design to ensure continued sampling in station 4.

After the catch from various gear was hauled in, the fishes were measured for standard length to the nearest 0.5 cm. Standard length is the distance from the front tip of the head to the end of the vertebral column and base of the caudal fin. This is evident in a crease perpendicular to the axis of the body when the caudal fin is pulled to the side.

If the identification of the fish was not certain in the field, the specimen was preserved in 10% formalin 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), and Eddy and Underhill (1978).

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.wims.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. Unfortunately, the VIMS SAV program was not successful in obtaining reliable images of the Gunston Cove area in 2011 so no data are available.

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 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 2011 air temperature was substantially above average for most of the year. All months from April through August were at least 1.5°C greater than normal (Table 2). July was the warmest month and also had the greatest positive departure from normal. There were 42 days with maximum temperature above 32.2°C (90°F) during 2011 compared with 4 in 2004, 18 in 2005, 29 in 2006, 33 in 2007, 31 in 2008, 16 days in 2009, and 62 in 2010. Precipitation was above normal in March and April, but well below normal in May, June and July. Very large rainfall amounts occurred in late August and early September attributable to Hurricane Irene and Tropical Storm Lee.

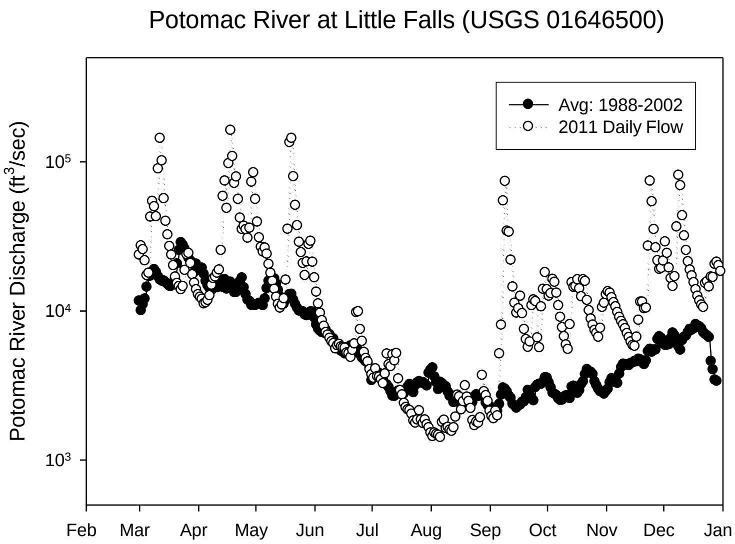
Table 2. Meteorological Data for 2011. National Airport. Monthly Summary.

MONTH	Air Temp (°C)		Precipitation (cm)	
March	7.7	(8.1)	11.2	(9.1)
April	15.0	(13.4)	8.2	(7.0)
May	20.3	(18.7)	4.4	(9.7)
June	26.1	(23.6)	4.4	(8.0)
July	29.2	(26.2)	7.7	(9.3)
August	26.7	(25.2)	22.7	(8.7)
September	21.9	(21.4)	22.5	(9.6)
October	14.8	(14.9)	10.0	(8.2)
November	11.5	(9.3)	4.9	(7.7)
December	6.5	(4.2)	12.5	(7.8)

Note: 2011 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. (+) 2011 month > 2x Long Term Avg. (-) 2011 month < ½ Long Term Avg.

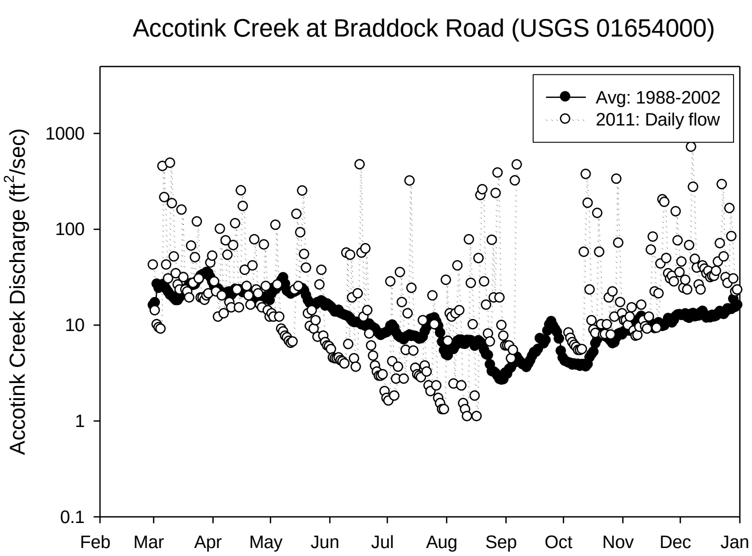
	Potomac River at Little Falls (cfs)		Accotink Creek at Braddock Rd (cfs)	
	2011	Long Term Average	2011	Long Term Average
January	2347 (-)	13700	11.2 (-)	31
February	9360	16600	31.0	35
March	34260	23600	74.2	42
April	43940 (+)	20400	48.1	36
May	33450 (+)	15000	32.4	34
June	7078	9030	28.4	28
July	3028	4820	17.2	22
August	2047 (-)	4550	53.1 (+)	22
September	14090 (+)	5040	206.8 (+)	27
October		5930		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 2011 was generally at or substantially above average from March through May, but dropped steadily to below normal values in July and August (Table 2, Figure 2). The higher flows in May were due to inputs from the upper Potomac watershed as local precipitation was well below normal in May. During August flows started to return to near normal and in early September Hurricane Irene and Tropical Storm Lee resulted in flows greatly above normal. Accotink Creek flows were not as elevated as river flows in spring, but showed an even larger response to Tropical Storm Lee. Even this was an underestimate as flow records were lost during strong flows in September (see data gap in September in Figure 3) and when reestablished showed above normal flows for the rest of the year.



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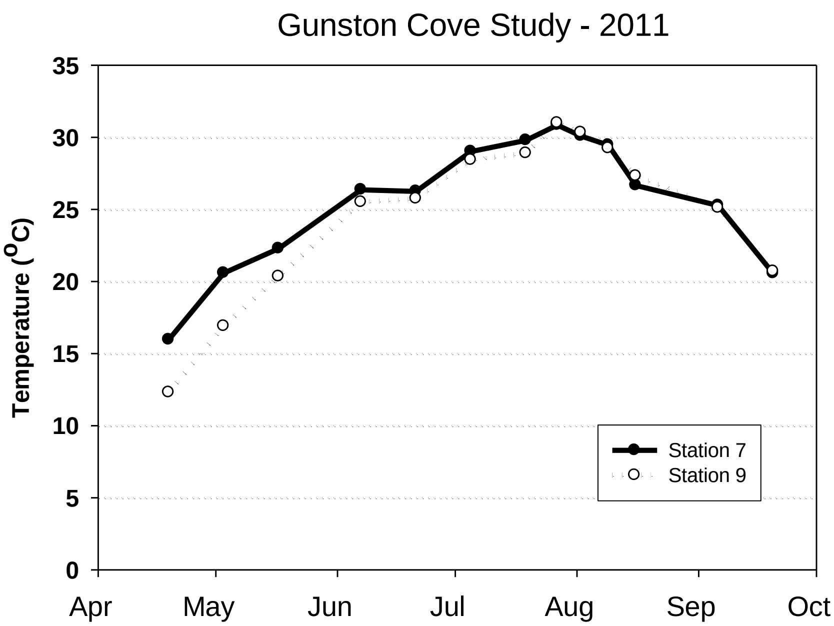
Figure 3. Mean Daily Discharge: Accotink Creek at Braddock Road (USGS Data).

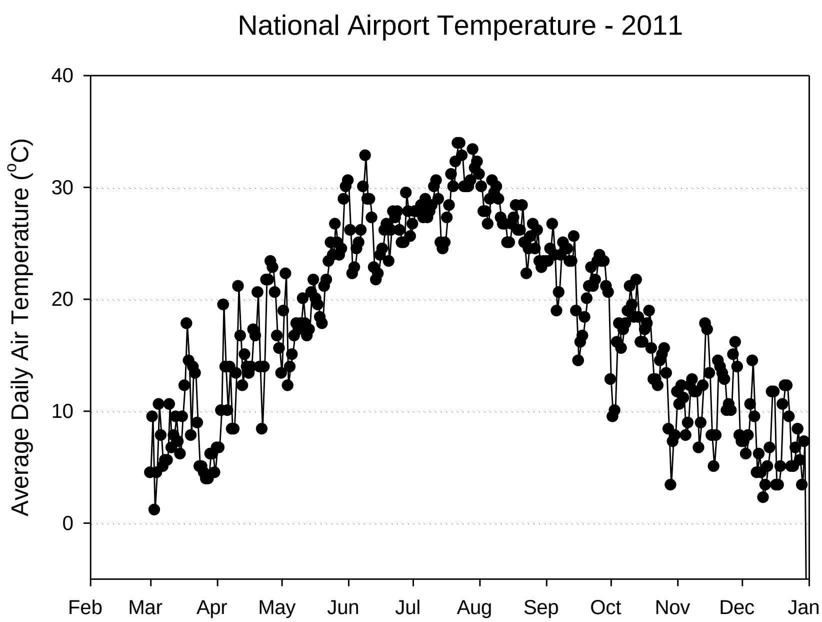
B. Physico-chemical Parameters – 2011



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.

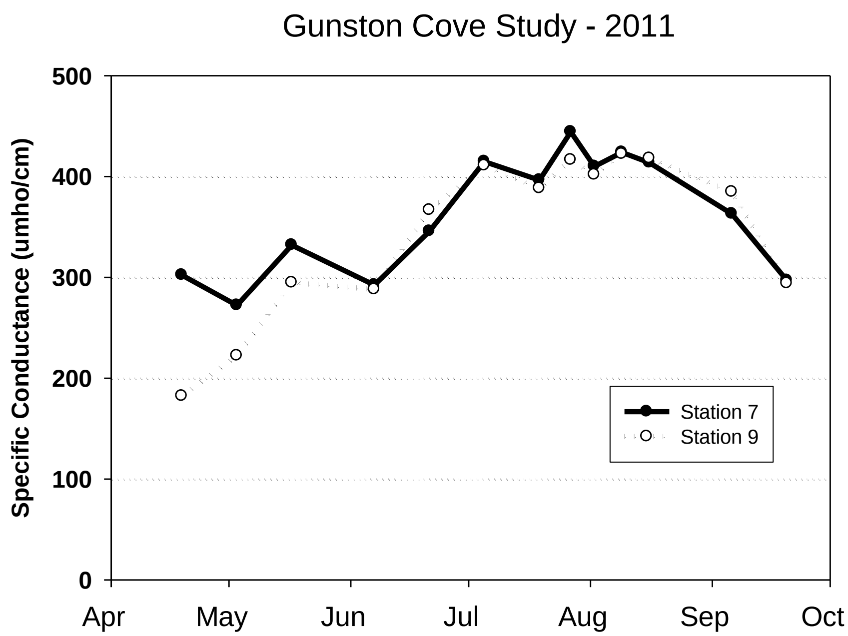
Figure 4. Water Temperature (°C). GMU Field Data. Month tick is at first day of month.

In 2011, water temperature followed the typical seasonal pattern at both sites (Figure 4). Both sites showed a steady increase during the spring and early summer, the cove site (Sta. 7) warming up more quickly, but both sites reaching 30°C in late July. For most of the summer, the two stations showed similar air temperatures between 25° and 30° C. Water temperature declined in August and September. Average daily air temperature peaked above 30°C briefly in early June and then was above that level for a somewhat longer period in late July.



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

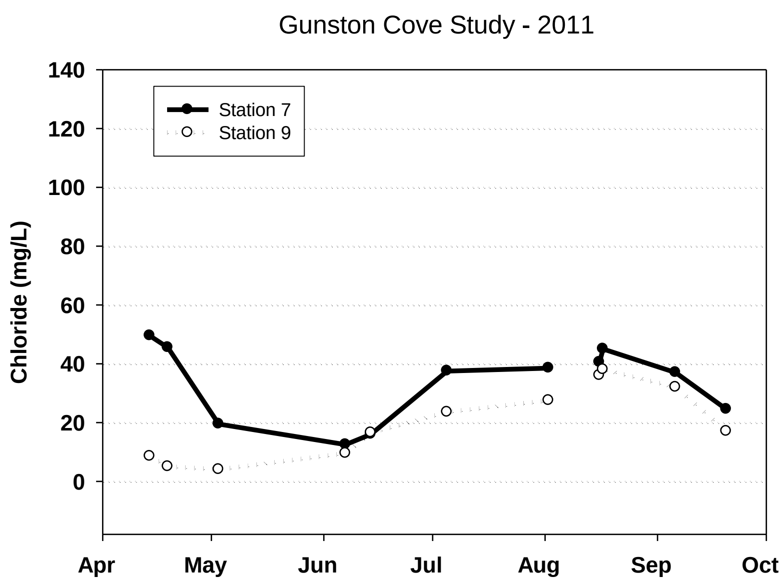
Figure 5. Average Daily Air Temperature (°C) at Reagan National Airport.



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.

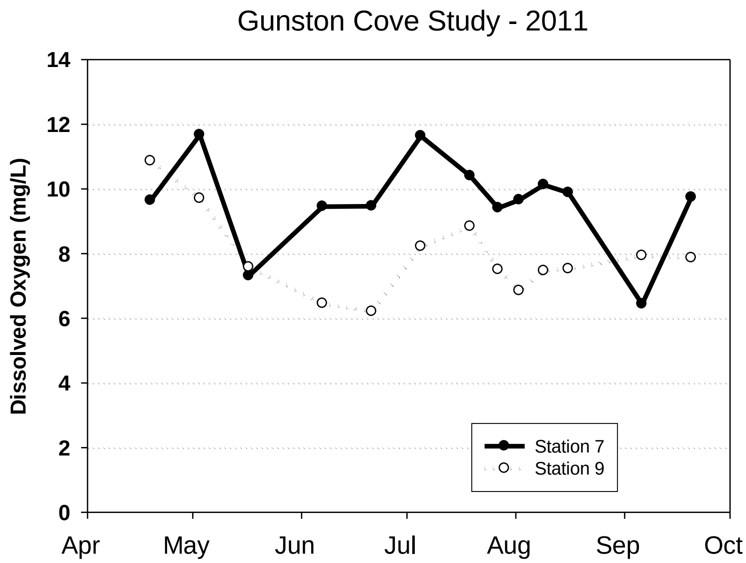
Figure 6. Specific Conductance (uS/cm). GMU Field Data. Month tick is at first day of month.

During most of 2011, specific conductance (Figure 6) exhibited similar patterns in the cove (Station 7) and the river (Station 9). During April and May specific conductance was unusually low in the river due to high spring flows (Figure 2), but by June values were quite similar. Specific conductance increased steadily through the summer reaching a maximum in late July and early August with a marked decline in September corresponding with increased river inflow. 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.

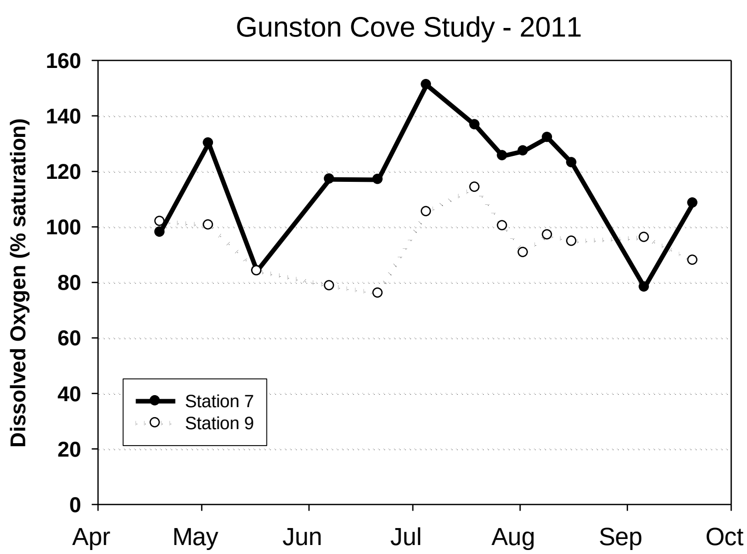
Figure 7. Chloride (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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.

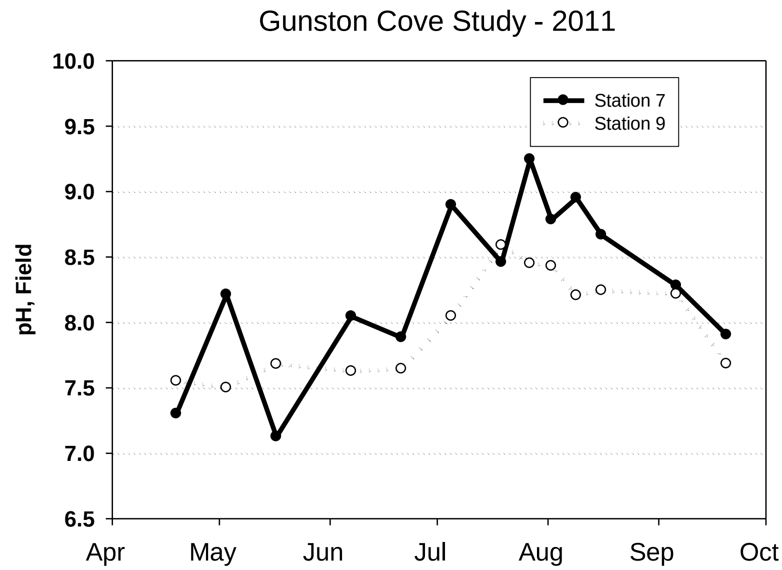
Figure 8. Dissolved Oxygen (mg/L). GMU Field Data. Month tick is at first day of month.

During the summer dissolved oxygen was generally 2-4 mg/L higher in the cove than in the river (Figure 8). In spring and fall, the pattern was more variable. In the cove dissolved oxygen was generally above 100% indicating a general surplus of photosynthesis over respiration (Figure 9). Values above 140%, observed in early July in the cove, are indicative of very active photosynthesis. In the river values were generally equal to or less than 100% indicating lower photosynthesis and an excess of respiration. An exception was during July when DO exceeded 100% in the river indicating moderate to intense photosynthesis. This coincided with a period of rapid chlorophyll increase in the river indicating algal growth.



