THE ONGOING AQUATIC MONITORING PROGRAM

FOR THE GUNSTON COVE AREA

OF THE TIDAL FRESHWATER POTOMAC RIVER

2008

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 Department of Environmental Science and Policy at George Mason University and supported by the Department of Public Works of Fairfax County, Virginia. 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 Work Unit, particularly Jimmie Jenkins, 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 Hayley Becker, Theresa Connor, Pete Dagata, Suzanne Dee, Saiful Islam, Jennifer Rafter, Chris Ruck, and Jonathan Witt. Claire Buchanan served as a voluntary consultant on plankton identification. Natalie Vu and Roslyn Cress 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.

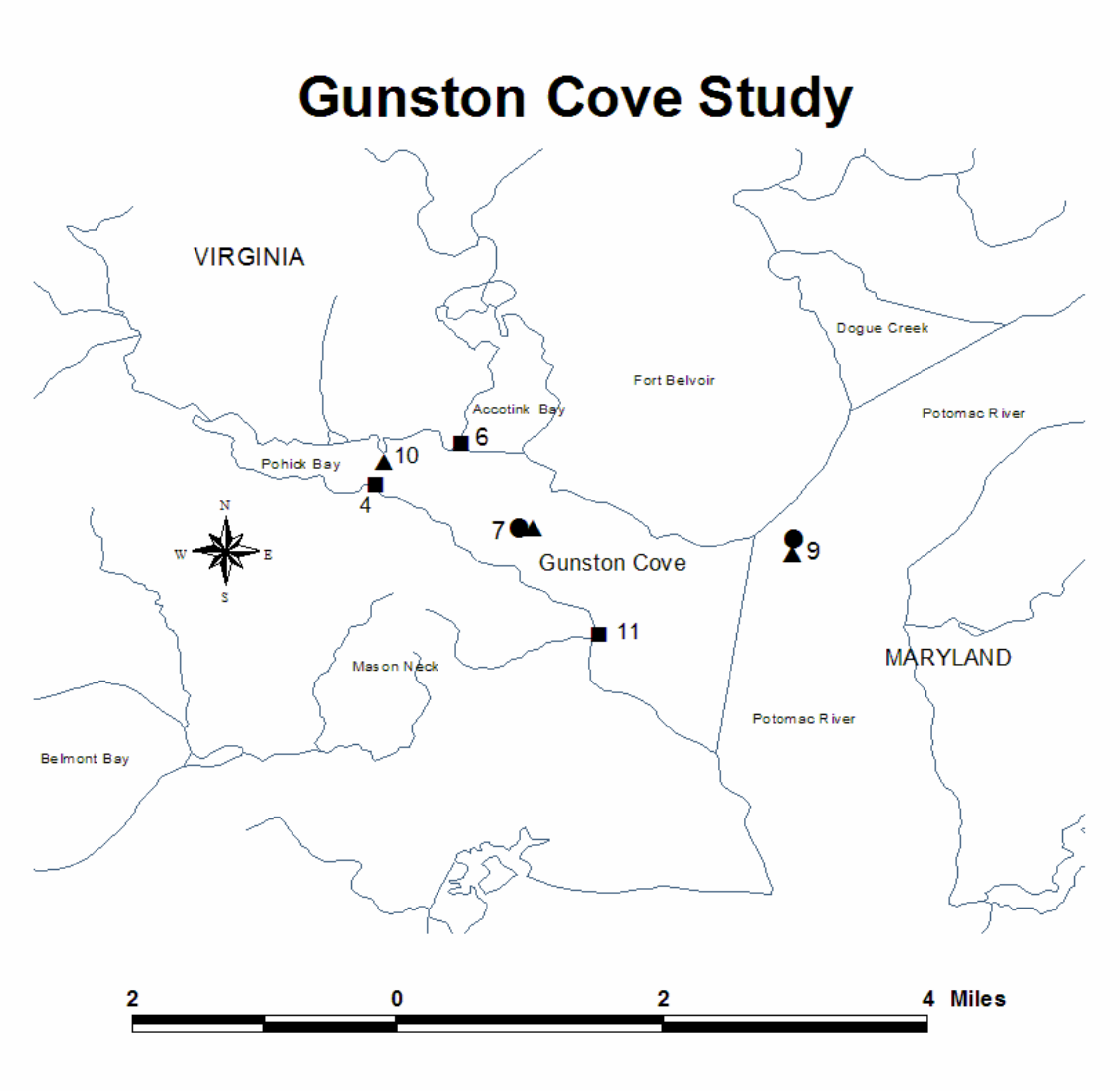


Figure 1. Gunston Cove area of the Tidal Potomac River showing sampling stations. Circles represent Plankton/Profile stations, triangles represent Fish Trawl stations, and squares represent Fish Seine stations.

Table 1
Sampling Dates and Weather Data for 2008

	Type of Sampling				Avg Daily Temp (^oC)		Precipitation (cm)	
Date	G	F	T	S	1-Day	3-Day	1-Day	3-Day
April 9	G	F			14.4	10.9	0	T
April 16		F*			13.9	11.7	0	T
April 25			T	S	20.6	20.0	0	0
May 14	G	F			17.2	14.4	0	3.35
May 15			T	S	21.1	18.1	0.74	0.74
May 23	G				16.7	16.5	0	T
May 27			T	S	24.4	22.0	T	T
June 6			T	S	25.0	25.0	0	3.78
June 11	G	F			26.7	28.9	0	0.84
June 19		F*			20.6	21.3	T	T
June 20	G				22.2	21.3	0	0.03
June 23			T	S	25.0	24.8	0.36	0.71
July 8			T	S	27.2	26.3	0	T
July 9	G	F			27.2	26.9	0.03	0.03
July 22			T	S	28.9	29.6	0.10	0.10
July 23	G				25.6	28.1	2.77	2.88
August 5			T	S	27.2	26.7	T	T
August 6	G	F			29.4	27.8	0	T
August 14		F*			25.0	24.8	0.51	0.51
August 19			T	S	27.8	26.9	0	0
August 20	G				23.9	26.3	0	0
Sept 16	G	F			21.7	25.7	0	0
Sept 19			T	S	20.0	21.1	0	0
Sept 30		F*			20.0	21.9	1.12	2.77

Type of Sampling: G: GMU profiles and plankton, F: nutrient and lab water quality by Fairfax County Laboratory, T: fish collected by trawling, S: fish collected by seining.
*Samples collected by Fairfax County Lab Personnel

Sampling was initiated at 8-9 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 Hydrolab 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 Hydrolab 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 m. Measurements were taken in air before and after each profile to assure that ambient light had not changed more than 10% during the profile. Secchi depth was also determined. The readings of at least two crew members were averaged.

A 2-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 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*. 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 0.44 µm nitex net glued to one end. The 0.44 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 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) 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) for 2 minutes at each of the same depths. Tows tended to follow an arc around the fixed profile site: 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. Each net was about 2 meters long with a 0.3 or 0.5 m opening into which a General Oceanics flowmeter was fitted. The depths were established 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 tows averaged 300 m in length and ichthyoplankton tows were about 600 m long. In the cove, the boat made a large arc while towing while in the river the net was towed along the channel. Macrozooplankton and ichthyoplankton were preserved immediately with formalin to a concentration of 5-10%. Rose bengal formalin with carbonated water pretreatment was used for macrozooplankton, but not for ichthyoplankton. Macrozooplankton was collected on each sampling trip; ichthyoplankton collections ended after July because larval fish were normally not found after this time.

Samples were delivered to the Fairfax County Environmental Services Laboratory by 1 pm on sampling day and returned to GMU by 2 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. 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: Followup 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. Fluroescence was determined before and after acidification with 2 drops of 10% HCl. Chlorophyll a was calculated from the following equation which corrects for pheophytin interference:

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

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

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

Phytoplankton species composition and abundance was determined using the inverted microscope-settling chamber technique (Lund et al. 1958). Ten milliters of well-mixed algal sample were added to a settling chamber and allowed to stand for several hours. The chamber was then placed on an inverted microscope and random fields were enumerated. At least two hundred cells were identified to species and enumerated on each slide. Counts were converted to number per mL by dividing number counted by the volume counted. Biovolume of individual cells of each species was determined by measuring dimensions microscopically and applying volume formulae for appropriate solid shapes. Diatom biovolume was corrected for vacuole volume using the method employed by the Chesapeake Bay Program. This method was applied directly for discoid centrics and pennates. Biovolume for filamentous centrics like Melosira was corrected by taking 2/3 of the calculated total cell biovolume.

Microzooplankton and macrozooplankton samples were rinsed by sieving a well-mixed subsample of know 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. A one mL subsample was placed in a Sedgewick-Rafter counting cell and whole slides were analyzed until at least 200 animals had been identified and enumerated. A minimum of two slides was examined for each sample. References for identification were: Ward and Whipple (1959), Pennak (1978), and Rutner-Kolisko (1974). Zooplankton counts were converted to number per liter (microzooplankton) or per cubic meter (macrozooplankton) with the following formula:

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

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:

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

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.

Shoreline fishes were sampled by seining at 3 stations: 4, 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. At the end of the prescribed distance, the offshore end of the net was swung in an arc to the shore and the net pulled up on the beach to trap the fish. Dates for seine sampling were generally the same as those for trawl sampling.