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.

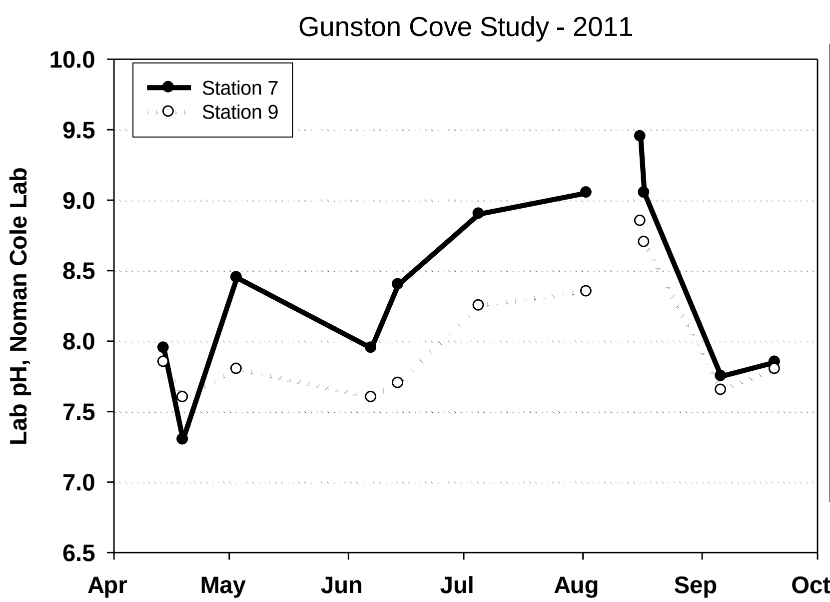
Figure 9. Dissolved Oxygen (% saturation). GMU Field Data. Month tick is at first day of month.



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.

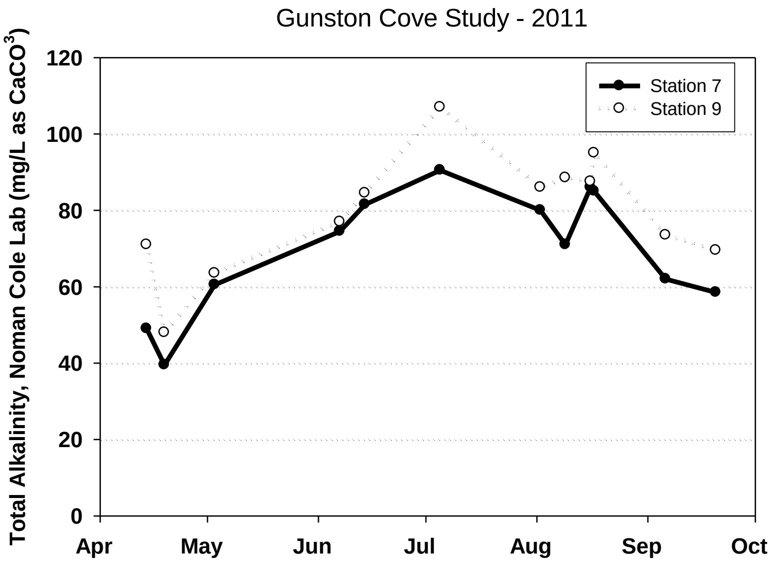
Figure 10. pH. GMU Field Data. Month tick is at first day of month.

Field pH at the Gunston Cove station was generally higher than the river station by about 0.5 pH units (Figure 10). There were some exceptions in spring. Values above 8.5 were typical in the cove during summer while values above 8.0 were found in the river channel. These differences are to be expected given the more intensive photosynthesis in the cove indicated by the dissolved oxygen data. Lab pH showed a similar difference between the two stations (Figure 11). Sustained pH's above 9 are expected to promote sediment P release; these were observed for brief periods in 2011.



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.

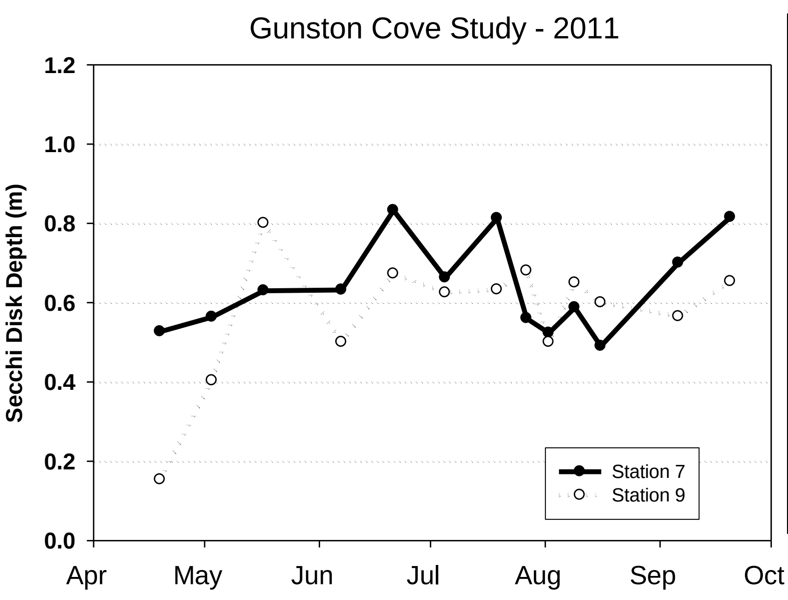
Figure 11. pH. Noman Cole Lab Data. Month tick is at first day of month.



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.

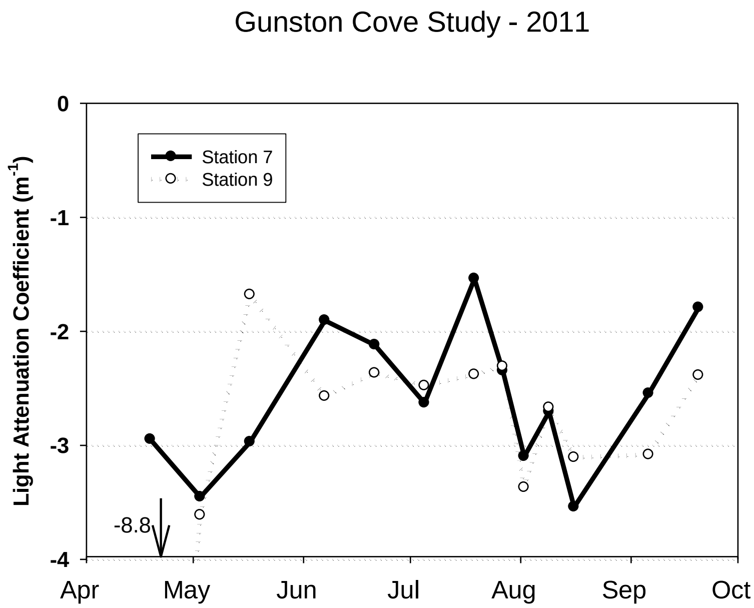
Figure 12. Total Alkalinity (mg/L as $CaCO_3$). Fairfax County Lab data. Month tick is at first day of month.

Total alkalinity was generally slightly higher in the river than in the cove (Figure 12). Values peaked in early May and then declined slowly for the rest of the year.
Water clarity as reflected by Secchi disk depth was higher in the cove in spring and early summer (Figure 13). In late summer both stations showed similar Secchi depth and in September, river water became noticeably clearer than cove water. Secchi disk depth in the river in April was greatly reduced due to high flows in early April which brought in a lot of suspended sediment.



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.

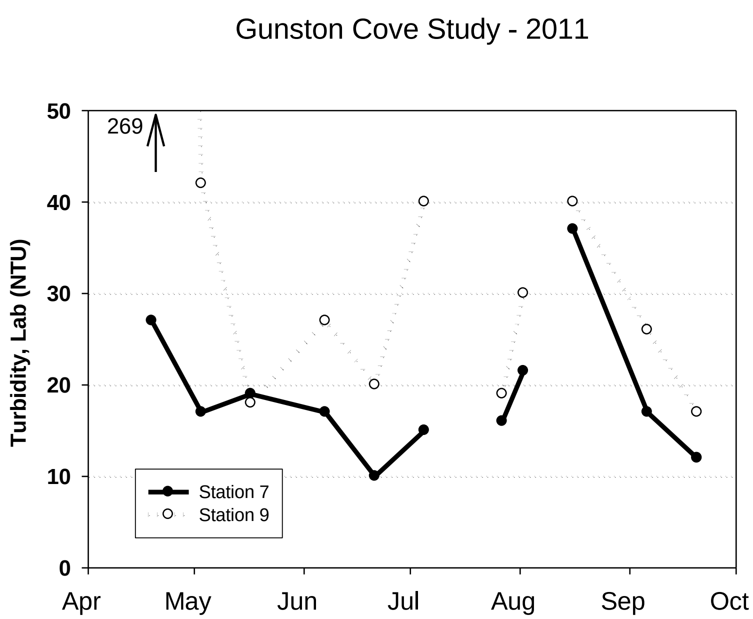
Figure 13. Secchi Disk Depth (m). GMU Field Data. Month tick is at first day of month.



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.

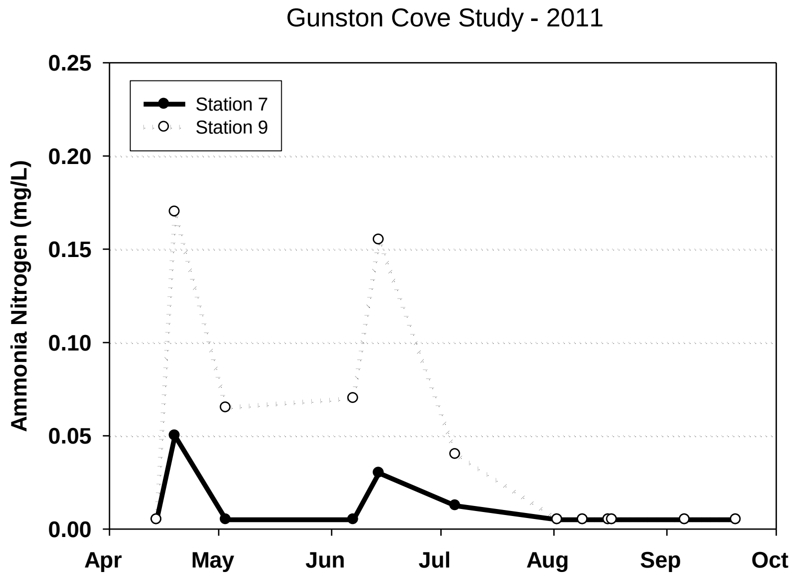
Figure 14. Light Attenuation Coefficient (m^{-1}). GMU Field Data. Month tick is at first day of month.

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 in the river was very high in April consistent with the low Secchi depth. Light attenuation was also enhanced in August probably due to phytoplankton. Turbidity was very high in the river in April and was moderately high in both regions in July and August (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.

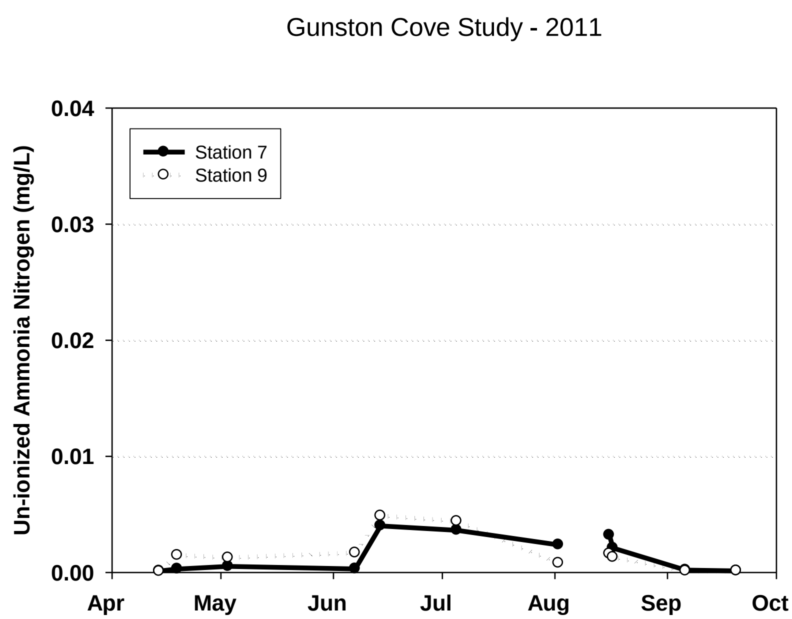
Figure 15. Turbidity (NTU). GMU Lab Data. Month tick is at first day of month.



Ammonia nmitrogen 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.

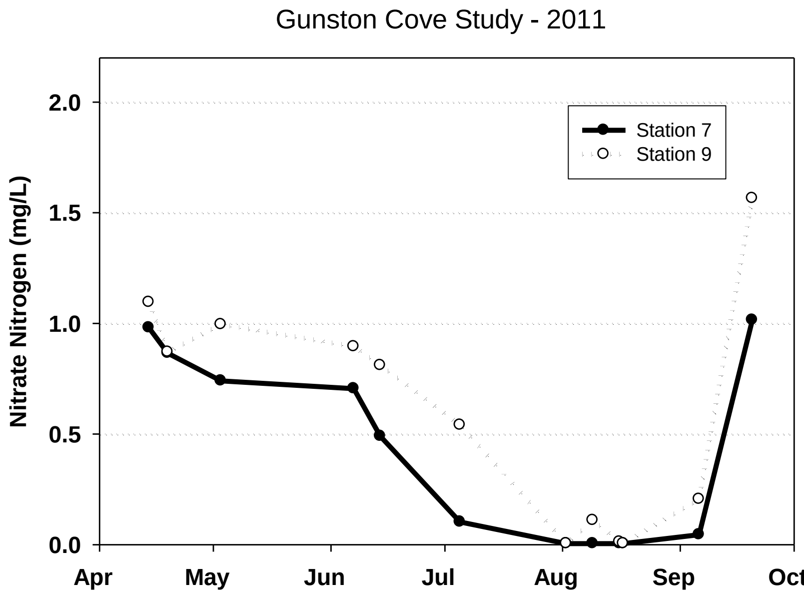
Figure 16. Ammonia Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.

Ammonia nitrogen was consistently very low (<0.05 mg/L) in the cove for the entire study period (Figure 16). River values were substantially higher in the spring and early summer exceeding 0.15 mg/L, but also decreased to very low levels in August and September. 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.

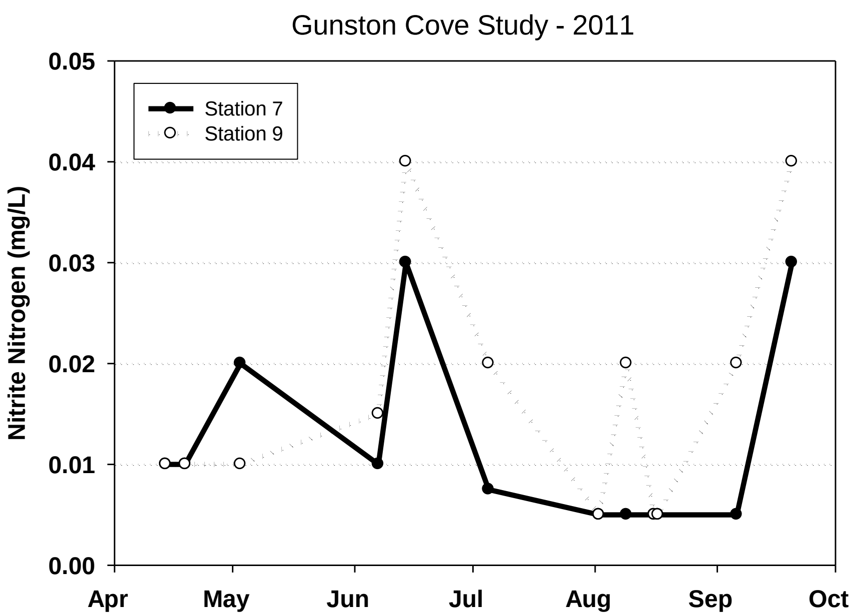
Figure 17. Un-ionized Ammonia Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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.

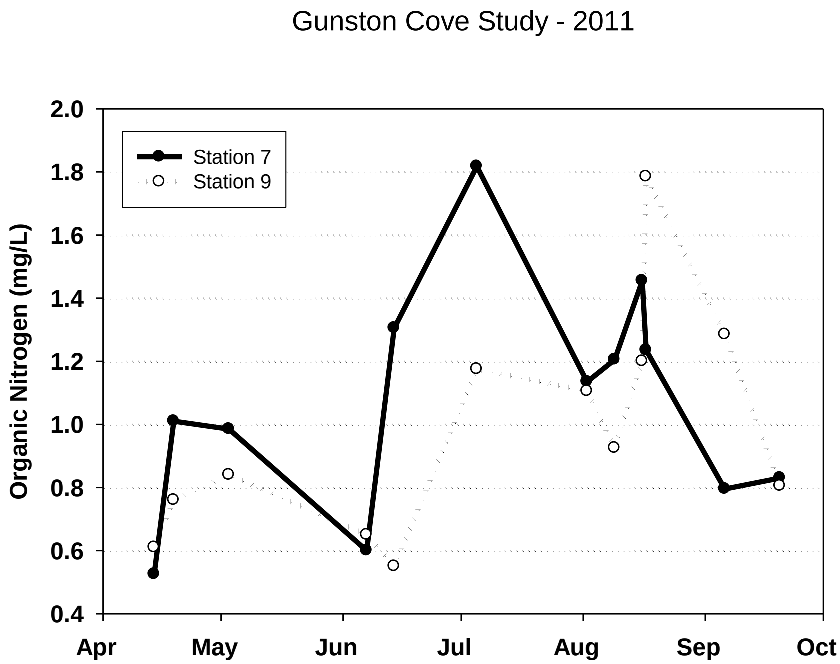
Figure 18. Nitrate Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.

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 returned in late September in the wake of Irene and Lee. Nitrite nitrogen remained very low throughout the year, was consistently higher in the river than in the cove (Figure 19). Values were highest in June and September.



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.

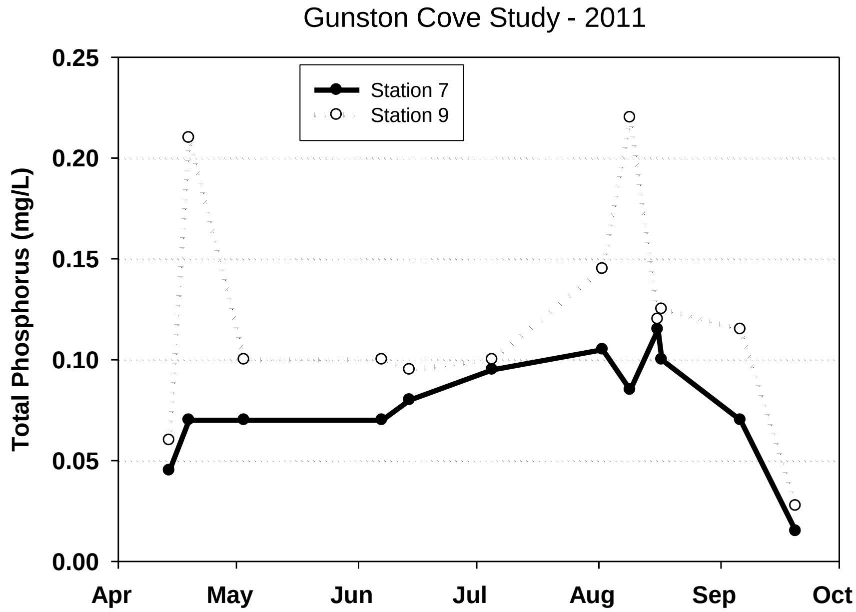
Figure 19. Nitrite Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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.

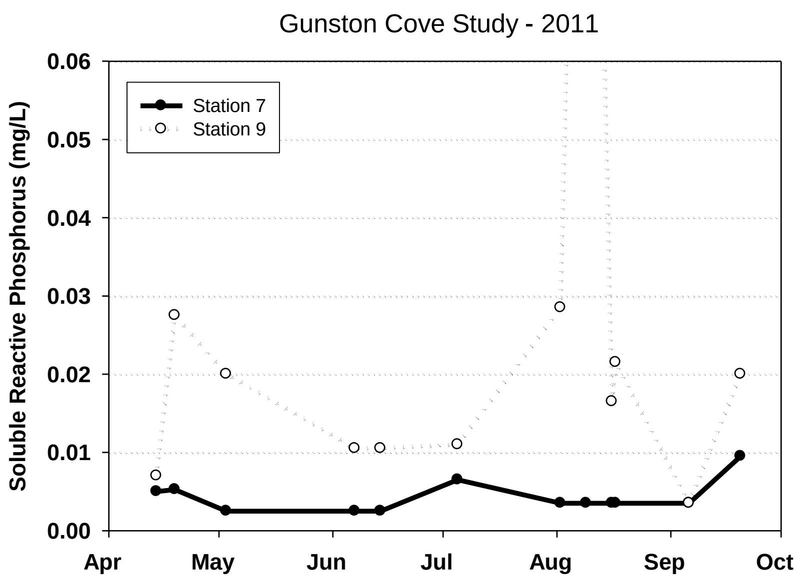
Organic nitrogen was generally higher in the cove than in the river through July with maximum of 1.8 mg/L in late June (Figure 20). However, in mid August and early September river values exceeded those in the cove attaining a maximum of 1.8 mg/L in late August.



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.

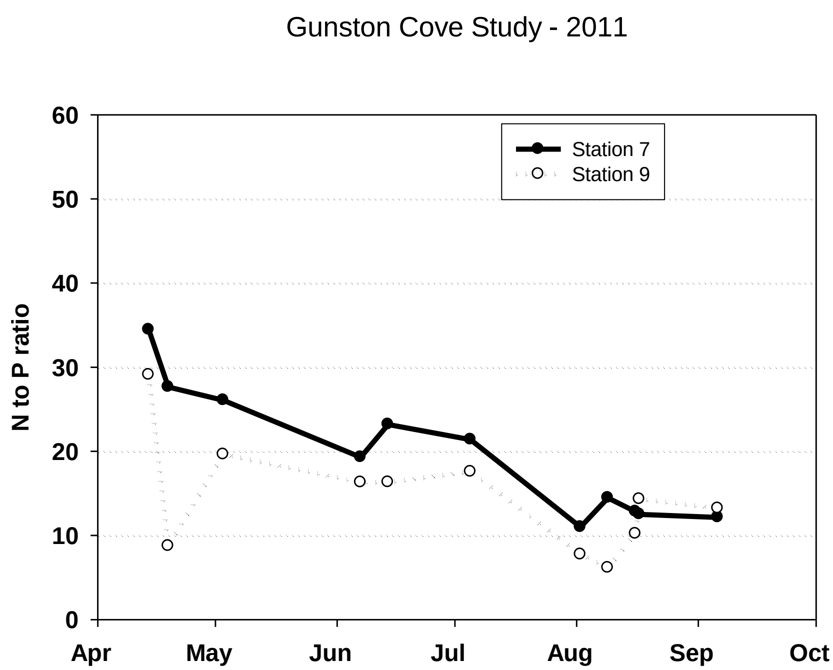
Figure 21. Total Phosphorus (mg/L). Fairfax County Lab Data. Month tick is at first day of month.

Total phosphorus was generally somewhat higher in the river than in the cove (Figure 21). In late April and early August, river values spiked and were substantially higher than those in the cove. In the cove values increased gradually through the summer reaching a peak in August. At both sites total P declined in September. Soluble reactive phosphorus was consistently higher in the river than in the cove (Figure 22). In the cove values were in the range 0.002-0.01 mg/L, while in the river values were generally 0.010-0.030. In the river very high values were found in one sample in early August.



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.

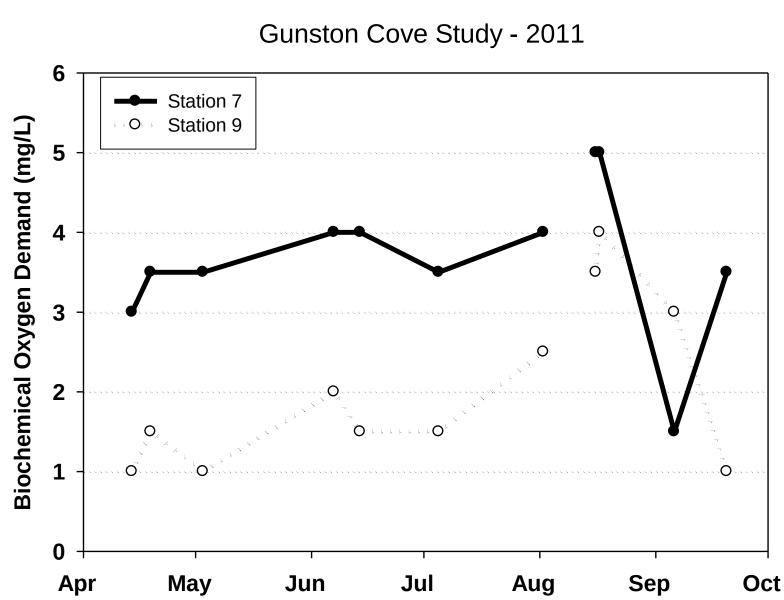
Figure 22. Soluble Reactive Phosphorus (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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.

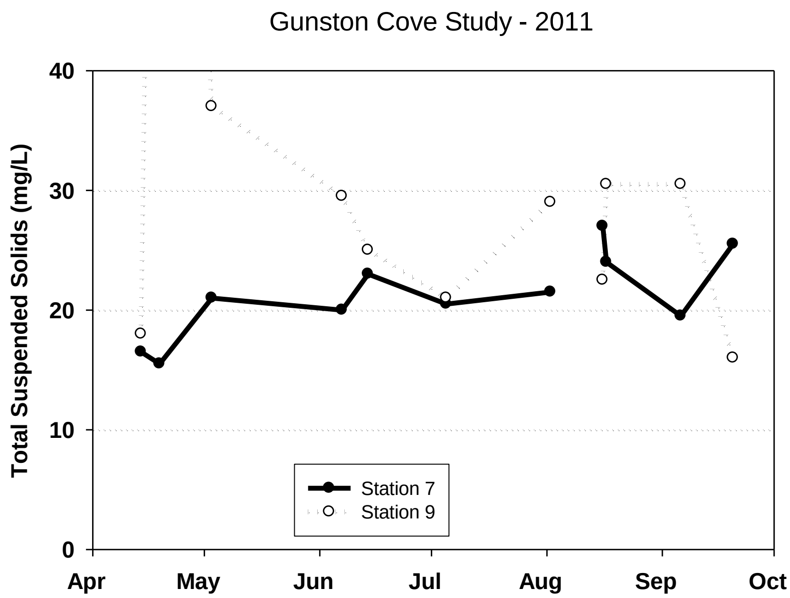
Figure 23. N/P Ratio (by mass). Fairfax County Lab Data. Month tick is at first day of month.

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 hovered 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). In the cove values were generally 3-5 mg/L whereas most river values were generally lower. River values increased markedly in mid August during the *Microcystis* bloom.



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.

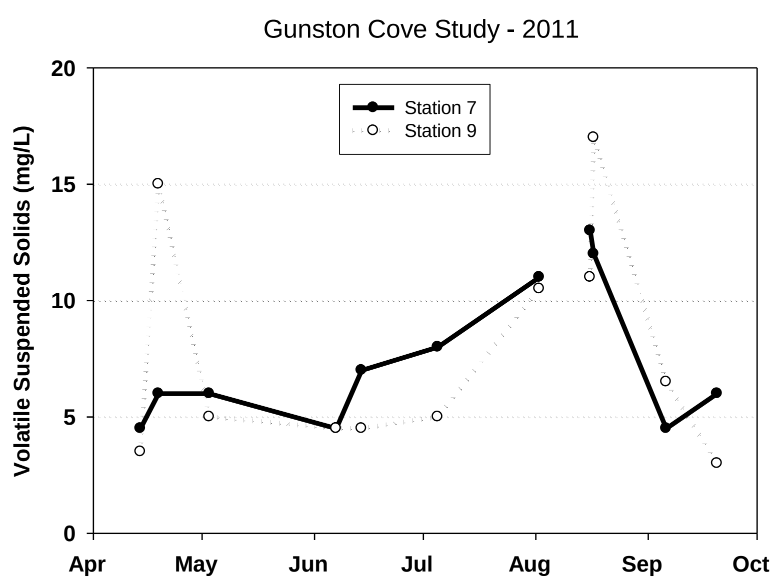
Figure 24. Biochemical Oxygen Demand (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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.

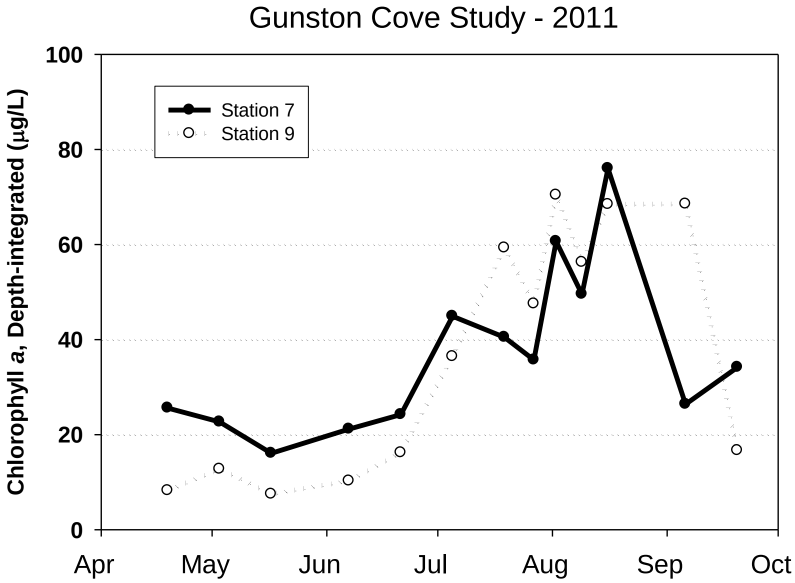
Total suspended solids was generally in the range 15-30 mg/L at both stations (Figure 25). TSS was highly elevated in late April in the river, corresponding to the increased light attenuation and turbidity noted early on that date. Volatile suspended solids were similar at both stations and showed a tendency to increase from May through mid August to about 15 mg/L (Figure 26). The high VSS values in July and August were related to increasing algal populations.



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.

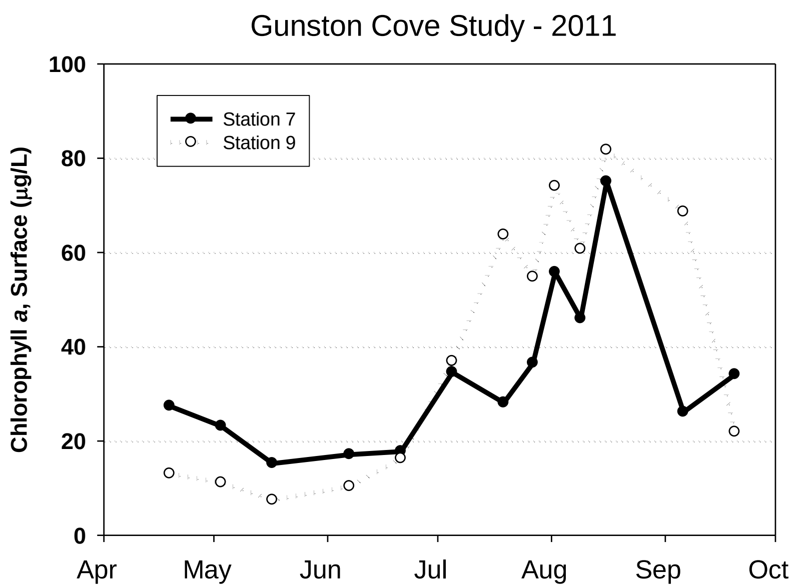
C. Phytoplankton -2011



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 20 ug/L in the spring to about 75 ug/L for the summer months. In the river, chlorophyll *a* levels were about 10 ug/L in spring increasing to about 70 ug/L in August and early September. Depth-integrated and surface chlorophyll showed similar spatial and temporal patterns (Figure 28). These summer values were higher than those observed in recent years and were related to higher diatom densities and *Microcystis* levels.



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.

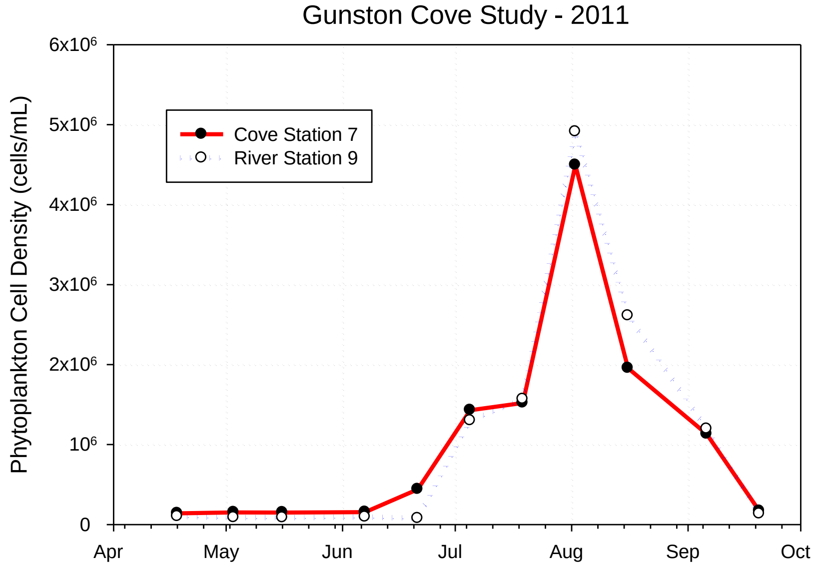


Figure 29. Phytoplankton Density (cells/mL).

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 June in both cove and river (Figure 29). At both stations density increased strongly in early June and July reaching peak values in early August. At both sites values peaked at about 4.5 x 10^6 cells/mL. Values declined through August, reaching low, spring-like levels by mid September. Total biovolume indicated two maxima at both stations, one in early July and the other in early August (Figure 30). Cove biovolume reached a peak of nearly 3.0 x 10^8 um^3/mL in early July and a second peak of nearly 2 x 10^8 um^3/mL on early August. In the river the early July maximum was lower, at 2.0 x 10^8 um^3/mL, while the early August peak was similar.