We conducted drop ring (a.k.a, Wegner ring) sampling of submerged aquatic vegetation (SAV) beds to better quantify densities of juvenile fishes in these habitats. In Gunston Cove SAV beds develop during mid-summer and hamper sampling efforts with seines and trawls in shallow habitats. Drop ring sampling uses a cylinder (0.8m diameter) to trap a column of water and SAV. The contents of the ring (including the water) are removed and examined for the presence of juvenile fishes, providing more efficient quantitative estimates of abundance. The drop ring was deployed on several days (July 29th, August 4th, 12th, and 27th), spanning the period of full SAV bed development within the cove. Due to various unforeseen logistical issues, we also sampled later in the season on October 1st to increase samples size. On the last sampling date, SAV beds were heavily fouled with algae, but had not yet started to senesce and were still fully developed. We employed a stratified random sampling routine with equal probability of sampling in Pohick or Accotink Bays. We collected 28 drop ring samples, containing a total of 126 juvenile fishes for a nominal fish density of 4.8 individuals per sample.

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.

F. Data Analysis

Data for each parameter were entered into spreadsheets (Quattro Pro, 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. 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

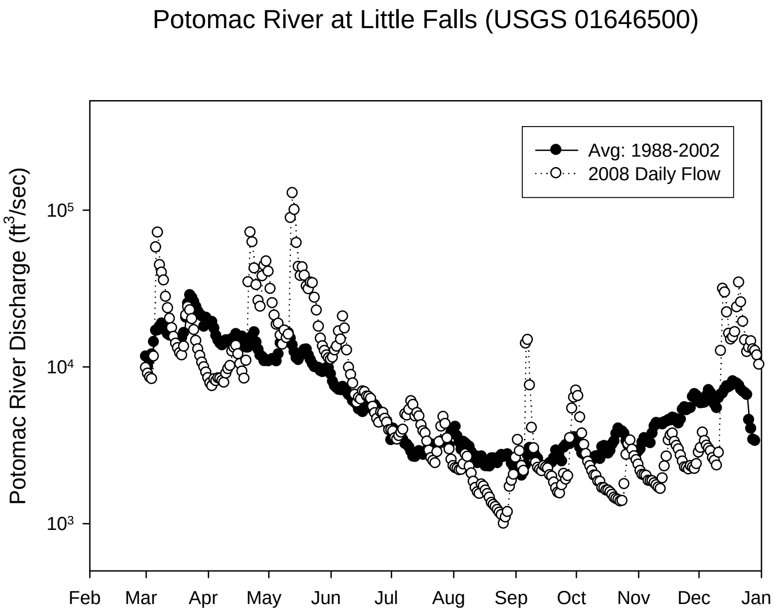
A. Climatic and Hydrologic Factors

In 2008 air temperature was at or above average for most of the year. The period June through October was particularly warm (Table 2). July was the warmest with June and August tied for second warmest months. There were 31 days with maximum temperature above 32.2^{o}C (90^{o}F) during 2008 compared with 4 in 2004, 18 in 2005, 29 in 2006, and 33 days in 2007. Temperature was cooler than normal only in May and November. Precipitation was variable with May and September being much wetter than normal and August and October being very dry.

Table 2
Meteorological Data for 2008. National Airport. Monthly Summary.

MONTH	Air Temp (^{o}C)		Precipitation (cm)	
March	9.4	(8.1)	7.1	(9.1)
April	14.9	(13.4)	12.5	(7.0)
May	18.2	(18.7)	27.1	(9.7)
June	25.5	(23.6)	12.2	(8.0)
July	27.1	(26.2)	9.2	(9.3)
August	25.5	(25.2)	3.1	(8.7)
September	23.2	(21.4)	16.3	(9.6)
October	14.9	(14.9)	2.9	(8.2)
November	8.1	(9.3)	6.2	(7.7)
December	4.6	(4.2)	7.5	(7.8)

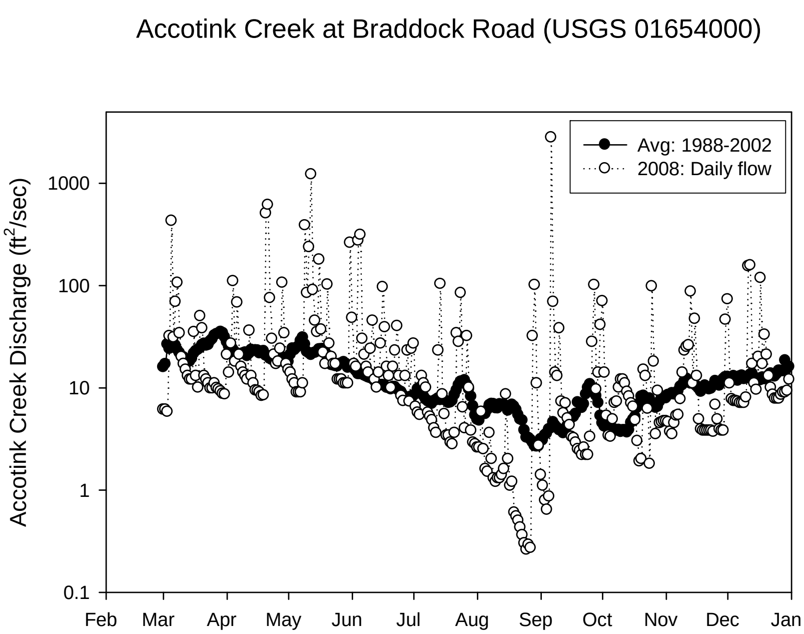
Note: 2008 monthly averages or totals are shown accompanied by long-term monthly averages (1971-2000).
Source: Local Climatological Data. National Climatic Data Center, National Oceanic and Atmospheric Administration.



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 is referred to as "river discharge" by hydrologists.

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

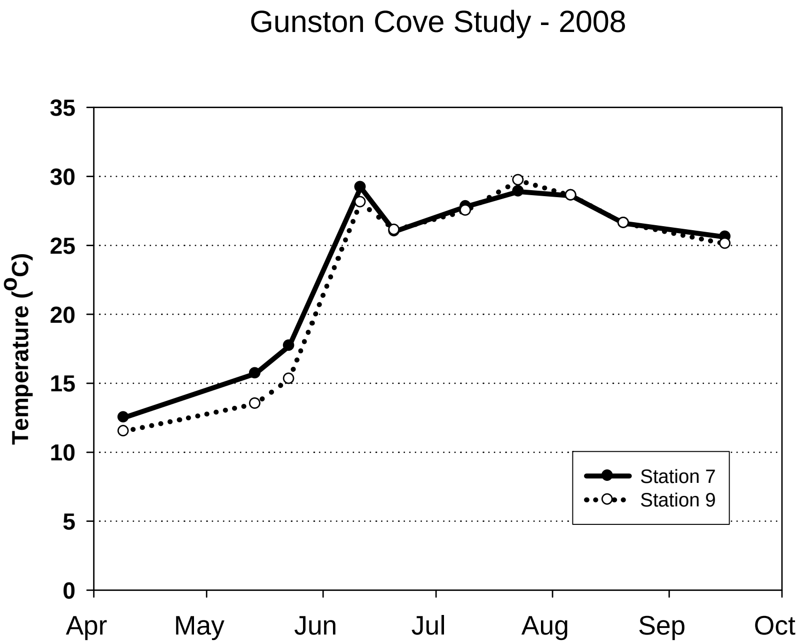
Potomac River discharge during 2008 was generally near average (Figure 2). Higher than normal flows occurred in May and June. During August flow steadily declined reaching a low of about 1000 cfs late in the month. Generally below normal flows occurred in the fall until mid December when a substantial increase was observed. Flows in Accotink Creek were near normal through July, but during the August drought flows were often very low, dropping below 1 cfs. The return of precipitation in September elevated Accotink Creek flows to near normal for the rest of the year.



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

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

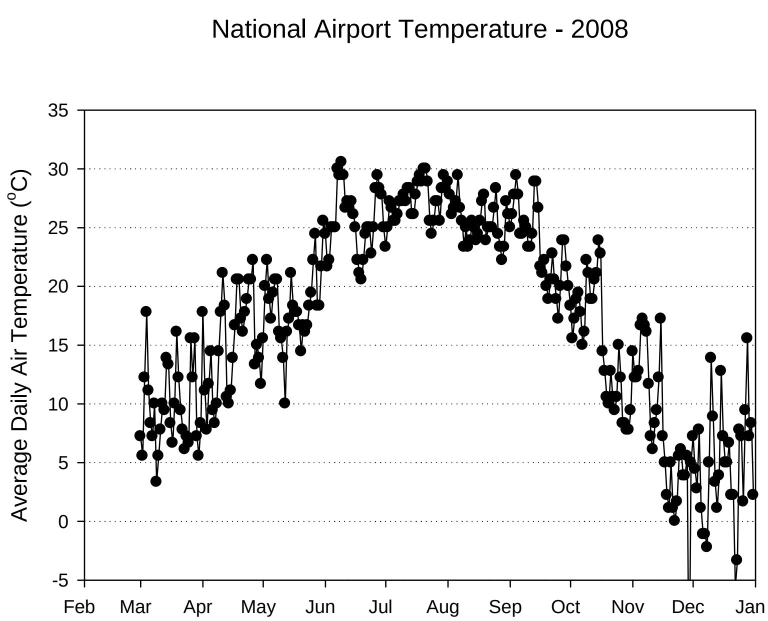
B. Physico-chemical Parameters – 2008



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.