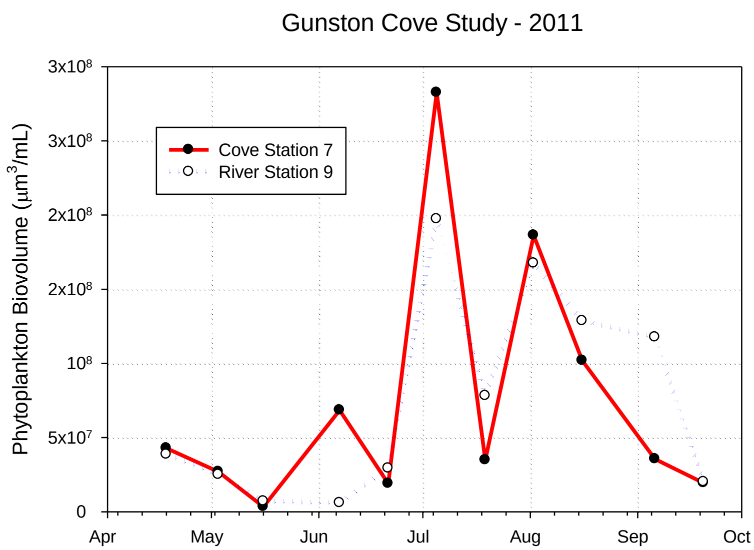
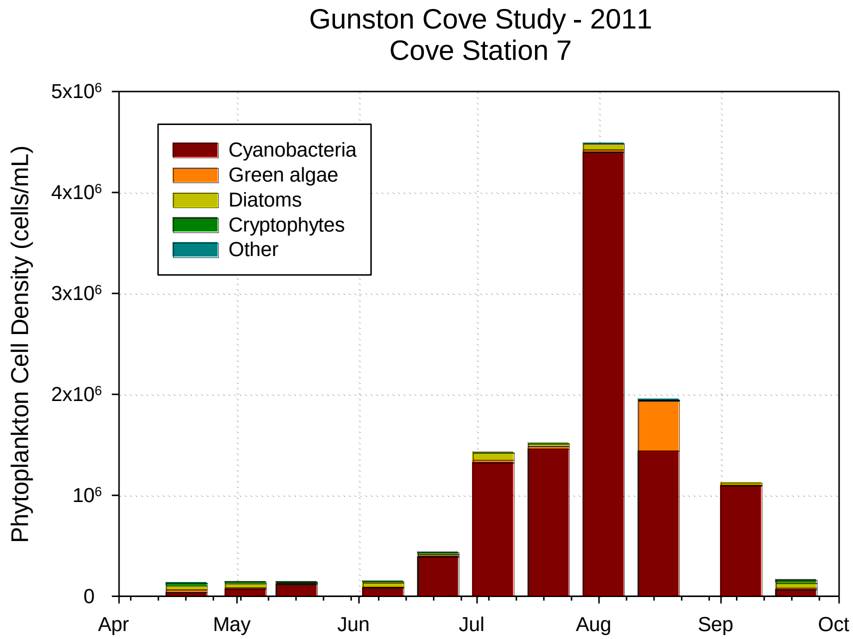


Figure 30. Phytoplankton Biovolume (um^3/mL).

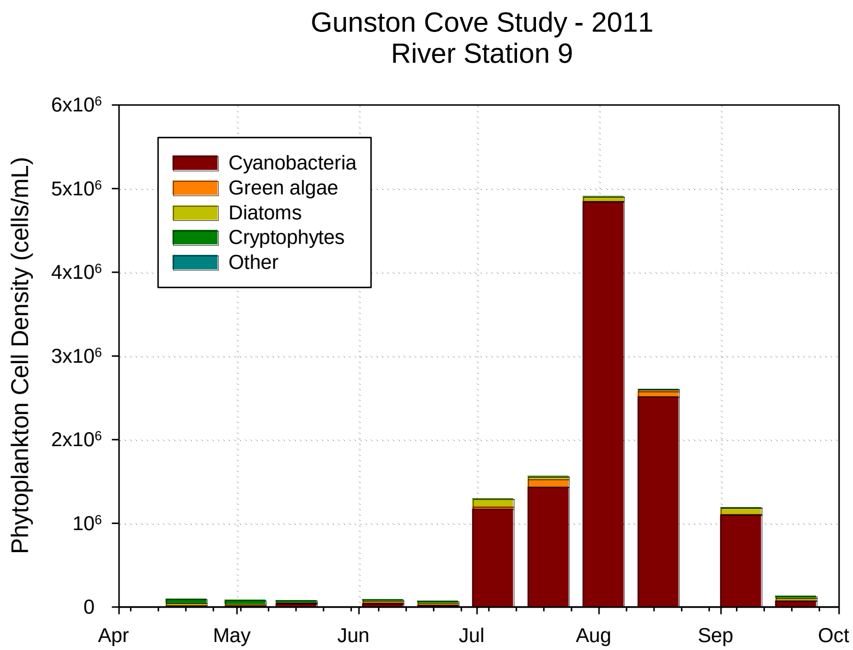
The volume of individual cells of each species is determined by approximating the cells of each species to an appropriate geometric shape (e.g. sphere, cylinder, cone, cube, etc.) and then making the measurements of the appropriate dimensions under the microscope. Total phytoplankton biovolume (shown 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.

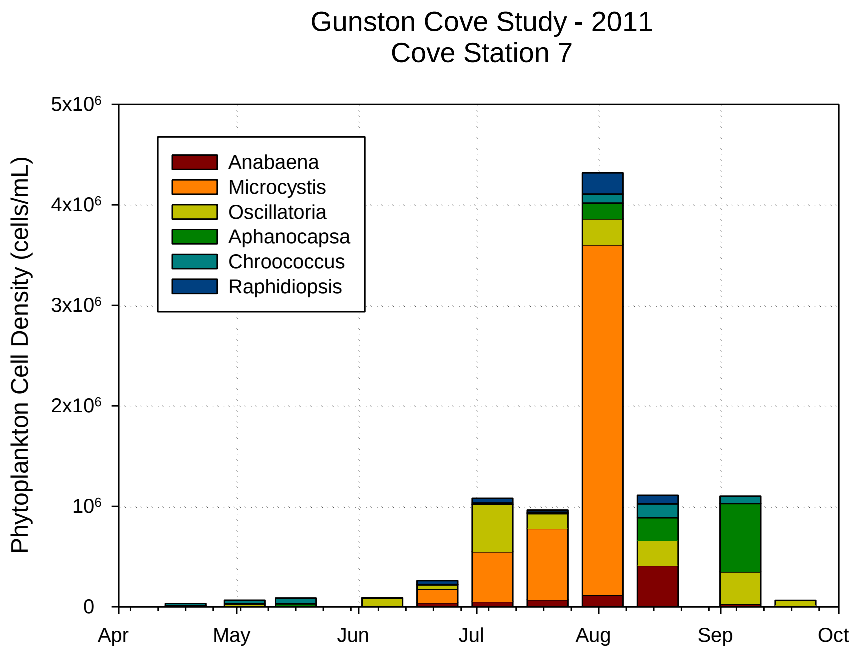
Figure 31. Phytoplankton Density by Major Group (cells/mL). Gunston Cove.

Phytoplankton density in the cove was fairly evenly divided among the major groups in spring, but in June 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 mid August when green algae were important. In the river cyanobacterial dominance began slightly later, but was similarly dominant over the rest of the year (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.

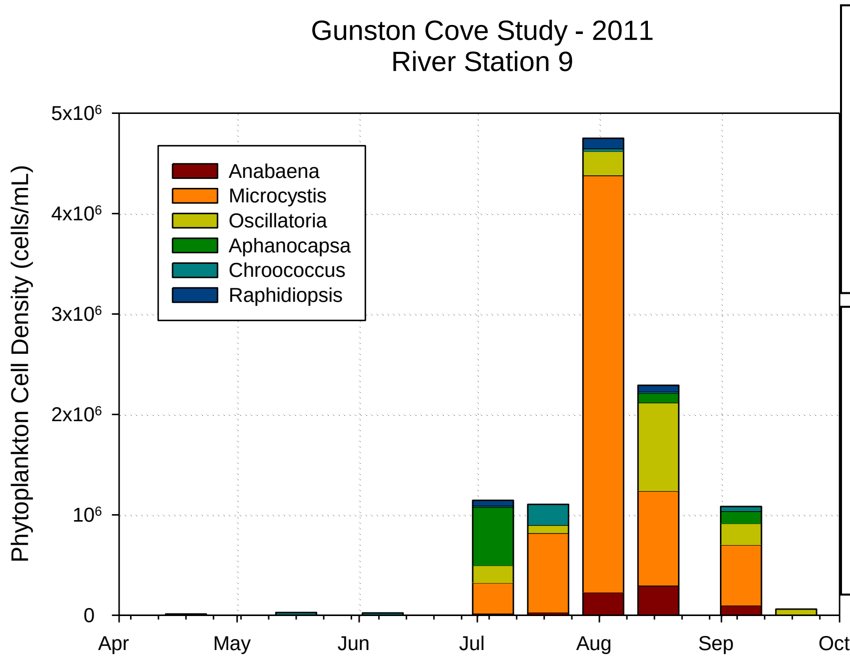
Figure 32. Phytoplankton Density by Major Group (cells/mL). River.

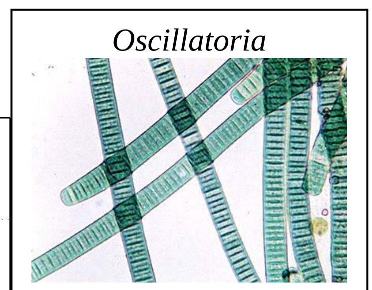


The dominant cyanobacteria on a numerical basis were:
- *Aphanocapsa* -- small sphere
- *Oscillatoria* – a filament with cylindrical cells
- *Microcystis* – an irregular colony of spherical cells
- *Anabaena* – a filament with bead-like cells & heterocysts
- *Raphidiopsis* -- a filament with cylindrical cells
- *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 *Chroococcus*. *Oscillatoria* and *Microcystis* were most important during the early summer with *Microcystis* responsible for the very high peak in August (Figure 33). In late August *Anabaena* was most numerous and by early September it was *Aphanocapsa* that was most numerous. In the river *Microcystis* was dominant for the entire period of elevated phytoplankton densities from July through early September (Figure 34). At both stations the *Microcystis* bloom reached its peak in early August.





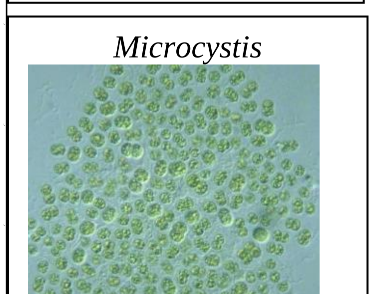
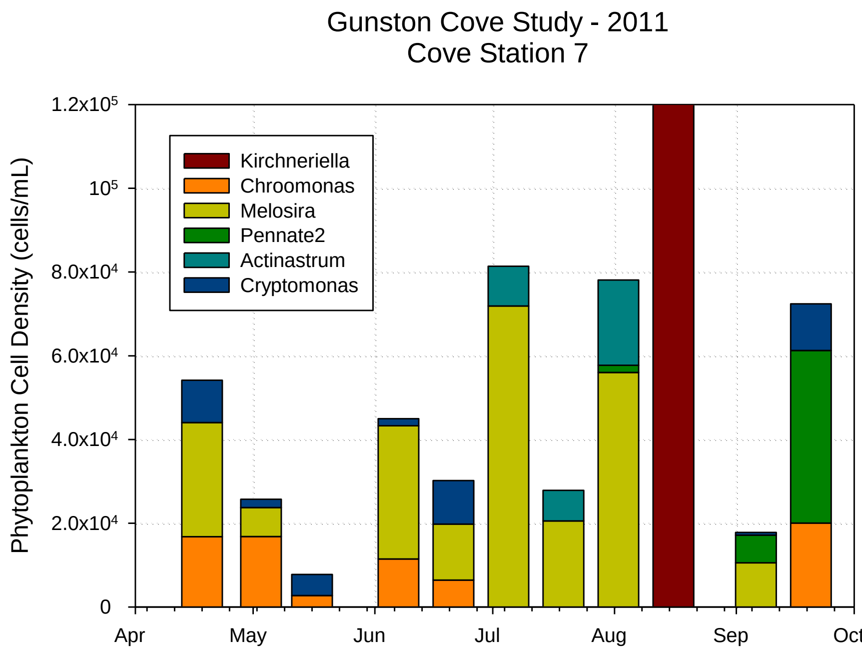


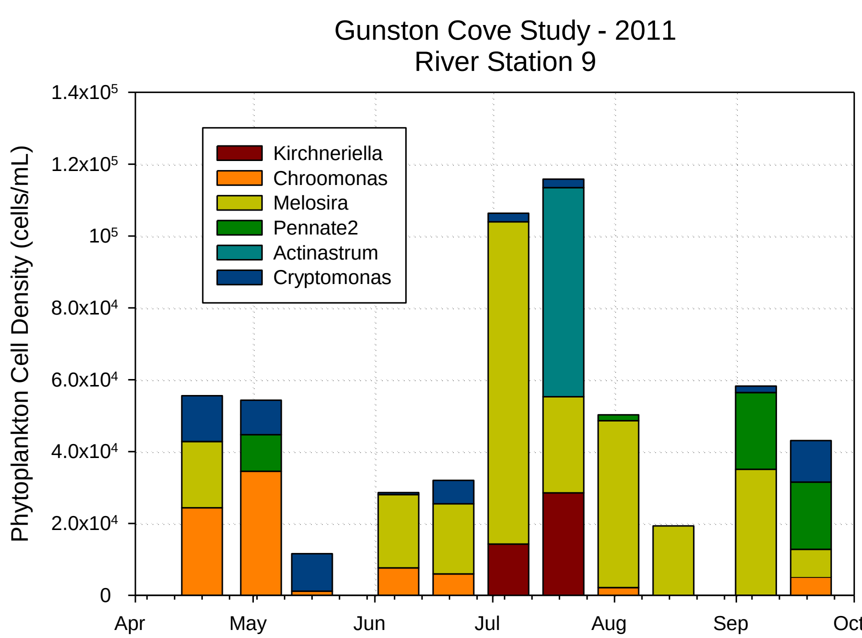
Figure 34. Phytoplankton Density by Dominant Cyanobacteria (cells/mL). River.



The most numerous non-cyanobacterial phyto-plankton were:
Melosira – a filamentous centric diatom
Pennate2 – an unidentified pinnate diatom
Cryptomonas – an ellip-soidal, flagellated unicell
Chroomonas – a flagellated cryptomonad unicell
Kirchneriella – a colonial green alga
Actinastrum – a colonial green alga

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

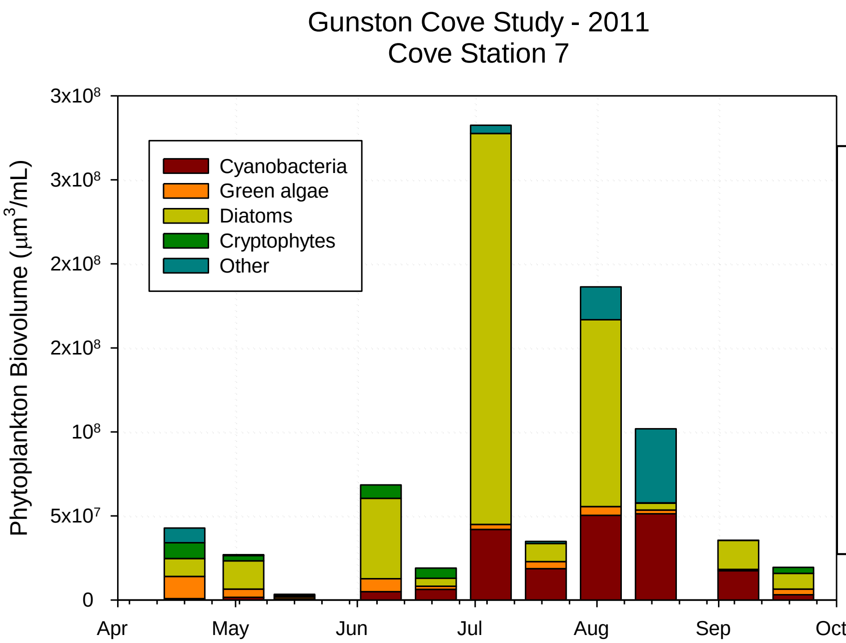
In the cove the filamentous diatom *Melosira* was the most numerous eukaryotic phytoplankter on almost all dates (Figure 35). Exceptions were mid August when the green alga *Kirchneriella* attained prominence and mid September when Pennate 2 was most abundant. *Chroomonas* was present in most samples and *Actinastrum* was especially common in midsummer. In the river *Melosira* led dominance on most dates, especially in summer. Pennate2 was of secondary importance is spring and fall and *Actinastrum* and *Kirchneriella* were subdominants in midsummer (Figure 36).



Melosira

Cryptomonas

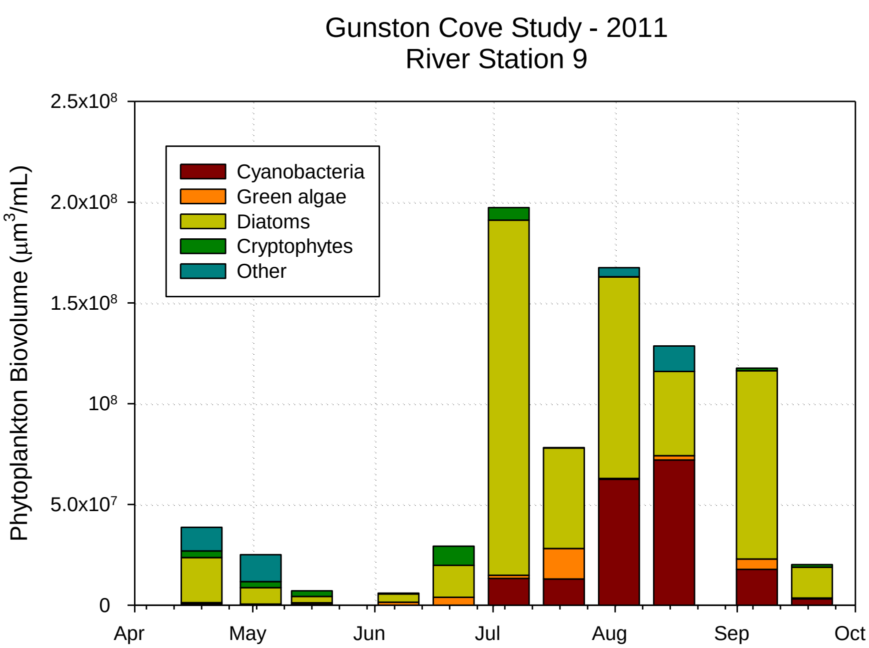
Figure 36. Phytoplankton Density (#/mL) by Dominant Taxa. River.



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

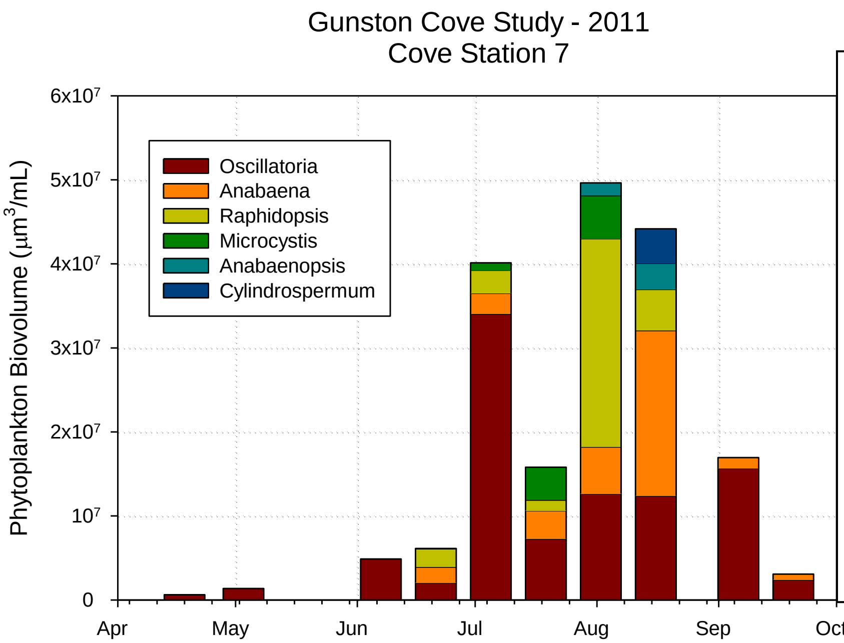
Figure 37. Phytoplankton Biovolume (um^3/mL) by Major Groups. Gunston Cove.

In the cove diatoms were dominant in biovolume in most samples (Figure 37). In particular, they were responsible for the very high values in early July and early August. Cyanobacteria were subdominant in summer. Other algae (mostly euglenoids) were present in August. In the river, diatoms were again the overwhelming dominants during most of the year, with cyanobacteria figuring prominently in August (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.

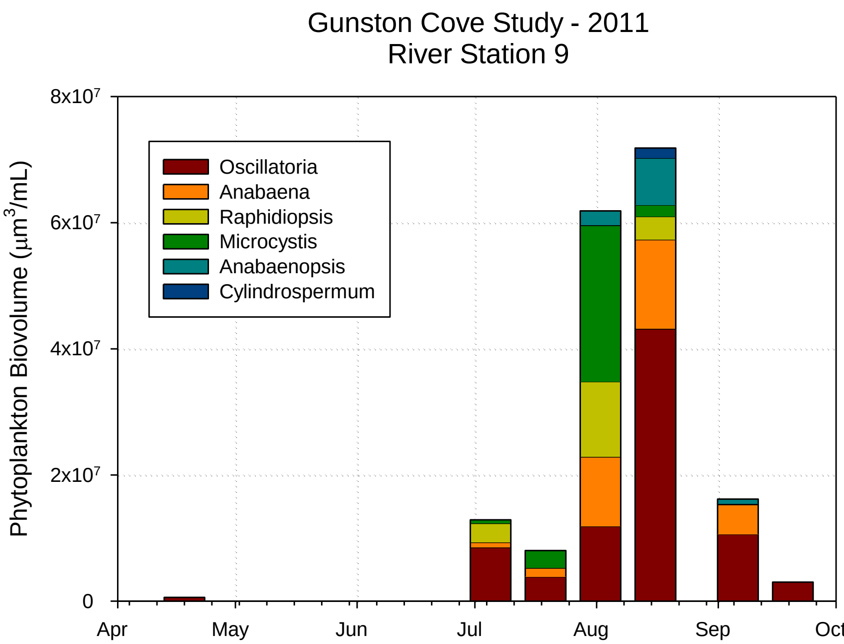


Cyanobacteria are generally most common in late summer and that is when they normally make the largest contribution to phytoplankton biovolume. Important taxa for biovolume which were not on the top list for cell density are:

- *Coelospherium* – a spherical colony of round unicells
- *Anabaena* – a filament of spherical cells
- *Raphidiopsis* – a filament of discoid cells

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

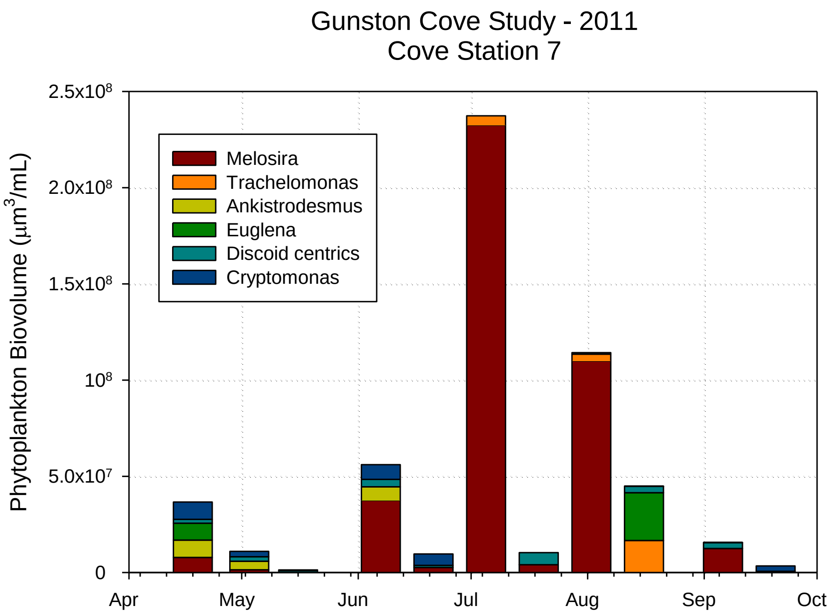
In the cove *Oscillatoria* was the dominant cyanobacterium in terms of biovolume for most of the year (Figure 39). *Microcystis*, *Anabaena*, and *Raphidiopsis* were important in July and August. In the river *Oscillatoria* was generally most important, but *Microcystis* was dominant in early August and *Anabaena* was important throughout August (Figure 40).



Anabaena

Chroococcus

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



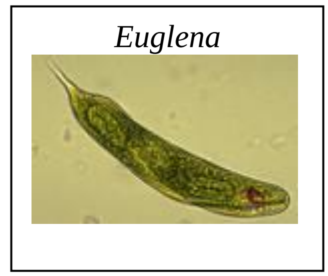
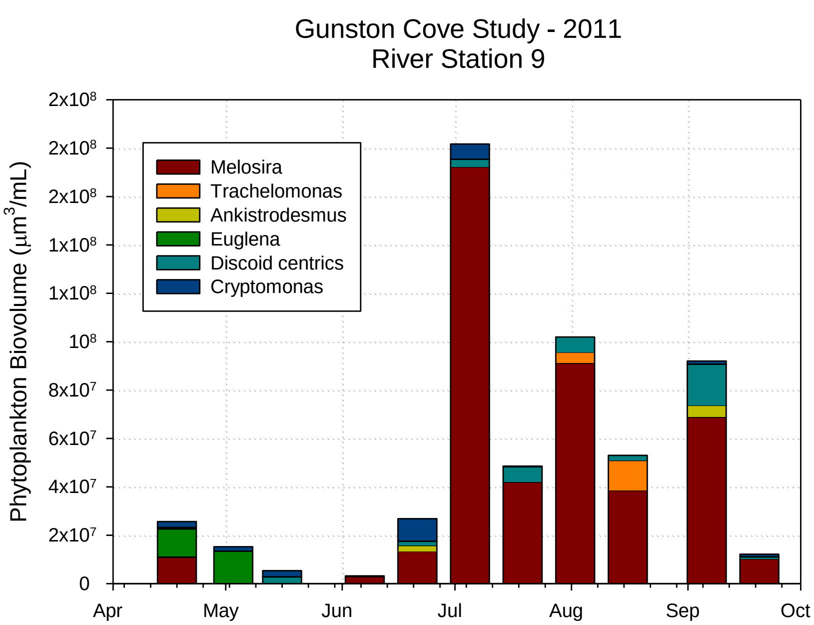


Figure 41. Phytoplankton Biovolume (um^3/mL) by Dominant Noncyanobacterial Taxa. Gunston Cove.

Melosira was the most important component of noncyanobacterial biovolume in the cove for most of the year and in particular during the peak levels in early July and early August (Figure 41). 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. It serves as food for many consumers like zooplankton and benthos and does not have toxic properties like many cyanobacteria.



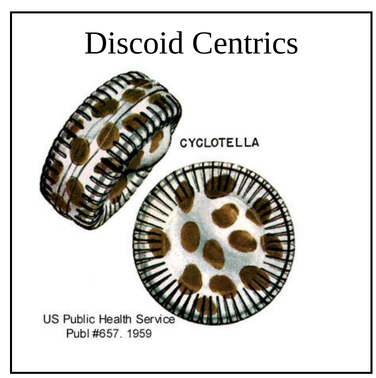


Figure 42. Phytoplankton Biovolume (um^3/mL) by Dominant Taxon. River.

D. Zooplankton – 2011

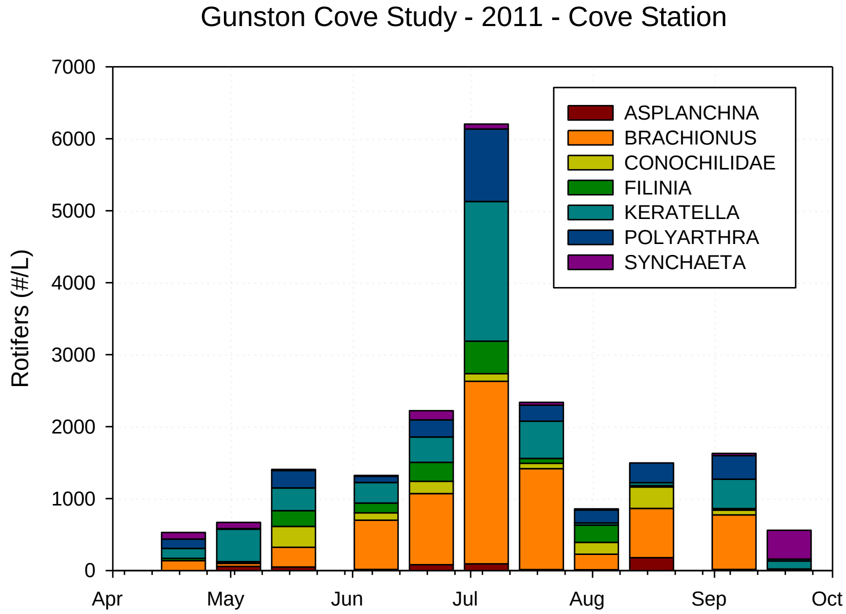
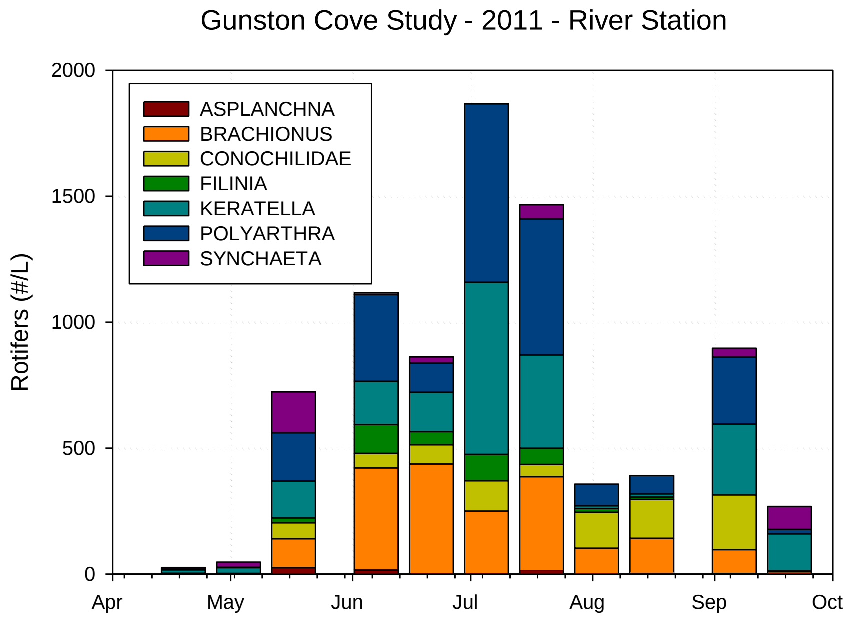
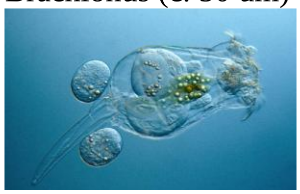


Figure 43. Rotifer Density by Dominant Taxa (#/L). Cove.

In the cove, rotifers increased in May to about 1500/L (Figure 43). During late June and early July rotifers further increased even further reaching a strong maximum of over 6000/L. Levels declined by late July and into early August with another small increase in late August and early September. *Brachionus* was the most important genus for most of the year. In early July *Keratella* and *Polyarthra* also made substantial contributions. *Synchaeta* was dominant in late September. In the river rotifers demonstrated a similar seasonal patter at lower abundance levels with a maximum in early July of about 1800/mL (Figure 44). *Brachionus*, *Keratella* , and *Polyarthra* were the co-dominant rotifers in the river.



Brachionus (c. 50 um)



Conochilidae

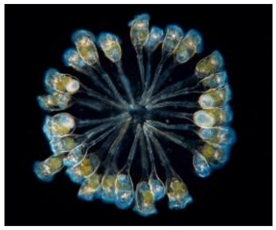
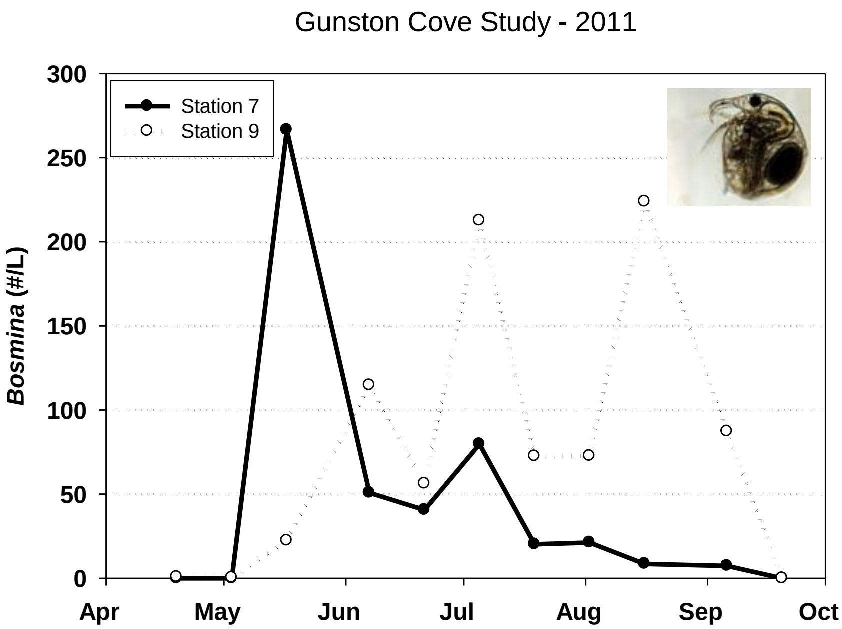


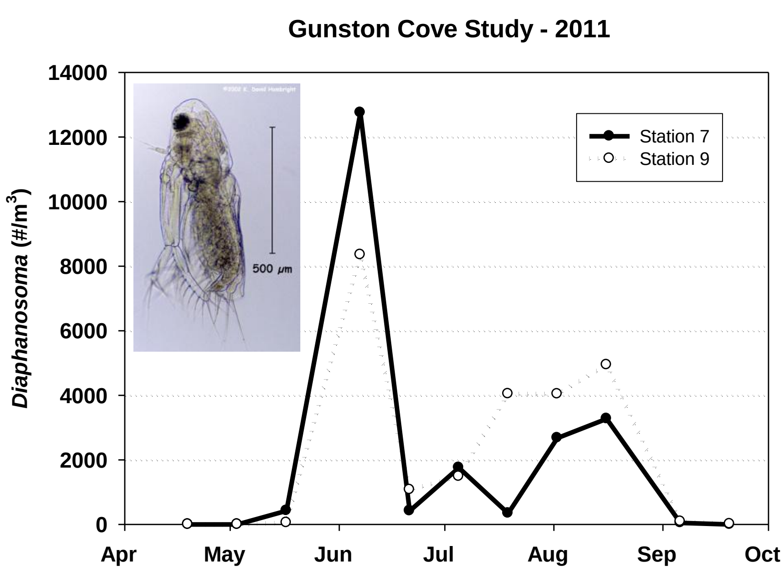
Figure 44. Rotifer Density by Dominant Taxa (#/L). River.



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.

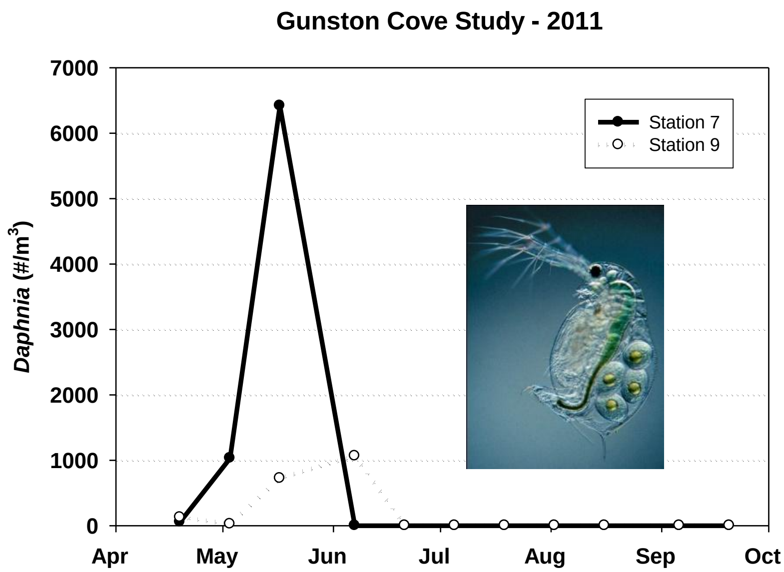
Figure 45. *Bosmina* Density by Station (#/L).