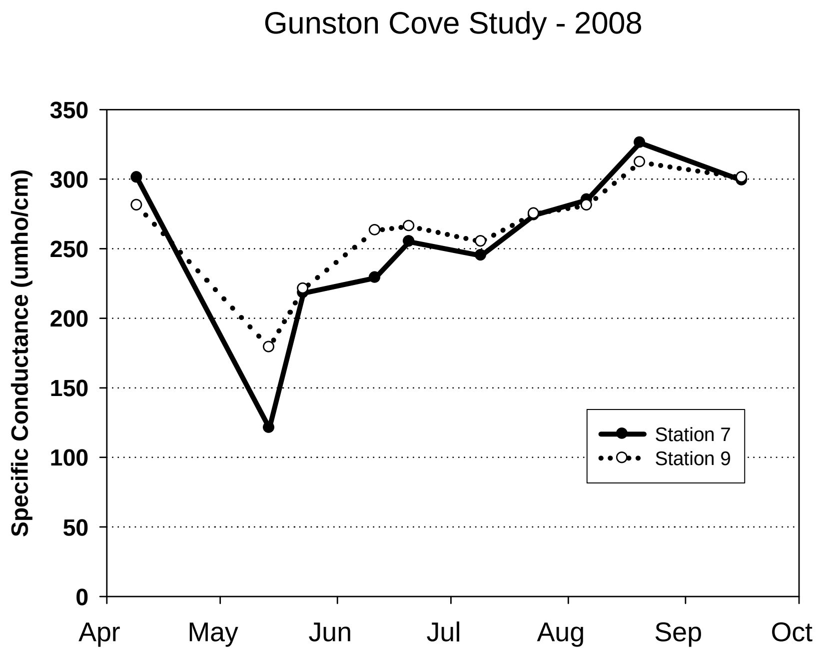
Figure 4. Water Temperature (°C). GMU Field Data. Month tick is at first day of month.

In 2008, water temperature followed the typical seasonal pattern at both sites (Figure 4). Station 7 warmed up more quickly in the spring typically being 1-2 C higher on each sampling date. Both sites exhibited a peak in June when average air temperature spiked above 30 C. For most of the summer, the two stations showed remarkably similar air temperatures between 25 and 30 C. Mean daily air temperature (Figure 5) was a good predictor of water temperature.



Note that in 2006 both air and water temperatures exceeded 30ºC in late July and early August.

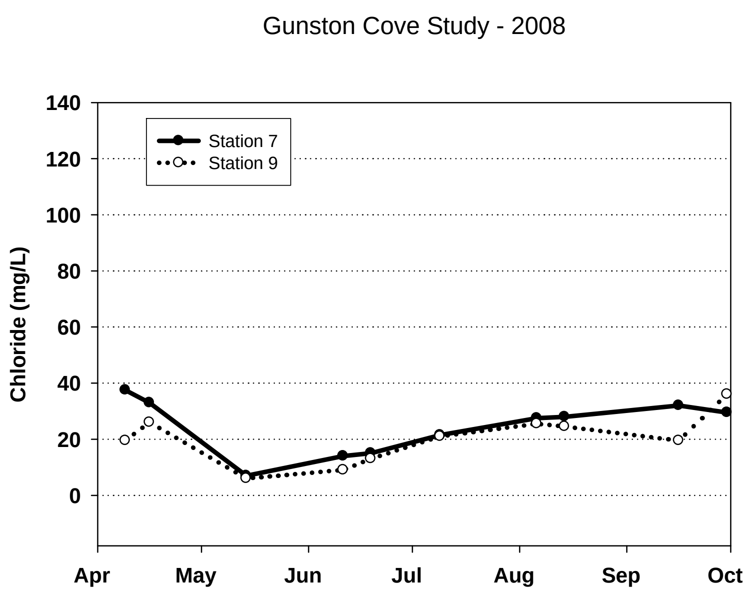
Figure 5. Average Daily Air Temperature (°C) at Reagan National Airport.



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.

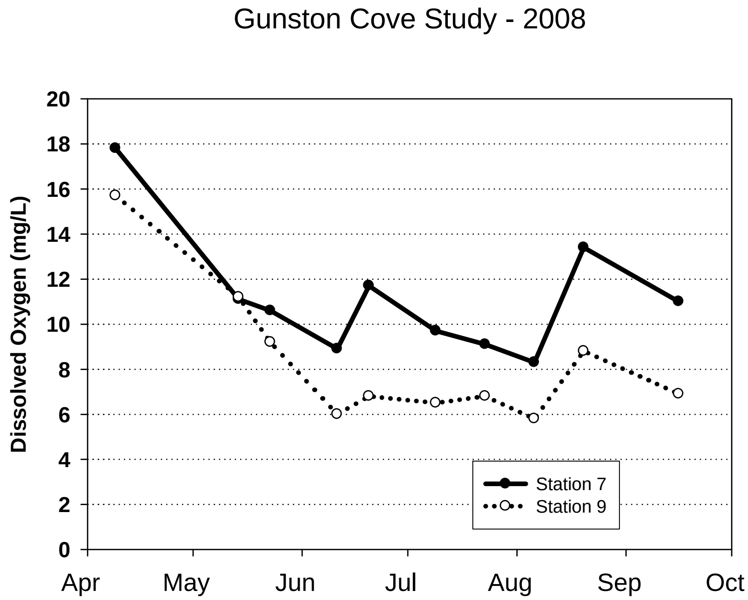
Figure 6. Specific Conductance (uS/cm). GMU Field Data. Month tick is at first day of month.

During most of 2008, specific conductance (Figure 6) exhibited similar patterns in the cove (Station 7) and the river (Station 9) with cove values showing somewhat higher high's and lower low's. Relatively high values in mid April gave way to much reduced conductance in mid May following some large freshwater runoff events. Conductivity then gradually increased at both sites through the remainder of the year reaching a peak in August. Chloride exhibited a similar pattern (Figure 7).



Chloride ion (Cl-) is a principal contributor to conductance. Major sources of chloride in the study area are sewage treatment plant discharges, road salt, and brackish water from the downriver portion of the tidal Potomac. Chloride concentrations observed in the Gunston Cove area are very low relative to those observed in brackish, estuarine, and coastal areas of the Mid-Atlantic region.

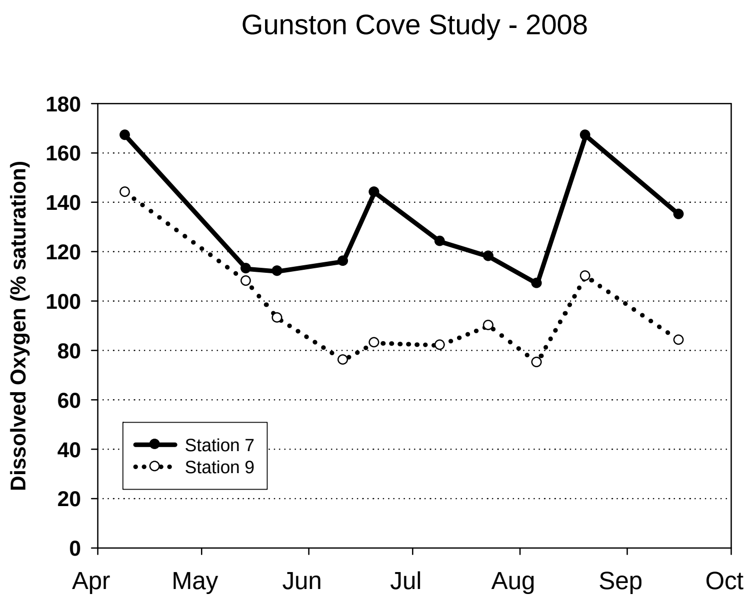
Figure 7. Chloride (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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

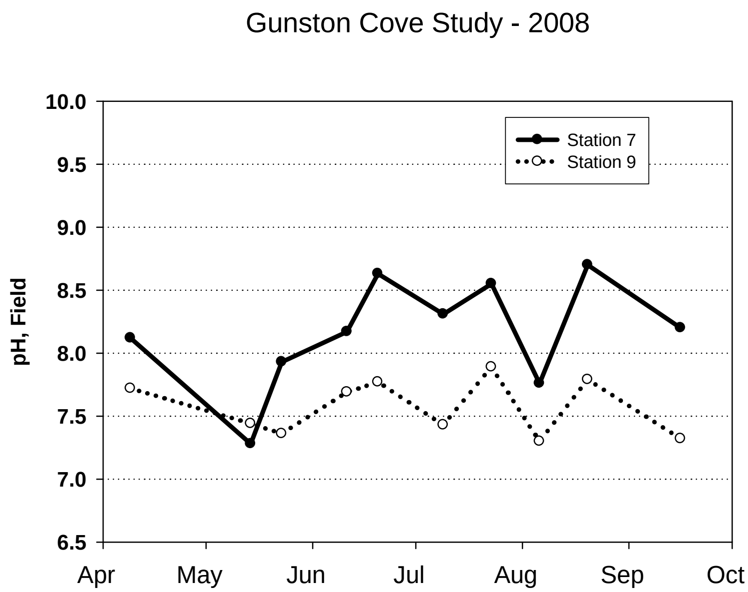
Figure 8. Dissolved Oxygen (mg/L). GMU Field Data. Month tick is at first day of month.