In 2011 the small cladoceran *Bosmina* was most abundant in the cove in spring and early summer reaching a maximum of about 260/L in late May steadily declining thereafter (Figure 45). In the river *Bosmina* increased more slowly in the spring and exhibited a couple of summer peaked at about 220/L in early July and late August. *Diaphanosoma*, typically the most abundant larger cladoceran in Gunston Cove, exhibited two peaks at both sites (Figure 46). The late May peak was greater in the cove, exceeding 12,000/m^3 there and 18,000/m^3 in the river. The second peak was more pronounced at the river site attaining 5000/m^3 whereas in the cove this August peak reached only 2500/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.

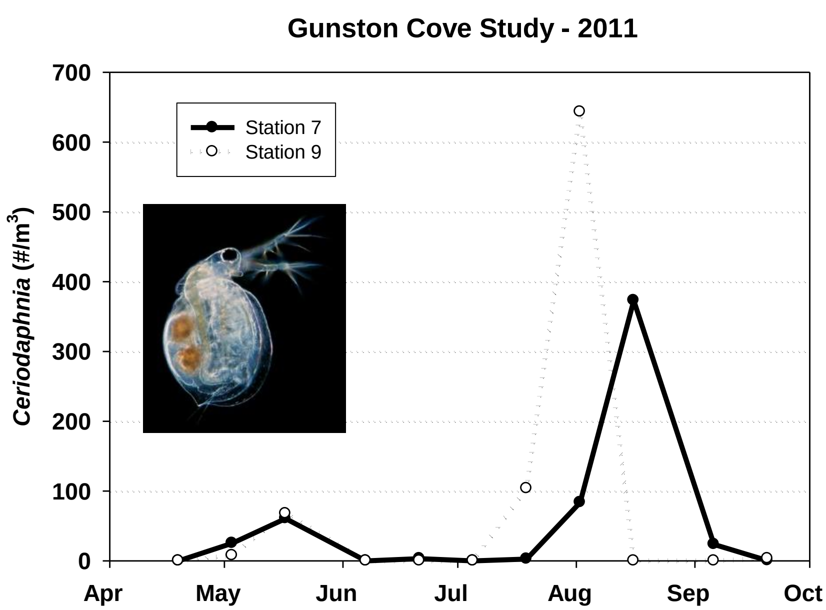
Figure 46. *Diaphanosoma* Density by Station (#/m^3).



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.

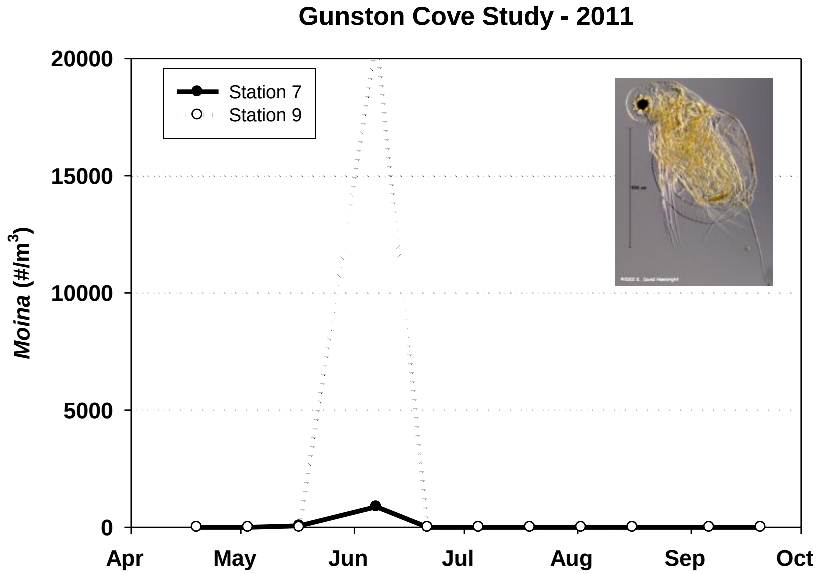
Figure 47. *Daphnia* Density by Station (#/m^3).

Daphnia was common mainly in May and early June and was most abundant in the cove reaching the unusually high level of 6400/m^3 (Figure 47). *Ceriodaphnia* was present sporadically at low densities in both river and cove in late summer reaching a maximum of about 400/m^3 in the cove and 400/m^3 in the river (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.

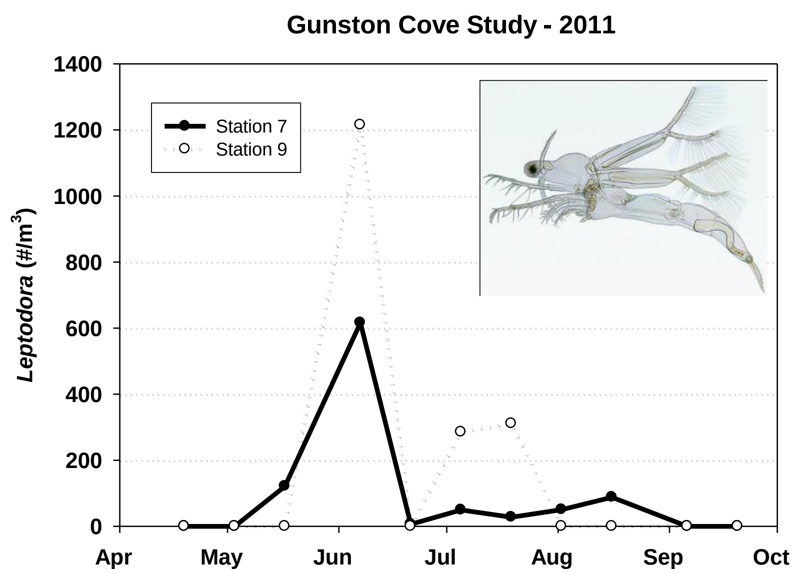
Figure 48. *Ceriodaphnia* Density by Station (#/m^3).



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.

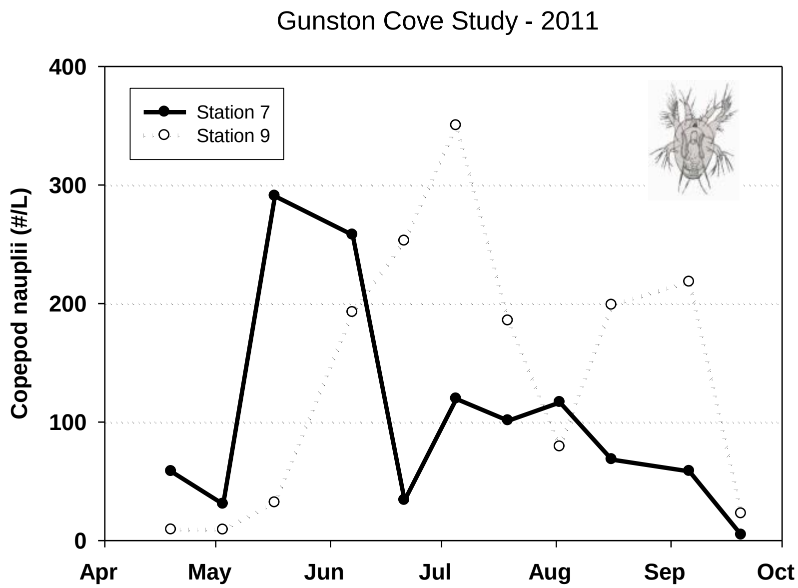
Figure 49. *Moina* Density by Station (#/m^3).

Moina was found almost exclusively in early June at very high levels of over 20,000/m^3 in the river and lower levels of about 1000/m^3 in the cove (Figure 49). *Leptodora*, the large cladoceran predator, was consistently present in June and July in both cove and river (Figure 50). In the cove the peak was in early June at 600/m^3. In the river an early June peak of about 1200/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.

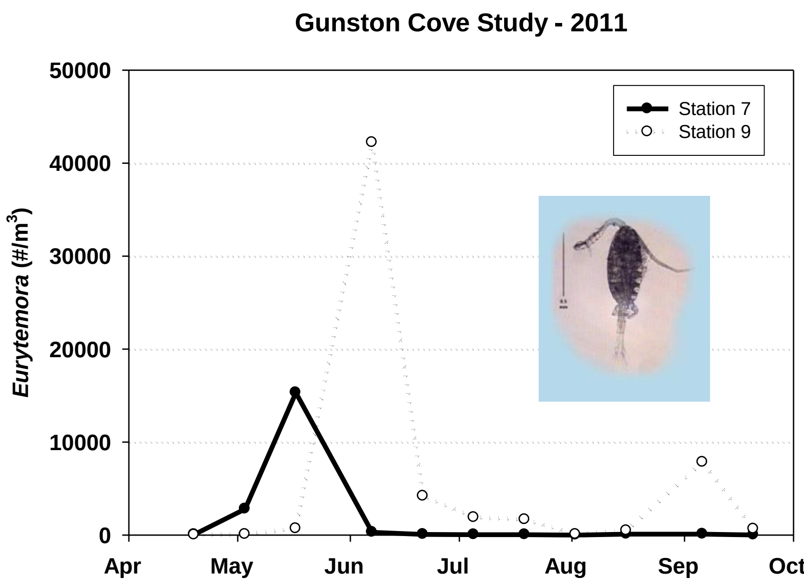
Figure 50. *Leptodora* Density by Station (#/m^3).



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.

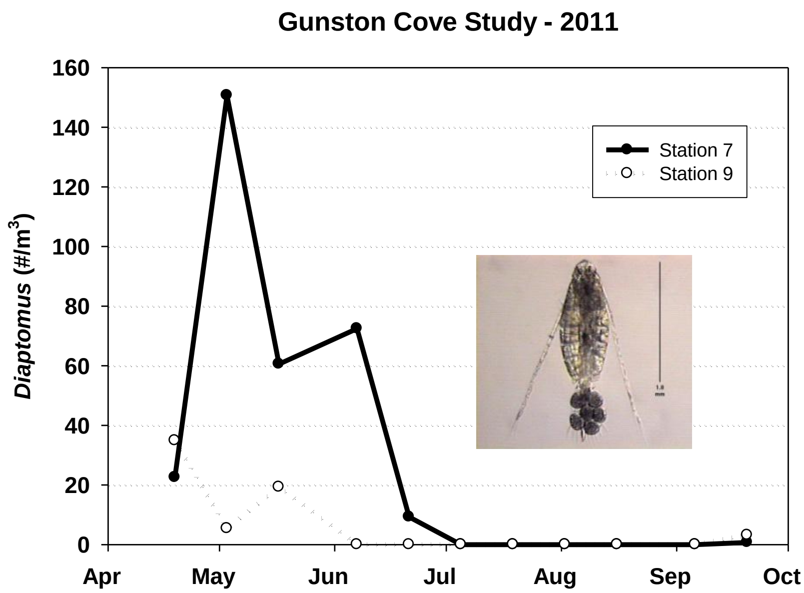
Figure 51. Copepod Nauplii Density by Station (#/L).

Copepod nauplii increased from levels of less than 50/L in early May reaching 300/L in late May in the cove (Figure 51). Cove values declined steadily over the remainder of the year. In the river a steady increase from April through June resulted in a peak of 350/L in early July. At both sites copepod nauplii continued to be found at substantial levels into early September. *Eurytemora* exhibited highest densities in May and early June (Figure 52). Maximum values were about 15,000/m^3 in the cove and 45,000/m^3 in the river. *Eurytemora* declined to very low levels by early June in the cove, but exhibited a second peak in the river at about 8000/m^3 in early September.



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*.

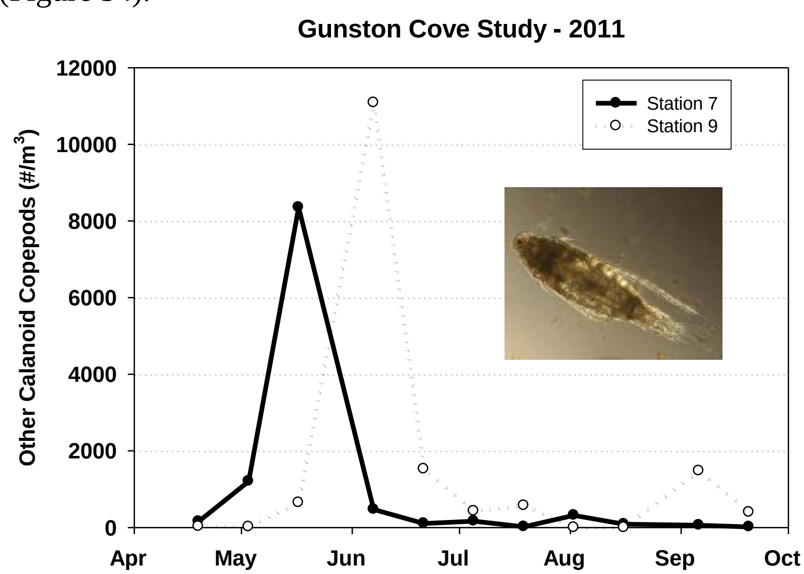
Figure 52. *Eurytemora* Density by Station (#/m^3).



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*.

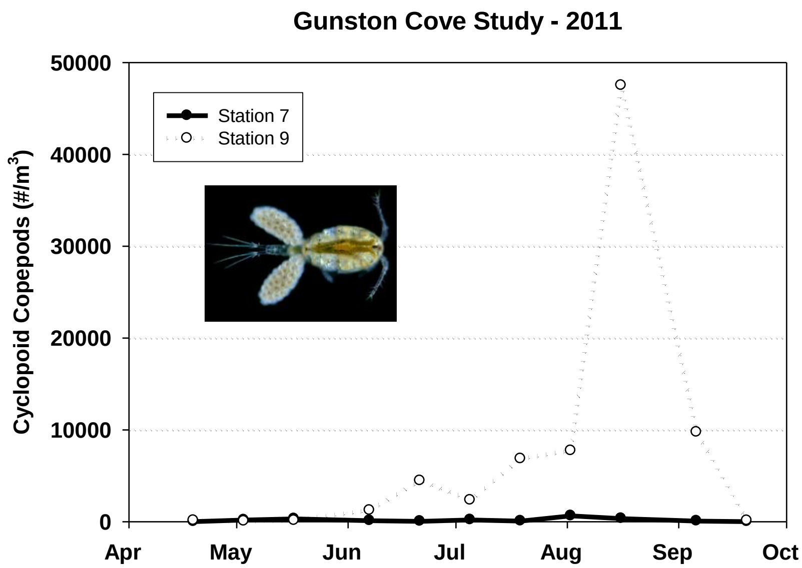
Figure 53. *Diaptomus* Density by Station (#/m^3).

Diaptomus was very low in 2011 compared with most recent years (Figure 53). The highest level attained was 150/m^3 in the cove in early May. Other calanoid copepods were quite abundant in spring reaching a peak of over 8600/m^3 in the cove and 11,000/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).



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

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

Cyclopoid copepods were very scarce in the cove in 2011, but quite abundant in the river (Figure 55). The peak in mid August attained about 47,000/m^3 in the river.

E. Ichthyoplankton – 2011

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 2011, we collected 14 samples (7 at Station 7 and 7 at Station 9) during the months April through July and obtained a total of 14550 larvae (Table 4). About 69% of the catch was collected on one date, May 17. 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 90.1% 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. Larval *Alosa sp*. were second in rank (6.6 %). White perch larvae were common too, comprising about 2.4-2.8% of total collections. 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 2011

Taxon	Common Name	Sta 7	Sta 9	Total	% of Tot.
Alosa mediocris	hickory shad	1	0	1	<0.1
Alosa pseudoharengus	alewife	0	458	458	3.1
Alosa sapidissima	American shad	4	0	4	<0.1
Alosa sp.	herring or shad	497	8	505	3.5
Carassius auratus	goldfish	0	2	2	<0.1
Cyprinella analostana	satinfin shiner	0	3	3	<0.1
Dorosoma sp.	gizzard or threadfin shad	6207	6903	13110	90.1
Lepomis gibbosus	pumpkinseed	9	0	9	<0.1
Lepomis sp.	sunfish	0	16	16	0.1
Menidia beryllina	Inland silverside	3	14	17	0.1
Micropterus salmoides	largemouth bass	9	0	9	<0.1
Morone americana	white perch	90	262	352	2.4
Morone saxatilis	striped bass	3	0	3	<0.1
Morone sp.		53	5	58	0.40
Perca flavescens	yellow perch	3	0	3	<0.1
		6879	7671	14550	100

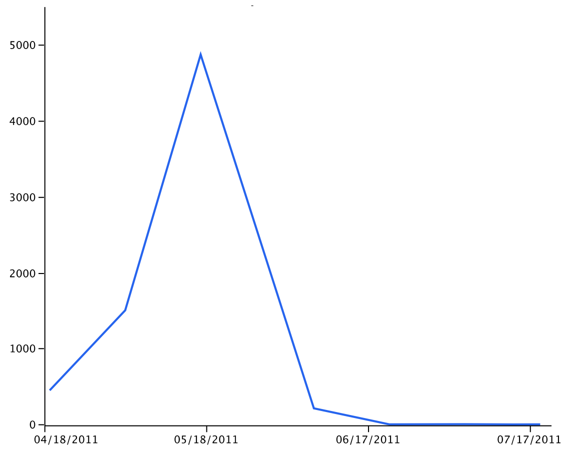


Figure 56. Clupeid Larvae, mean abundance.

Clupeid larvae include hickory shad, alewife, American shad, gizzard shad, threadfin shad and possibly blueback herring (if some were 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 mid-May (Figure 56). The other larvae collected had a similar pattern of abundance (Figure 57). Almost all individual larval species had their highest abundance mid-May. *Lepomis* sp. and *Menidia beryllina* were found at their highest abundance early June.

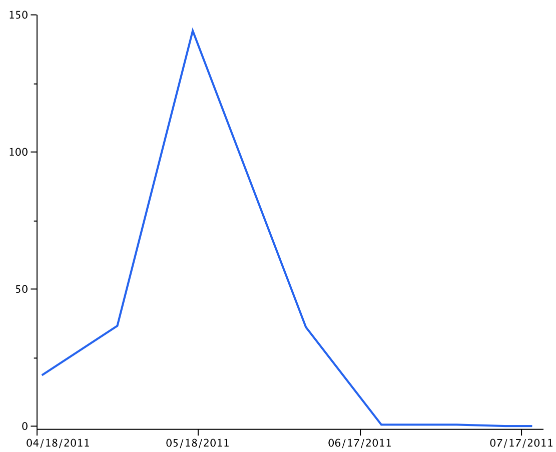


Figure 57. All other Larvae, mean abundance.