Dissolved oxygen was generally about 2-4 mg/L higher in the cove than in the river (Figure 8). An exception was in mid-May when cove and river values were similar. In the cove dissolved oxygen was generally above 100% indicating a general surplus of photosynthesis over respiration (Figure 9). Values above 140%, observed on three occasions in the cove, are indicative of very active photosynthesis. In the river values were generally less than 100% indicating lower photosynthesis and an excess of respiration.



The temperature effect on oxygen concentration can be removed by calculating DO as percent saturation. This allows examination of the balance between photosynthesis and respiration 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.

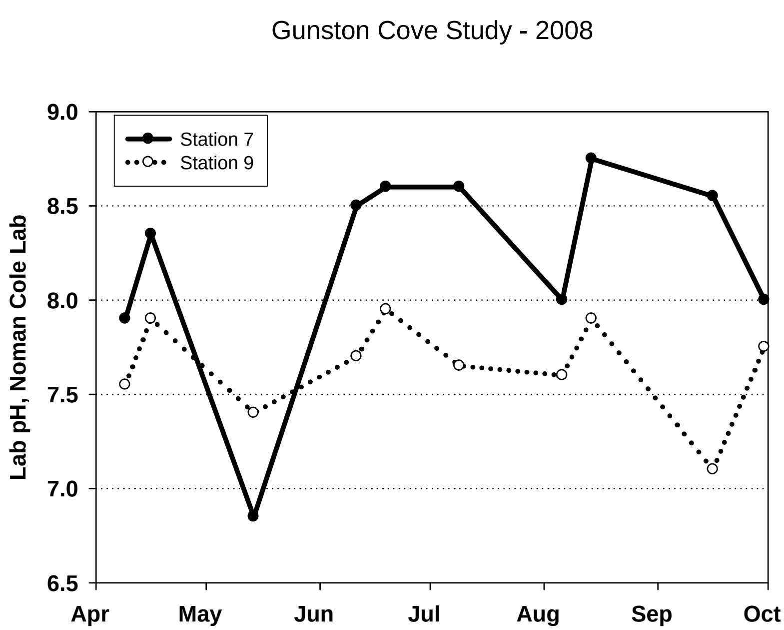
Figure 9. Dissolved Oxygen (% saturation). GMU Field Data. Month tick is at first day of month.



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.

The Gunston Cove station was consistently higher than the river station by about 0.5-1 pH unit (Figures 10 & 11). The exception was in mid May following major runoff events from the watershed. Values above 8 were typical in the cove while values of 7.3-7.9 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.



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.

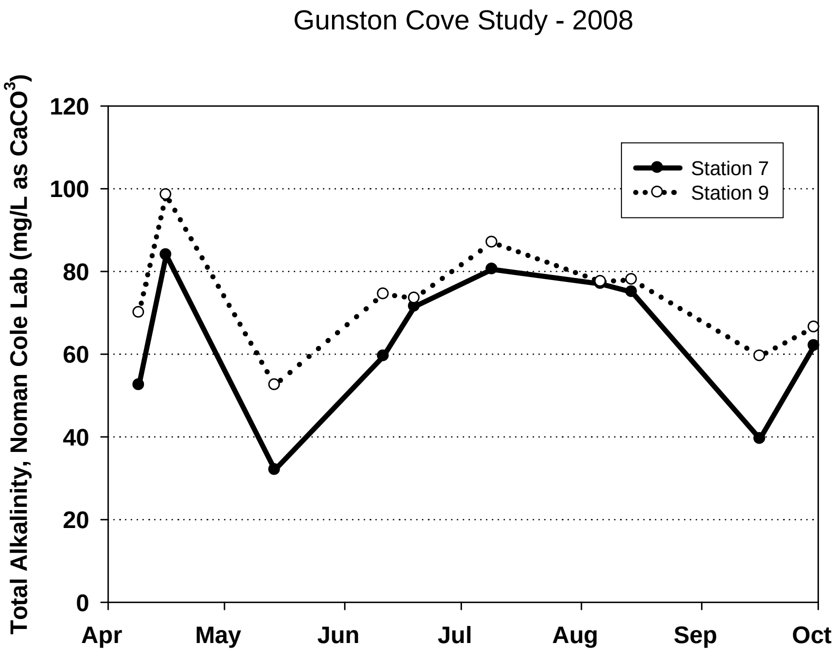
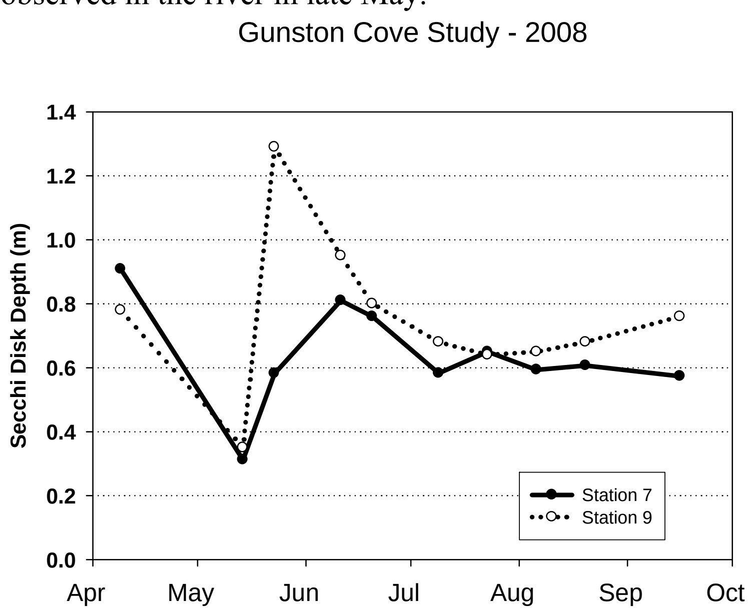


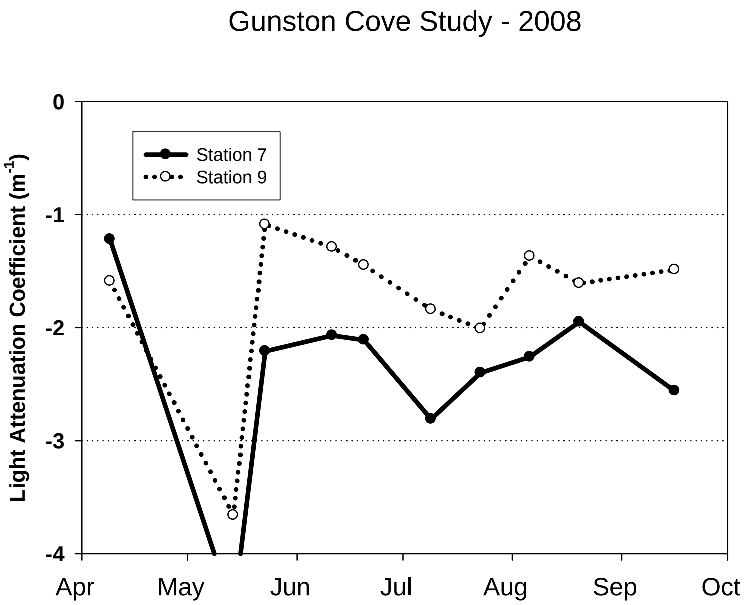
Figure 12. Total Alkalinity (mg/L as $CaCO_3$). Noman Cole Lab data. Month tick is at first day of month.

Total alkalinity was generally about 10-15 units higher in the river than in the cove (Figure 12). Values declined strongly at both stations in mid May and somewhat in mid September following increased freshwater stream input. Values were typical of previous years. Water clarity as reflected by Secchi disk depth exhibited a strong decline in mid May, but rebounded in late May and June (Figure 13). Maximum cove Secchi was 80-90 cm while a maximum of 1.3 m were observed in the river in late May.



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.

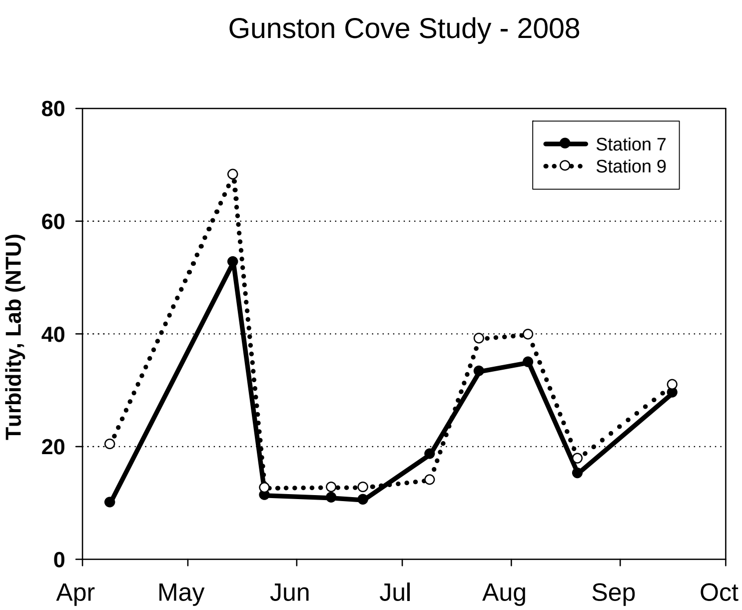
Figure 13. Secchi Disk Depth (m). GMU Field Data. Month tick is at first day of month.



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.

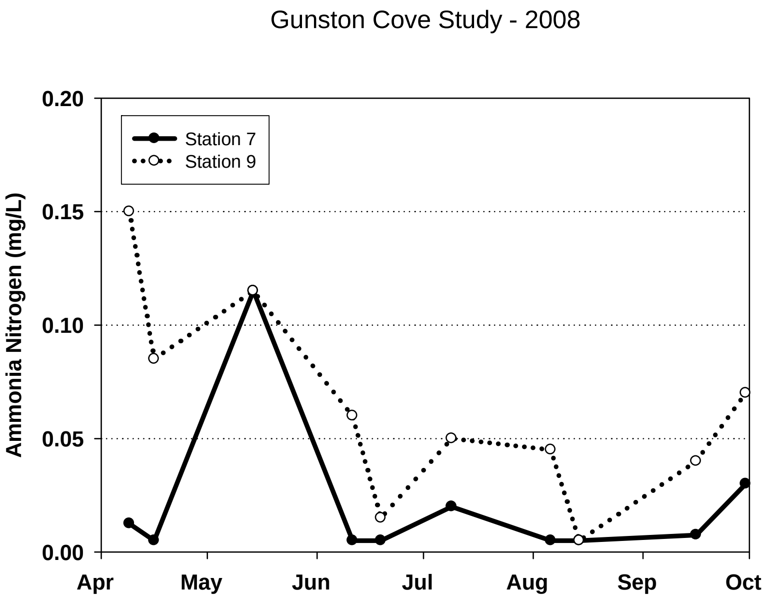
Figure 14. Light Attenuation Coefficient (m^{-1}). GMU Field Data. Month tick is at first day of month.

Light attenuation coefficient data generally fell in the range -1.0 to -2.5 m^{-1} (Figure 14). Much greater attenuation was found in mid May following storm inflows. Light was generally attenuated more strongly with depth in the cove than in the river. Turbidity also exhibited the effect of suspended sediment brought in by May storms reaching a peak in mid May in both areas (Figure 15). Values were similar in both river and cove.



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

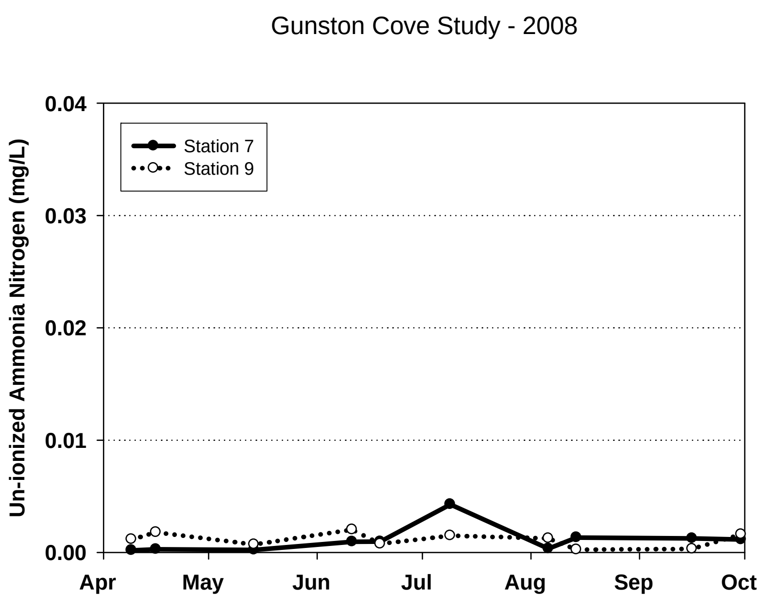
Figure 15. Turbidity (NTU). GMU Lab Data. Month tick is at first day of month.



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

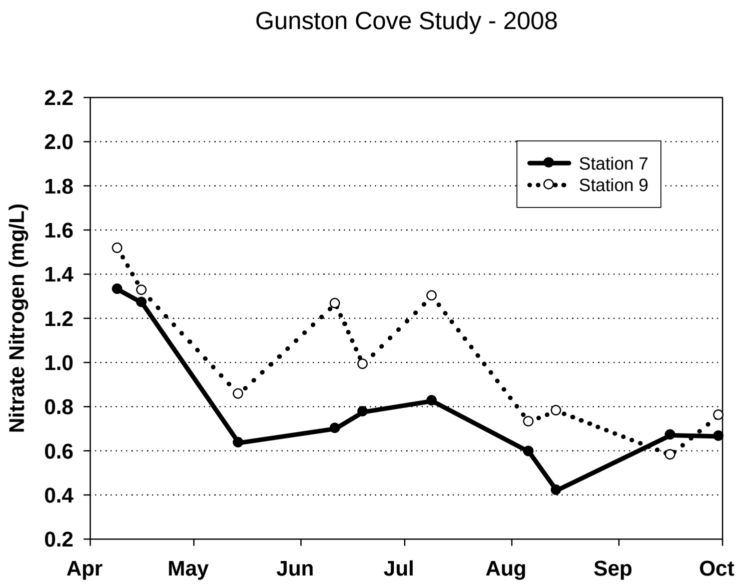
Figure 16. Ammonia Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.

Ammonia nitrogen was generally higher at the river station than in the cove (Figure 16). Cove values were in the range 0-0.03 mg/L for most of the year. Exception was in mid May when cove values increased to over 0.10 mg/L. River values steadily declined from about 0.15 mg/L in April to less than 0.01 in August. 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.

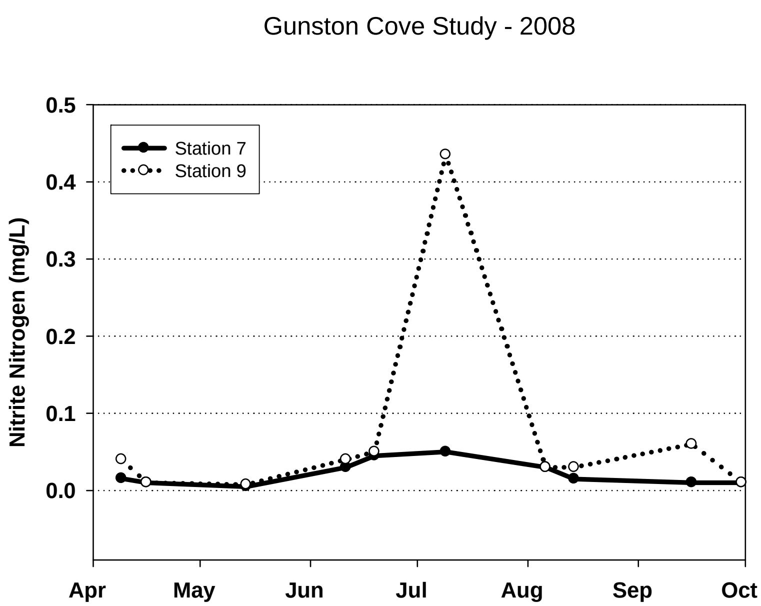
Figure 17. Un-ionized Ammonia Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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.

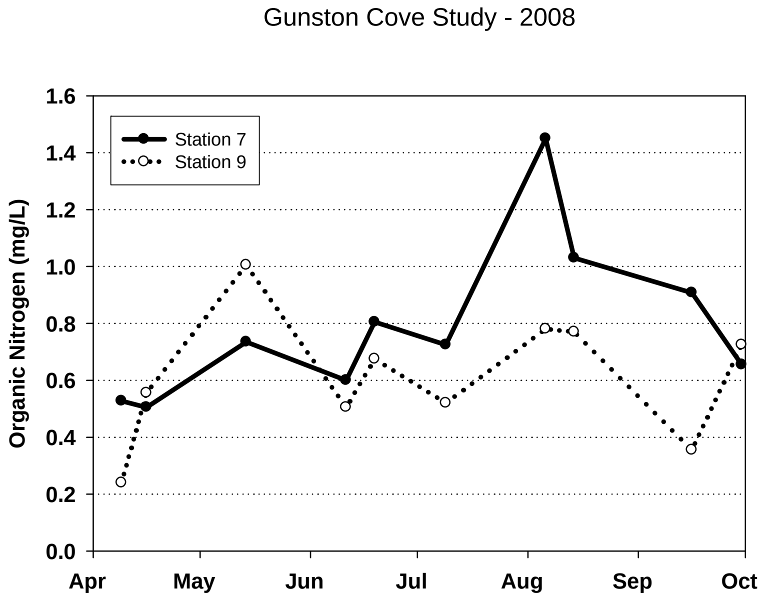
Figure 18. Nitrate Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.