F. Adult and juvenile fishes – 2011

Trawls

Trawl sampling was conducted between April 26 and September 23 at three fixed stations (7, 9, and 10) that have been sampled continuously since the inception of the survey. A total of 2226 fishes comprising 23 species were collected (Table 5). The majority (87.1%, numerically) of the fish collected were represented by 3 species: white perch (49.6%), sunfish (*Lepomis sp*.) (19.2%), and spottail shiner (18%). Other numerically abundant species (annual total >20) included: *Alosa* sp. (4.1%), channel catfish (3.1%), blue catfish (2.8%), and banded killifish (1.6%). 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 – 2011

FAMILY	SPECIES	COMMON NAME	Total Caught
Anguillidae	*Anguilla rostrata*	American eel	1
Atherinidae	*Menidia beryllina*	inland silverside	10
Belonidae	*Strongylura marina*	Atlantic needlefish	0
Catastomidae	*Catostomus commersonii*	white sucker	0
	Moxostoma macrolepidotum	shorthead redhorse	0
	Carpiodes cyprinus	quillback	0
	Erimyzon oblongatus	creek chubsucker	0
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	5
	Lepomis auritus	redbreast sunfish	0
	Lepomis cyannellus	green sunfish	0
	Lepomis gibbosus	pumpkinseed	39
	Lepomis macrochirus	bluegill	154
	Lepomis microlophus	redear sunfish	19
	Lepomis sp.	sunfish	215
	Micropterus dolomieu	smallmouth bass	0
	Micropterus salmoides	largemouth bass	2
	Pomoxis nigromaculatus	black crappie	11
Clupeidae	*Alosa aestivalis*	blueback herring	20
	Alosa mediocris	hickory shad	0
	Alosa pseudoharengus	alewife	39
	Alosa sapidissima	American shad	2
	Alosa sp.	herring or shad	30
	Brevoortia tyrannus	Atlantic menhaden	0
	Dorosoma cepedianum	gizzard shad	3
Cyprinidae	*Carassius auratus*	goldfish	8
	Cyprinella analostana	satinfin shiner	0
	Cyprinus carpio	common carp	1
	Hybognathus regius	eastern silvery minnow	8
	Notemigonius crysoleucas	golden shiner	0
	Notropis hudsonius	spottail shiner	401
	Pimephales promelas	fathead minnow	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	36
	Fundulus heteroclitus	mummichog	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	0
Gobiidae	*Gobiosoma bosc*	naked goby	0
Ictaluridae	*Ameiurus catus*	White catfish	0
	Ameiurus nebulosus	Brown bullhead	3
	Ictalurus furcatus	blue catfish	62
	Ictalurus punctatus	channel catfish	70
Lepisosteidae	*Lepisosteus osseus*	longnose gar	0
Percichthyidae	*Morone americana*	white perch	1105
	Morone saxatilis	striped bass	0
Percidae	*Etheostoma olmstedi*	tessellated darter	16
	Perca flavescens	yellow perch	18
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0
Soleidae	*Trinectes maculatus*	hogchoker	0
Total			2226

Table 6. Adult and Juvenile Fish Collected by Trawling. Gunston Cove Study - 2011

			4/26	5/10	5/20	6/03	6/17	6/30	7/18	7/29	8/12	8/26	9/23
Anguillidae	*Anguilla rostrata*	American eel	0	0	0	0	0	0	0	0	1	0	0
Atherinidae	*Menidia beryllina*	inland silverside	0	0	0	3	2	5	0	0	0	0	0
Belonidae	*Strongylura marina*	Atlantic needlefish	0	0	0	0	0	0	0	0	0	0	0
Catastomidae	*Catostomus commersonii*	white sucker	0	0	0	0	0	0	0	0	0	0	0
	Moxostoma macrolepidotum	shorthead redhorse	0	0	0	0	0	0	0	0	0	0	0
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	0	0	0	0	0	0	0	0	0	0	5
	Lepomis auritus	redbreast sunfish	0	0	0	0	0	0	0	0	0	0	0
	Lepomis cyanellus	green sunfish	0	0	0	0	0	0	0	0	0	0	0
	Lepomis gibbosus	pumpkinseed	2	5	8	3	8	0	1	12	0	0	0
	Lepomis macrochirus	bluegill	2	5	1	1	1	1	77	37	1	7	21
	Lepomis microlophus	redear sunfish	0	0	0	0	0	0	0	0	0	0	19
	Lepomis sp.	sunfish	0	0	0	0	5	0	143	57	0	3	7
	Micropterus dolomieu	smallmouth bass	0	0	0	0	0	0	0	0	0	0	0
	Micropterus salmoides	largemouth bass	0	0	0	0	1	0	0	1	0	0	0
	Pomoxis nigromaculatus	black crappie	1	1	0	0	2	0	5	0	0	2	0
Clupeidae	*Alosa aestivalis*	blueback herring	0	0	0	0	0	0	0	20	0	0	0
	Alosa mediocris	hickory shad	0	0	0	0	0	0	0	0	0	0	0
	Alosa pseudoharengus	alewife	0	0	0	3	28	1	1	1	0	5	0
	Alosa sapidissima	American shad	0	0	0	0	0	0	2	0	0	0	0
	Alosa sp.	herring or shad	0	0	0	0	0	0	0	0	30	0	0
	Brevoortia tyrannus	Atlantic menhaden	0	0	0	0	0	0	0	0	0	0	0
	Dorosoma cepedianum	gizzard shad	0	0	0	0	0	0	3	0	0	0	0
Cyprinidae	*Carassius auratus*	goldfish	2	3	0	0	0	1	0	2	0	0	0
	Cyprinella analostana	satinfin shiner	0	0	0	0	0	0	0	0	0	0	0
	Cyprinus carpio	common carp	0	0	0	0	0	0	1	0	0	0	0
	Hybognathus regius	eastern silvery minnow	0	0	0	6	0	0	2	0	0	0	0
	Notemigonus crysoleucas	golden shiner	0	0	0	0	0	0	0	0	0	0	0
	Notropis hudsonius	spottail shiner	5	1	17	9	23	33	192	117	0	3	1
	Pimephales promelas	fathead minnow	0	0	0	0	0	0	0	0	0	0	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	0	0	1	0	0	4	10	17	0	0	4
	Fundulus heteroclitus	mummichog	0	0	0	0	0	0	0	0	0	0	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	0	0	0	0	0	0	0	0	0
Gobiidae	*Gobiosoma bosc*	naked goby	0	0	0	0	0	0	0	0	0	0	0
Ictaluridae	*Ameiurus catus*	white catfish	0	0	0	0	0	0	0	0	0	0	0
	Ameiurus nebulosus	brown bullhead	0	0	0	1	1	1	0	0	0	0	0
	Ictalurus furcatus	blue catfish	0	0	0	11	15	1	2	0	0	19	14
	Ictalurus punctatus	channel catfish	0	0	1	0	0	2	2	31	34	0	0
Lepisosteidae	*Lepisosteus osseus*	longnose gar	0	0	0	0	0	0	0	0	0	0	0
Percichthyidae	*Morone americana*	white perch	12	6	2	8	95	557	254	102	51	12	6
	Morone saxatilis	striped bass	0	0	0	0	0	0	0	0	0	0	0
Percidae	*Etheostoma olmstedi*	tessellated darter	2	0	2	0	0	0	1	3	0	0	8
	Perca flavescens	yellow perch	2	0	5	11	0	0	0	0	0	0	0
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0	0	0	0	0	0	0	0	0	0	0
Total			28	21	37	53	153	606	696	379	117	51	85

Seasonal patterns in catches exhibited a unimodal pattern peaking the months of June and July that were driven by reproduction and successful recruitment of the dominant species. The dominant anadromous species, white perch, was ubiquitous occurring at all stations on nearly every sampling date (Tables 6 and 7). In the spring adult white perch were primarily caught in the nets while later in the summer juveniles dominated. Unlike previous years, bay anchovy was not caught at any of the sampling dates or sites. This is likely not an indication of extirpation since its occurrence is erratic. Whether there is a trend in declining should be evaluated during upcoming sampling more years.

In total numbers and species richness of fish, Station 7 dominated the other stations with 1224 individuals from 17 species. Stations 9 and 10 had 371 individuals from 9 species and 631 individuals from 17 species, respectively (Table 7).

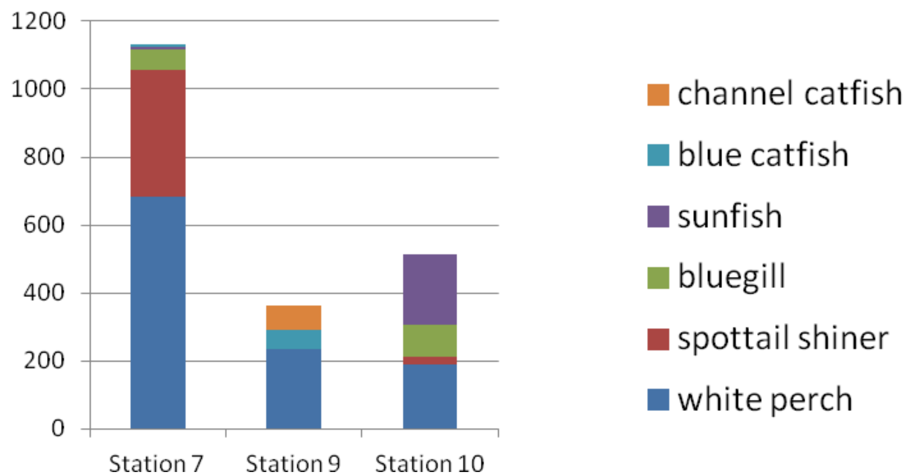


Figure 58. Adult and Juvenile Fishes Collected by Trawling. Dominant Species by Station.

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 maturily at about 5.5 cm and may attain a length of 10 cm. They feed primarily on benthic invertebrates and occasionally on algae and plants.

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

Table 7. Adult and Juvenile Fish Collected by Trawling. Gunston Cove Study - 2011

			Station		
			7	9	10
Anguillidae	*Anguilla rostrata*	American eel	0	1	0
Atherinidae	*Menidia beryllina*	inland silverside	3	0	7
Belonidae	*Strongylura marina*	Atlantic needlefish	0	0	0
Catastomidae	*Catostomus commersonii*	white sucker	0	0	0
	Moxostoma macrolepidotum	shorthead redhorse	0	0	0
	Carpiodes cyprinus	quillback	0	0	0
	Erimyzon oblongatus	creek chubsucker	0	0	0
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	0	0	5
	Lepomis auritus	redbreast sunfish	0	0	0
	Lepomis cyannellus	green sunfish	0	0	0
	Lepomis gibbosus	pumpkinseed	13	0	26
	Lepomis macrochirus	bluegill	62	0	92
	Lepomis microlophus	redear sunfish	9	0	10
	Lepomis sp.	sunfish	7	0	208
	Micropterus dolomieu	smallmouth bass	0	0	0
	Micropterus salmoides	largemouth bass	0	0	2
	Pomoxis nigromaculatus	black crappie	9	0	2
Clupeidae	*Alosa aestivalis*	blueback herring	20	0	0
	Alosa mediocris	hickory shad	0	0	0
	Alosa pseudoharengus	alewife	16	4	19
	Alosa sapidissima	American shad	2	0	0
	Alosa sp.	herring or shad	30	0	0
	Brevoortia tyrannus	Atlantic menhanden	0	0	0
	Dorosoma cepedianum	gizzard shad	3	0	0
Cyprinidae	*Carassius auratus*	goldfish	0	0	8
	Cyprinella analostana	satinfin shiner	0	0	0
	Cyprinus carpio	common carp	0	0	1
	Hybognathus regius	eastern silvery minnow	7	0	1
	Notemigonius crysoleucas	golden shiner	0	0	0
	Notropis hudsonius	spottail shiner	374	2	25
	Pimephales promelas	fathead minnow	0	0	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	1	0	35
	Fundulus heteroclitus	mummichog	0	0	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	0
Gobiidae	*Gobiosoma bosc*	naked goby	0	0	0
Ictaluridae	*Ameiurus catus*	white catfish	0	0	0
	Ameiurus nebulosus	brown bullhead	1	1	1
	Ictalurus furcatus	blue catfish	5	57	0
	Ictalurus punctatus	channel catfish	0	70	0
Lepisosteidae	*Lepisosteus osseus*	longnose gar	0	0	0
Percichthyidae	*Morone americana*	white perch	682	234	189
	Morone saxatilis	striped bass	0	0	0
Percidae	*Etheostoma olmstedi*	tessellated darter	1	2	13
	Perca flavescens	yellow perch	9	3	6
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0	0	0
Soleidae	*Trinectes maculatus*	hogchoker	0	0	0
Total			1224	371	631

The six most abundant species varied in representation across stations (Figure 58). Blue catfish were almost exclusively observed at station 9 in relatively high abundance. Blue catfish are primarily a mainstem species and have not featured prominently at stations within the cove. At all stations, white perch made up a significant proportion of the total catch. Clupeids were not as abundant as in previous years and the individual species could not be counted among the six most abundant species. Added together, 71 clupeids were collected in station 7, 4 in station 9, and 19 in station 10. Station 7 was overall the most productive site, with an abundance about 2-3 times higher than the other two stations.

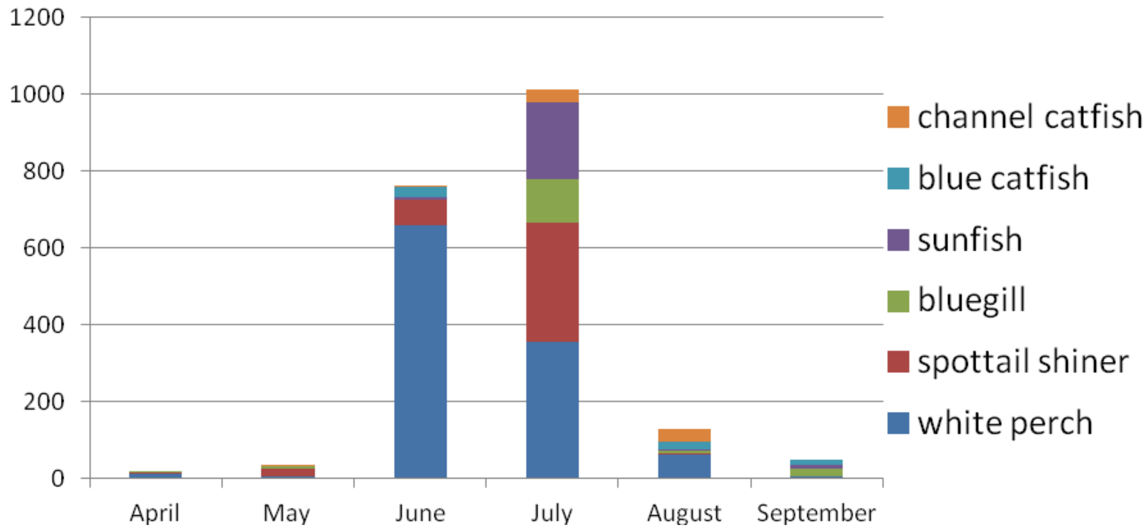


Figure 59. Adult and Juvenile Fishes Collected by Trawling. Dominant Species by Month.

White perch and spottail shiner were the most common species (Figure 59). Whereas white perch were present throughout the season, blue catfish (primarily juveniles) were mainly captured at the end of the season. Other common species were sunfish and catfish species. In 2011, the most productive months were June and July, which were dominated by cohorts of juvenile fishes.

Blueback herring (*Alosa aestivalis*) was formerly a major commercial species, but is now less common due to overfishing. Adults grow to over 30 cm and are found in the coastal ocean. They return to tidal freshwater embayments and freshwater creeks to spawn in April and May. They feed on zooplankton and may eat fish larvae.

Alewife (*Alosa pseudo-harengus*), like blueback herring, was once a valuable commercial species. They also grow in the coastal ocean to about 30 cm as adults and return to tidal creeks in March and April to spawn at about age 4. As juveniles they feed on zooplankton and, sometimes, on fish larvae.

Channel catfish (*Ictalurus punctatus*) is an intro-duced species from the Mississippi River basin. They are year round residents, growing to more than 45 cm and are sexually mature at 4-6 years of age. They spawn in nests on the bottom in May-June and the eggs and larvae are protected by the male. As larvae they feed on zooplankton; juveniles and adults on benthos, fishes, and plant material.

Seines

Seine sampling was conducted approximately semi-monthly at 4 stations between 26 April and 5 October. There were some complications due to heavy rains in 2011. On May 20 only station 4A and 11 could be sampled. Therefore we returned on May 23 to sample stations 4 and 6. On July 18 only 4A, 6, and 11 could be sampled; station 4 was sampled on July 19. Station 6 could not be completed on the last sampling date, 23 September. Therefore, we returned October 5 to complete sampling at station 6.

Stations 4, 6, and 11 have been sampled continuously since 1985. The fourth ancillary station (4A) was added in recent years as a substitute for station 4 when dense SAV impeded seining. Station 4A is located approximately 520 m ESE of station 4 at the canoe launch beach of Pohick Regional Park. Although both sites have cobble substrate, SAV at 4A is routinely cleared to allow access to boaters; therefore, seining there is not impeded. In 2011 (as in the previous year), regardless of SAV density, station 4A was sampled concurrently with station 4 so that catch composition could be compared.

A total of 44 seine samples were conducted, comprising 6524 fishes and 32 species (Table 8). The most abundant species in seine catches were banded killifish (55.3%), followed by white perch (22.3%). Several other species occurred at high abundances (>100 total) including: quillback, bluegill, blueback herring, gizzard shad, spottail shiner, mummichog, striped bass and tessellated darter. Other species occurred at medium or low abundances (Table 8). Continuing a recent trend were moderate catches of (primarily juvenile) largemouth bass, which reflects relatively high recruitment success in 2007, 2008, 2009, 2010, and 2011.