Nitrate nitrogen exhibited a steady decline through the growing season in the cove decreasing from 1.4 mg/L in April to 0.4 mg/L in August (Figure 18). The river showed a similar decline through the summer, but remained slightly higher than the cove with a minimum of 0.6 mg/L in September. Nitrite nitrogen remained very low throughout the year, but showed an unusual spike in July in the river to over 0.4 mg/L (Figure 19).



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

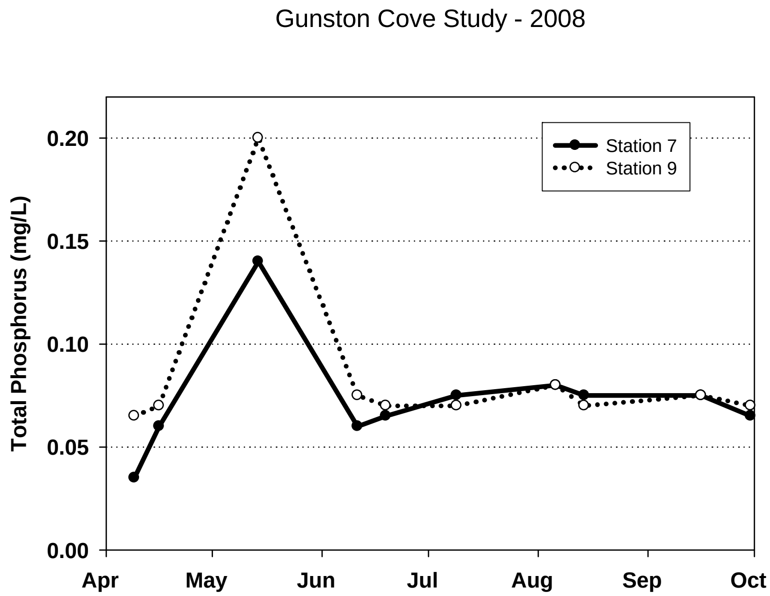
Figure 19. Nitrite Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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

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

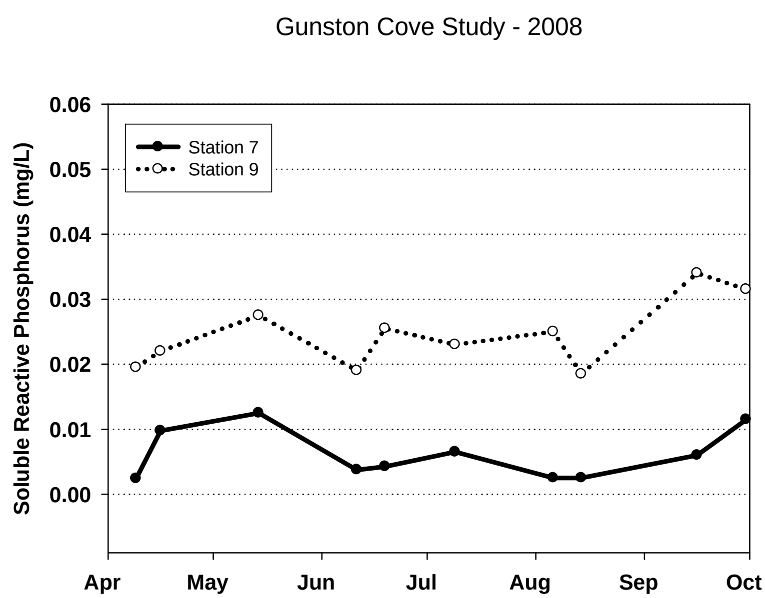
Organic nitrogen exhibited a steady increase during the spring and early summer in the cove reaching a peak in August at about 1.5 mg/L (Figure 20). In the river values exhibited a less marked seasonal pattern with peak value in May at about 1.0 mg/L.



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.

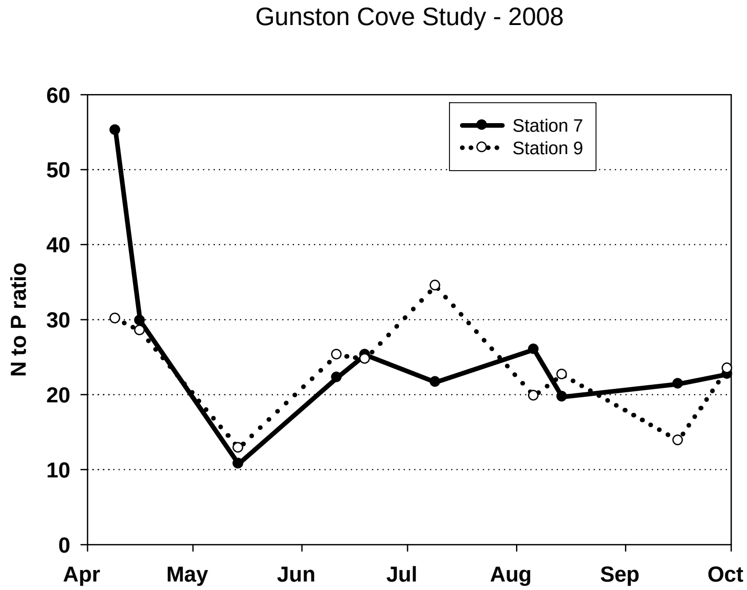
Figure 21. Total Phosphorus (mg/L). Fairfax County Lab Data. Month tick is at first day of month.

Total phosphorus was fairly constant through much of the year in the range of 0.05-0.10 mg/L at both stations (Figure 21). A major increase was found in May at both sites, probably due to runoff spikes and associated higher suspended sediment levels. Soluble reactive phosphorus was consistently higher in the river than in the cove (Figure 22). In the cove values were fairly constant in the range 0.002-0.012 mg/L while in the river values were generally 0.019-0.034. There was little seasonal variation.



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.

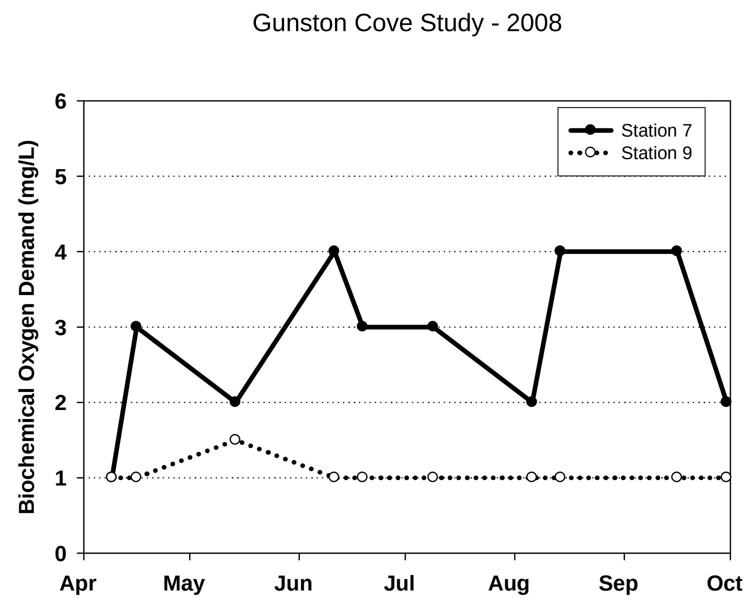
Figure 22. Soluble Reactive Phosphorus (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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 produc-tion in a given freshwater system. Generally, values above 16 are considered indicative of P limitation while values below 16 suggest N limitation. N limitation could lead to dominance by cyano-bacteria who can fix their own N from the atmosphere.

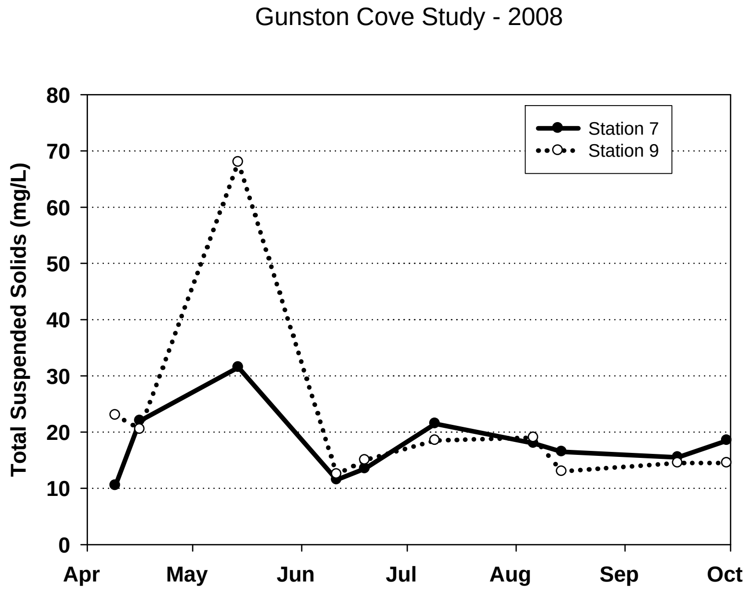
Figure 23. N/P Ratio (by mass). Fairfax County Lab Data. Month tick is at first day of month.

N/P ratio was generally in the range 15-35 (Figure 23). All of the readings were above 7.2 indicating P limitation. Substantial variation was observed in the spring as flows varied. High values were found at low April flows and low values at high May flows. The rest of the year was quite stable. Biochemical oxygen demand (BOD) was consistently higher in the cove than in the river (Figure 24). In the cove a seasonal pattern was somewhat apparent with highest value of 4 in June, August, and September. In the river values never exceeded 1.5 mg/L.



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

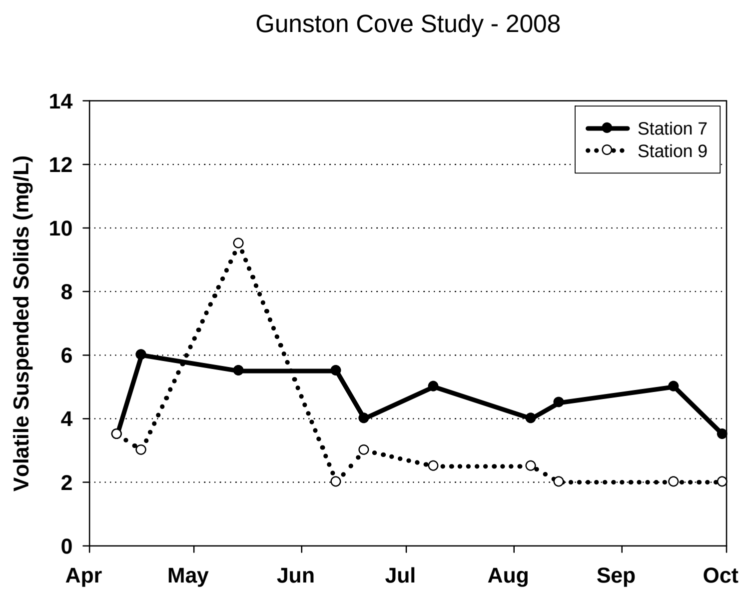
Figure 24. Biochemical Oxygen Demand (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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

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

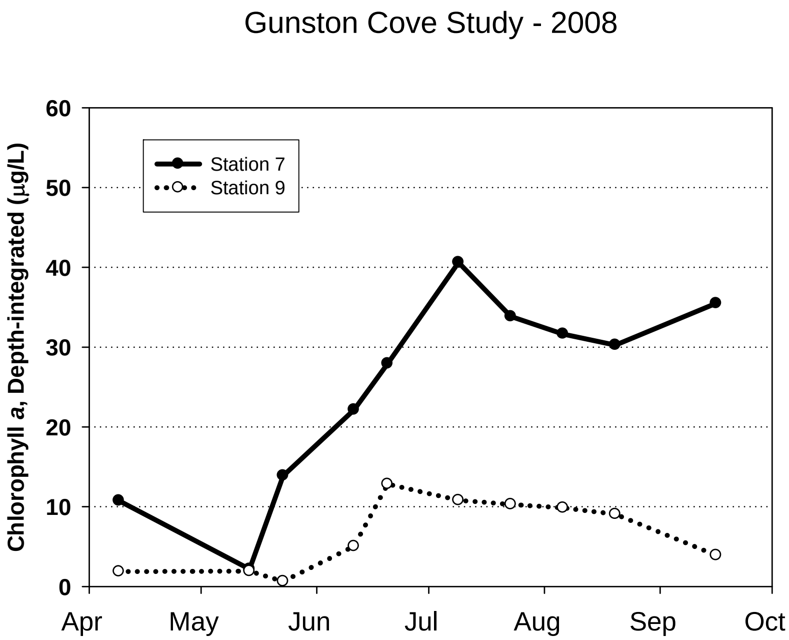
Total suspended solids were generally in the range 10-30 mg/L at both stations (Figure 25). As with many other parameters TSS spiked in May especially at the river site due to storm inflows. River values were similar to those in the cove except in May. Volatile suspended solids were generally 2-3 mg/L greater in the cove than in the river (Figure 26). In May the river concentration increased, but not the value in the cove.



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.

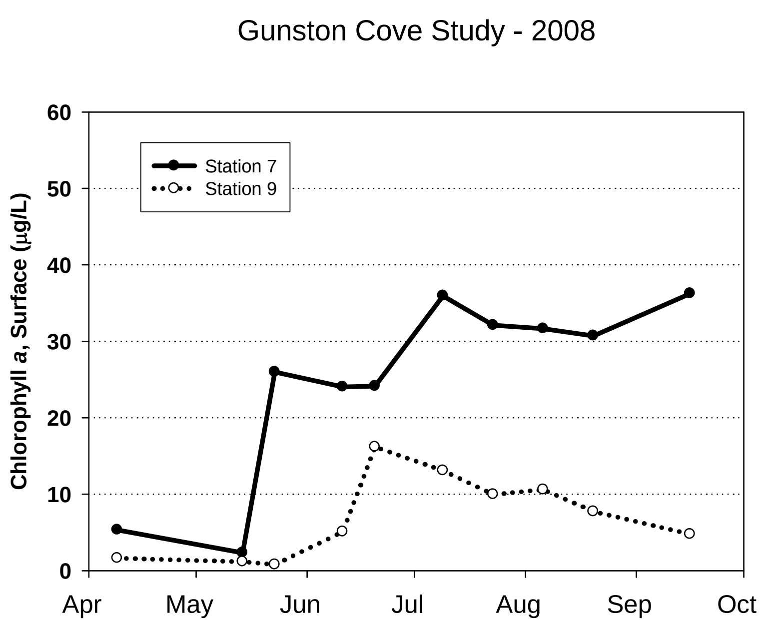
C. Phytoplankton -2008



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 substantially higher in the cove. In the cove values declined in May due to the flow event, but then increased steadily to a peak in July of about 40 ug/L and remained elevated through September (Figure 27 & 28). In the river, chlorophyll *a* levels peaked in June at 15 ug/L and gradually declined through the remainder of the year. Depth-integrated and surface chlorophyll showed a similar pattern.



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.

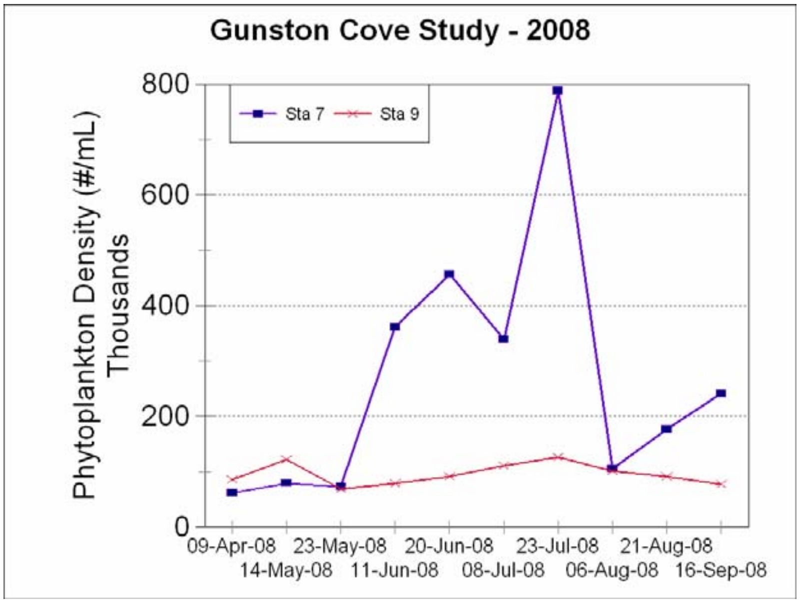


Figure 29. Phytoplankton Density (cells/mL).

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 in April and May in both areas (Figure 29). In the cove density increased strongly in early June and continued to increase in late June reaching about 0.5 x 10^6 cells/mL. Following a drop in early July higher levels were observed in the cove in late July reaching nearly 0.8 x 10^6 cells/mL before falling back again in August. In the river densities were fairly constant throughout the study period with highest values in mid-May and late July at 0.1 x 10^6 cells/mL. Total biovolume showed a similar seasonal pattern in the cove (Figure 30). Cove biovolume increased in late May reaching about 35 x 10^6 um^3/mL in mid-June and then slowly declined through August. In the river biovolume was relatively high in April, lower in May and June and then increased through July and especially August reaching a peak of nearly 60 x 10^6 um^3/mL before dropping back.