Seasonal catch patterns were variable with June and July representing the most productive period, although a single catch of 845 banded killifish was responsible for the fact that the highest total abundance found on May 10 (Table 9). Peaks in abundance tended to be short represented by one or 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). For the numerically dominant banded killifish, catches averaged 375 per sampling round.

Total abundance at the sites was close to evenly distributed, varying from n=1477 fish at Station 11 to n=1774 at Station 4A (Table 10). In the previous year, highest abundance was found in Station 11 and lowest at Station 4A, so the sites seem to be similarly productive over the long-term. The stations were also similar to each other in species richness with values ranging between 20 and 24 species during 2011. Banded killifish and white perch made up >75% of the total abundance, while dominance of those species varied slightly by site. At sites 4, 4A and 6, banded killifish were the dominant species. At site 4A and 6, white perch was the second most dominant, while only 1 white perch was found in site 4. At site 11, white perch was dominant, while high numbers (>100) were found of blueback herring, gizzard shad, banded killifish and striped bass.

Table 8. Adult and Juvenile Fish Collected by Seining. Gunston Cove Study - 2011

Anguillidae	*Anguilla rostrata*	American eel	1
Atherinidae	*Menidia beryllina*	inland silverside	72
Belonidae	*Strongylura marina*	Atlantic needlefish	2
Catastomidae	*Moxostoma macrolepidotum*	shorthead redhorse	0
	Catostomus commersonii	white sucker	2
	Erimyzon oblongatus	creek chubsucker	3
	Carpiodes cyprinus	quillback	114
Centrarchidae	*Pomoxis nigromaculatus*	black crappie	5
	Lepomis macrochirus	bluegill	138
	Enneacanthus gloriosus	bluespotted sunfish	51
	Lepomis cyannellus	green sunfish	2
	Micropterus salmoides	largemouth bass	22
	Lepomis gibbosus	pumpkinseed	43
	Lepomis auritus	redbreast sunfish	58
	Lepomis microlophus	redear sunfish	68
	Micropterus dolomieu	smallmouth bass	0
	Lepomis sp.	sunfish	62
Clupeidae	*Alosa pseudoharengus*	alewife	30
	Alosa sapidissima	American shad	3
	Brevoortia tyrannus	Atlantic menhaden	0
	Alosa aestivalis	blueback herring	156
	Dorosoma cepedianum	gizzard shad	141
	Alosa sp.	herring or shad	22
	Alosa mediocris	hickory shad	3
Cyprinidae	*Cyprinus carpio*	common carp	0
	Hybognathus regius	eastern silvery minnow	42
	Pimephales promelas	fathead minnow	0
	Notemigonius crysoleucas	golden shiner	15
	Carassius auratus	goldfish	3
	Cyprinella analostana	satinfin shiner	1
	Notropis hudsonius	spottail shiner	114
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	3611
	Fundulus heteroclitus	mummichog	111
Engraulidae	*Anchoa mitchilli*	bay anchovy	0
Gobiidae	*Gobiosoma bosc*	naked goby	0
Ictaluridae	*Ictalurus furcatus*	blue catfish	0
	Ameiurus nebulosus	brown bullhead	2
	Ictalurus punctatus	channel catfish	0
	Ameiurus catus	white catfish	0
Lepisosteidae	*Lepisosteus osseus*	longnose gar	1
Percichthyidae	*Morone saxatilis*	striped bass	168
	Morone americana	white perch	1455
Percidae	*Etheostoma olmstedi*	tessellated darter	153
	Perca flavescens	yellow perch	1
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	6
Soleidae	*Trinectes maculatus*	hogchoker	0
Total			6524

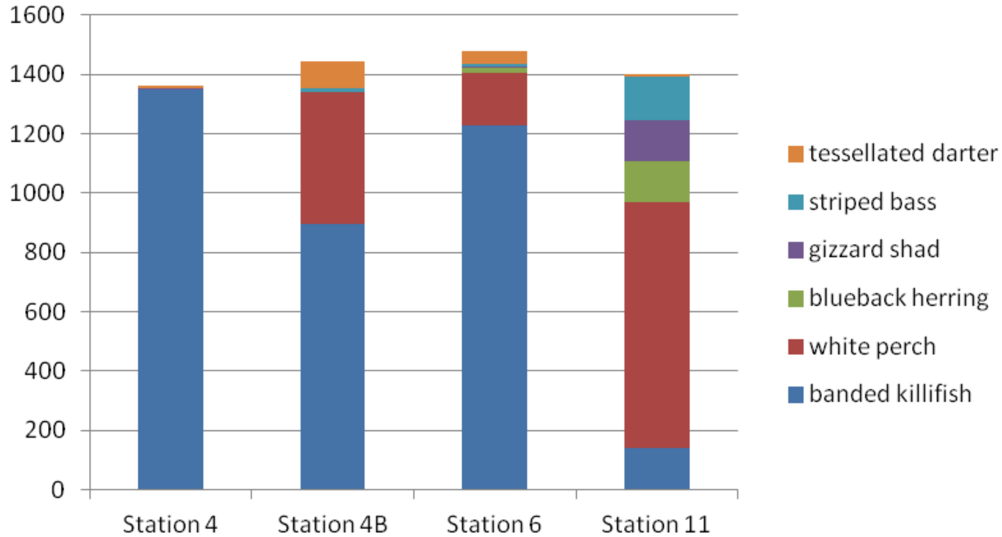
Table 9. Adult and Juvenile Fish Collected by Seining. Gunston Cove Study - 2011

			4/26	5/10	5/20	5/23	6/03	6/17	6/30	7/18	7/19	7/29	8/12	8/26	9/23	10/05
Anguillidae	*Anguilla rostrata*	American eel	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Atherinidae	*Menidia beryllina*	inland silverside	4	52	8	0	1	0	0	0	0	0	3	4	0	0
Belonidae	*Strongylura marina*	Atlantic needlefish	0	0	0	0	0	1	0	0	0	0	0	1	0	0
Catastomidae	*Catostomus commersonii*	white sucker	0	0	1	1	0	0	0	0	0	0	0	0	0	0
	Moxostoma macrolepidotum	shorthead redhorse	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Carpiodes cyprinus	quillback	0	0	0	0	1	25	29	23	0	27	9	0	0	0
	Erimyzon oblongatus	creek chubsucker	0	0	0	0	0	0	0	0	0	0	2	1	0	0
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	0	0	0	49	0	0	0	0	0	0	0	0	0	2
	Lepomis auritus	redbreast sunfish	0	0	0	0	0	0	0	0	0	0	1	57	0	0
	Lepomis cyannellus	green sunfish	0	0	0	0	0	0	0	0	0	0	0	0	2	0
	Lepomis gibbosus	pumpkinseed	8	3	1	1	1	6	1	0	0	0	22	0	0	0
	Lepomis macrochirus	bluegill	6	2	1	2	1	2	2	25	4	25	19	31	14	4
	Lepomis microlophus	redear sunfish	0	0	0	0	1	0	6	0	0	3	0	47	6	5
	Lepomis sp.	sunfish	8	9	0	11	0	5	0	11	0	4	13	1	0	0
	Micropterus salmoides	largemouth bass	4	2	0	0	0	2	5	2	0	2	4	0	1	0
	Pomoxis nigromaculatus	black crappie	0	0	1	1	0	0	0	2	0	0	0	1	0	0
Clupeidae	*Alosa aestivalis*	blueback herring	0	0	0	0	20	136	0	0	0	0	0	0	0	0
	Alosa mediocris	hickory shad	0	0	0	0	0	0	1	2	0	0	0	0	0	0
	Alosa pseudoharengus	alewife	0	0	0	0	0	1	0	1	0	8	0	20	0	0
	Alosa sapidissima	American shad	0	0	0	0	0	0	3	0	0	0	0	0	0	0
	Alosa sp.	herring or shad	0	0	0	0	0	0	0	0	0	0	18	0	4	0
	Dorosoma cepedianum	gizzard shad	3	0	0	2	0	129	0	4	0	0	3	0	0	0
Cyprinidae	*Carassius auratus*	goldfish	1	0	0	0	0	0	0	0	0	0	2	0	0	0
	Cyprinella analostana	satinfin shiner	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	Cyprinus carpio	common carp	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hybognathus regius	eastern silvery minnow	3	2	1	0	0	4	3	1	0	0	1	25	2	0
	Notemigonius crysoleucas	golden shiner	1	1	2	0	1	0	0	0	0	0	6	3	1	0
	Notropis hudsonius	spottail shiner	16	0	3	0	0	2	6	12	0	6	4	21	44	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	143	845	47	93	843	652	121	118	24	47	235	328	72	43
	Fundulus heteroclitus	mummichog	3	19	0	0	3	3	8	9	3	6	32	23	2	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ictaluridae	*Ameiurus catus*	white catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ameiurus nebulosus	brown bullhead	0	0	0	1	0	0	1	0	0	0	0	0	0	0
Lepisosteidae	*Lepisosteus osseus*	longnose gar	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Percichthyidae	*Morone americana*	white perch	76	0	23	0	0	8	279	372	0	205	175	303	14	0
	Morone saxatilis	striped bass	2	0	7	0	0	70	53	24	0	1	0	10	1	0
Percidae	*Etheostoma olmstedi*	tessellated darter	30	11	1	0	2	3	14	12	0	4	8	65	3	0
	Perca flavescens	yellow perch	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0	0	0	0	0	0	0	0	0	0	0	3	1	2
Total			309	946	96	161	854	912	533	619	31	338	558	944	167	56

Table 10. Adult and Juvenile Fish Collected by Seining. Gunston Cove Study - 2011

			Station 11	4	4A	6
Anguillidae	*Anguilla rostrata*	American eel	0	0	0	1
Atherinidae	*Menidia beryllina*	inland silverside	68	1	2	1
Belonidae	*Strongylura marina*	Atlantic needlefish	1	0	1	0
Catastomidae	*Catostomus commersonii*	white sucker	2	0	0	0
	Moxostoma macrolepidotum	shorthead redhorse	0	0	0	0
	Carpiodes cyprinus	quillback	27	1	84	2
	Erimyzon oblongatus	creek chubsucker	0	0	3	0
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	0	0	0	51
	Lepomis auritus	redbreast sunfish	0	29	7	22
	Lepomis cyannellus	green sunfish	0	2	0	0
	Lepomis gibbosus	pumpkinseed	1	4	23	15
	Lepomis macrochirus	bluegill	9	30	67	32
	Lepomis microlophus	redear sunfish	1	18	16	33
	Lepomis sp.	sunfish	5	1	26	30
	Micropterus dolomieu	smallmouth bass	0	0	0	0
	Micropterus salmoides	largemouth bass	1	6	10	5
	Pomoxis nigromaculatus	black crappie	1	1	3	0
Clupeidae	*Alosa aestivalis*	blueback herring	136	0	0	20
	Alosa mediocris	hickory shad	2	0	1	0
	Alosa pseudoharengus	alewife	23	0	7	0
	Alosa sapidissima	American shad	3	0	0	0
	Alosa sp.	herring or shad	14	0	8	0
	Brevoortia tyrannus	Atlantic menhaden	0	0	0	0
	Dorosoma cepedianum	gizzard shad	137	2	1	1
Cyprinidae	*Carassius auratus*	goldfish	1	0	2	0
	Cyprinella analostana	satinfin shiner	0	0	1	0
	Cyprinus carpio	common carp	0	0	0	0
	Hybognathus regius	eastern silvery minnow	9	21	4	8
	Notemigonius crysoleucas	golden shiner	9	3	2	1
	Notropis hudsonius	spottail shiner	37	1	60	16
	Pimephales promelas	fathead minnow	0	0	0	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	141	1349	894	1227
	Fundulus heteroclitus	mummichog	0	57	4	50
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	0	0
Gobiidae	*Gobiosoma bosc*	naked goby	0	0	0	0
Ictaluridae	*Ameiurus catus*	white catfish	0	0	0	0
	Ameiurus nebulosus	brown bullhead	0	1	0	1
	Ictalurus furcatus	blue catfish	0	0	0	0
	Ictalurus punctatus	channel catfish	0	0	0	0
Lepisosteidae	*Lepisosteus osseus*	longnose gar	0	0	0	1
Percichthyidae	*Morone americana*	white perch	830	1	447	177
	Morone saxatilis	striped bass	148	1	10	9
Percidae	*Etheostoma olmstedi*	tessellated darter	8	9	91	45
	Perca flavescens	yellow perch	0	0	0	1
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0	3	0	3
Soleidae	*Trinectes maculatus*	hogchoker	0	0	0	0
Total			1477	1541	1774	1732

Of the 6 dominant species ranked by catch rate, banded killifish and white perch were most abundant (Figure 60). Other dominant species in 2011 included river herrings, gizzard shad, striped bass, and tessellated darter. Striped bass was not among the dominant species last year, which may be an indication of the recovery of striped bass stock. The preference of banded killifish for the shallow littoral zone is evident in the distribution. Abundance is high everywhere but Station 11, close to the mainstem.



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.

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

Typical of shallow littoral zone habitats in Gunston Cove during the past decade, the most productive period for seine sampling occurred in June (Figure 61). Banded killifish occurred in every month peaking in June, while white perch peaked primarily in July and August. Most other species occurred at their highest abundance in June.

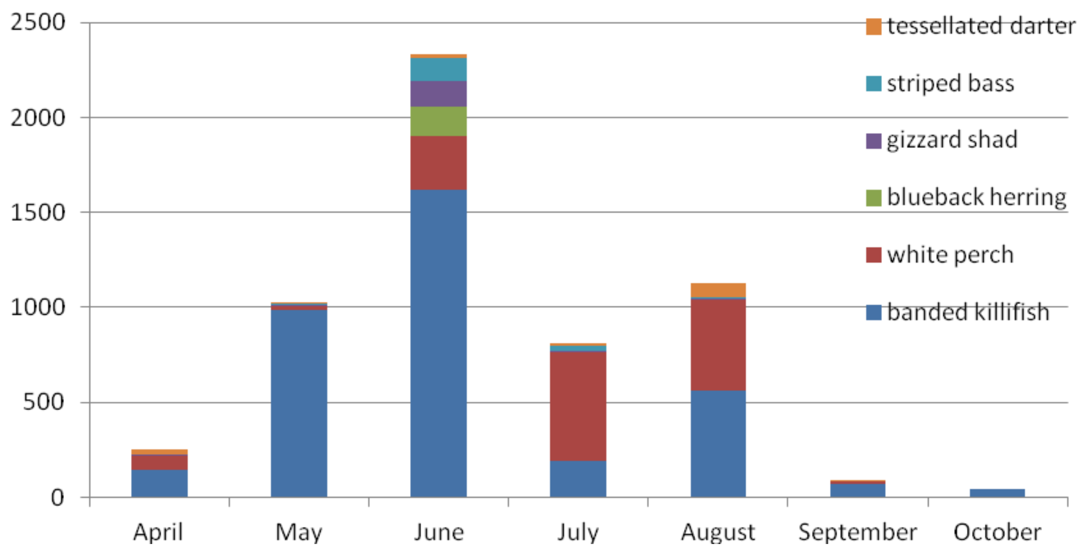


Figure 61. Adult and Juvenile Fish Collected by Seining. Dominant Species by Month.

White perch (*Morone americana*), which was discussed earlier in the trawl section, is also a common shoreline fish as juveniles collected in seines.

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.

F. Submersed Aquatic Vegetation – 2011

SAV data were not available from VIMS for 2011. Both Hurricane Irene and Tropical Storm Lee came through during their normal period for aerial photography which greatly compressed the window for flights. When they finally did fly the area, the tide was abnormally high and the images were not adequate to make assessments (R. Orth, personal communication).

H. Benthic Macroinvertebrates - 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). 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 65). This was similar to observations made in 2010. In the cove diptera (chironomid/midge) larvae made up the bulk of the remaining organisms although they were present in lower numbers than in most years. A handful of amphipods were found in some of the cove samples. In the river, amphipods (crustaceans commonly known as scuds) were found in moderate numbers. *Corbicula* (Asiatic clam) was absent from the cove and rarer in the river than in recent years.. Diptera were rare in the river and *Corbicula* were absent in the cove.

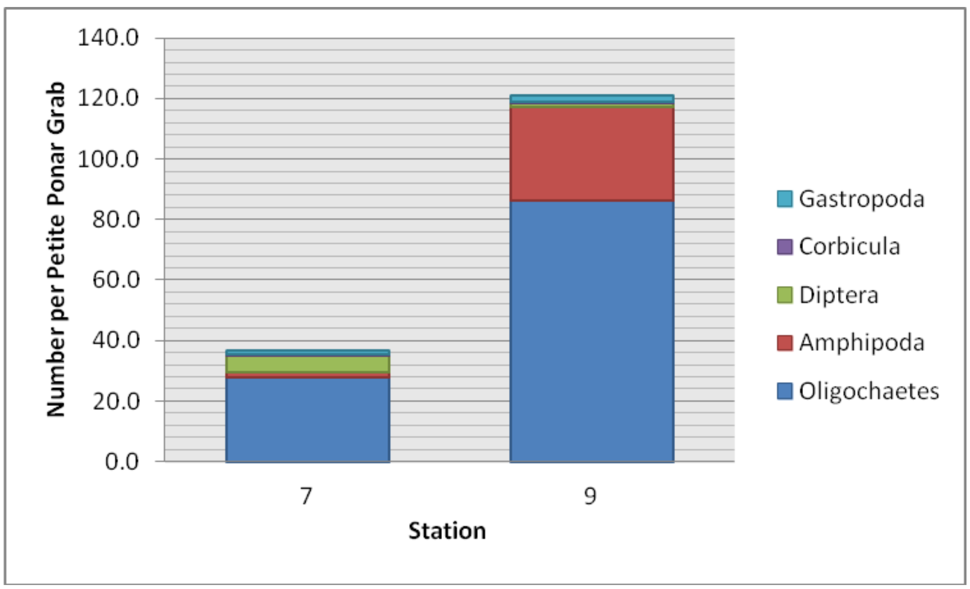


Figure 65. Average abundance of various benthic macroinvertebrate taxa in petite ponar samples collected on four dates in 2010.

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.