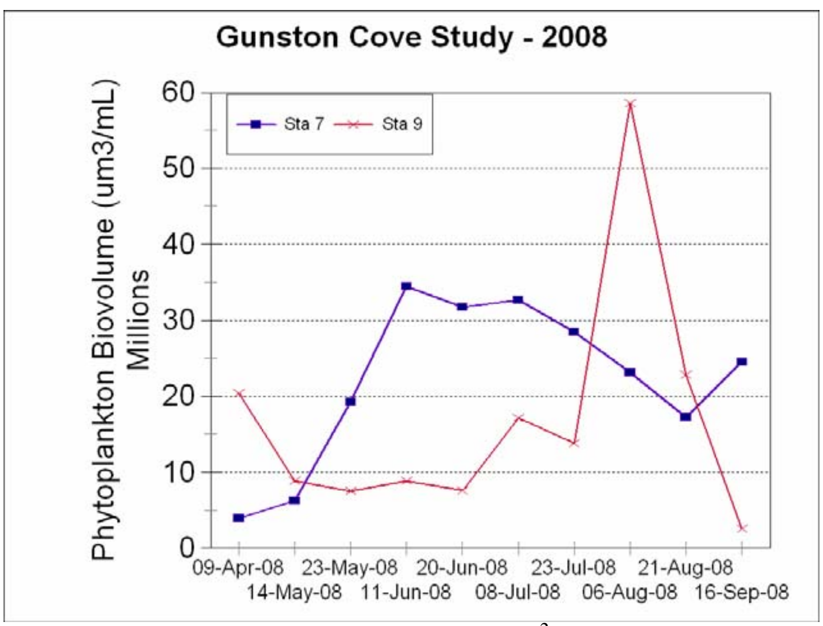
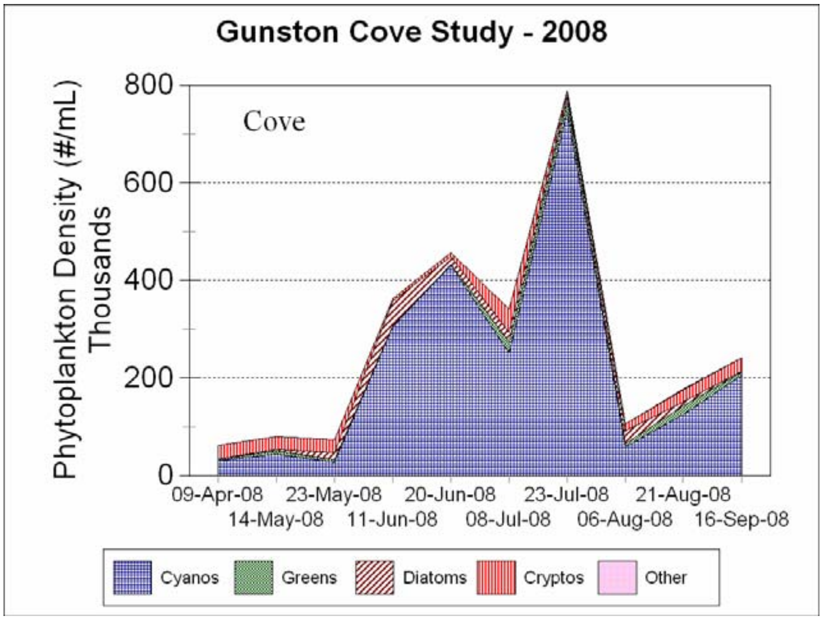


Figure 30. Phytoplankton Biovolume (um^3/mL).

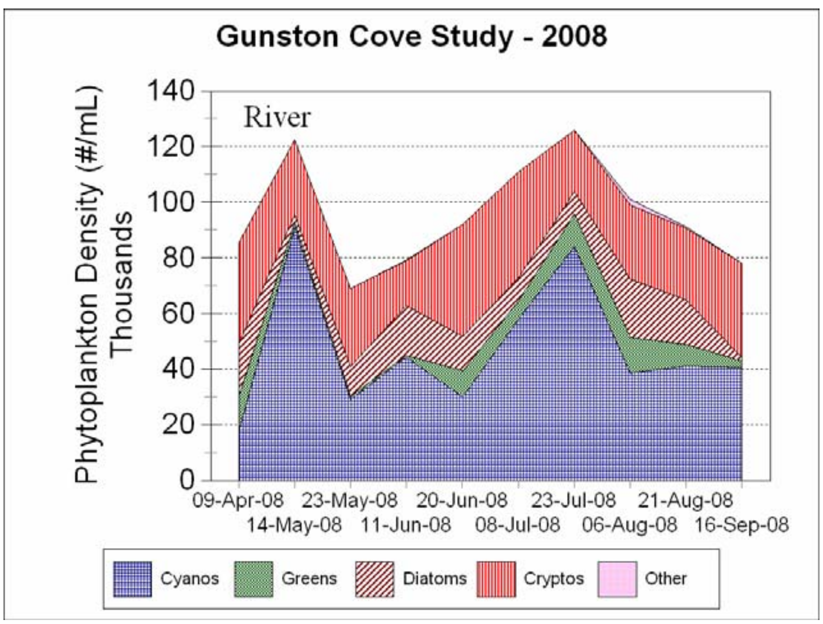
The volume of individual cells of each species is determined by approximating the cells of each species to an appropriate geometric shape (e.g. sphere, cylinder, cone, cube, etc.) and then making the measurements of the appropriate dimensions under the microscope. Total phytoplankton biovolume (shown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

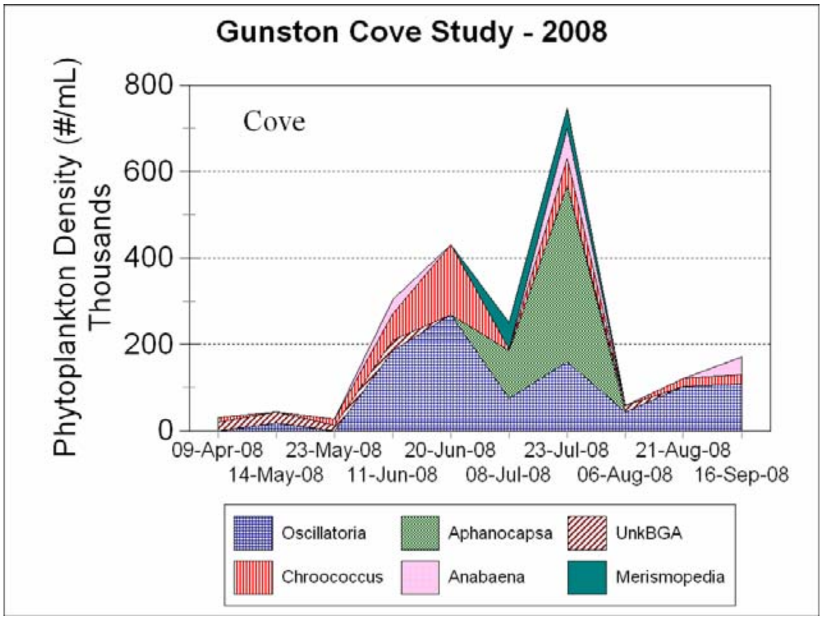
Figure 31. Phytoplankton Density by Major Group (cells/mL). Gunston Cove.

Phytoplankton density in the cove was overwhelmingly dominated by cyanobacteria for most of the year (Figure 31). Cryptophytes were roughly coequal to cyanobacteria in April and May. Diatoms contributed to the abundance total in June. In the river cyanobacteria were still generally dominant, but cryptophytes were often co-dominant and diatoms were substantial over most of the year (Figure 32). Total density was much lower in the river.



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.

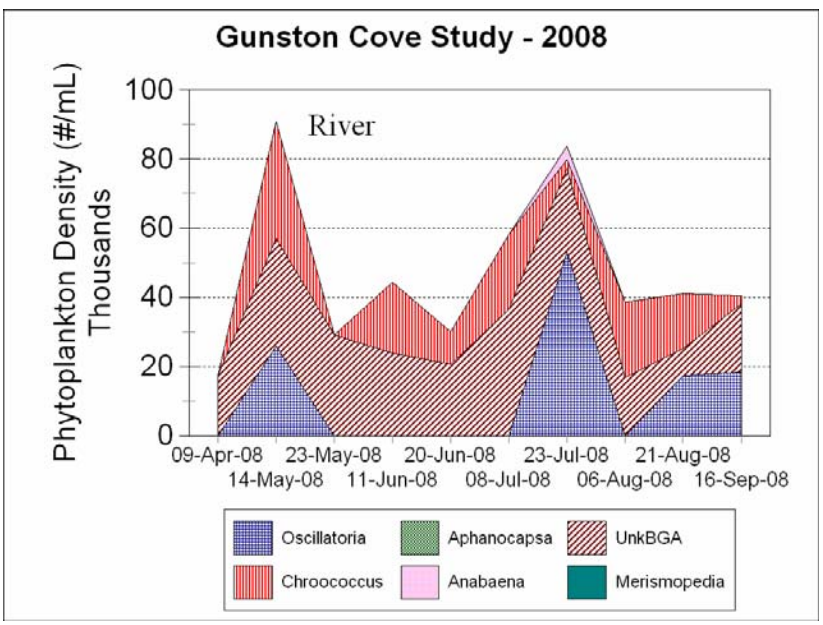


The dominant cyanobacteria on a numerical basis were:

- *Aphanocaps*a -- small sphere
- Merismopedia – a rectangular colony of small spheres
- Unk. Cyano – small spherical cells of unknown species
- *Oscillatoria* – a filament
- *Chroococcus* – individual spherical cells
- *Microcystis* – an irregular colony of spherical cells

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

In the cove *Oscillatoria* was either dominant or co-dominant in terms of cyanobacterial density for most of the year. In July, *Aphanocapsa* was co-dominant and *Chroococcus* was co-dominant in June (Figure 33). In the river Chroococcus and an unknown spherical cyanobacterium (UnkBGA) were most numerous through most of the year (Figure 34). *Oscillatoria* was important in mid-May, late July, late August and mid September.



Oscillatoria

Microcystis

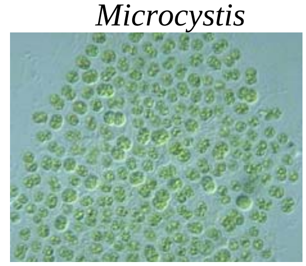
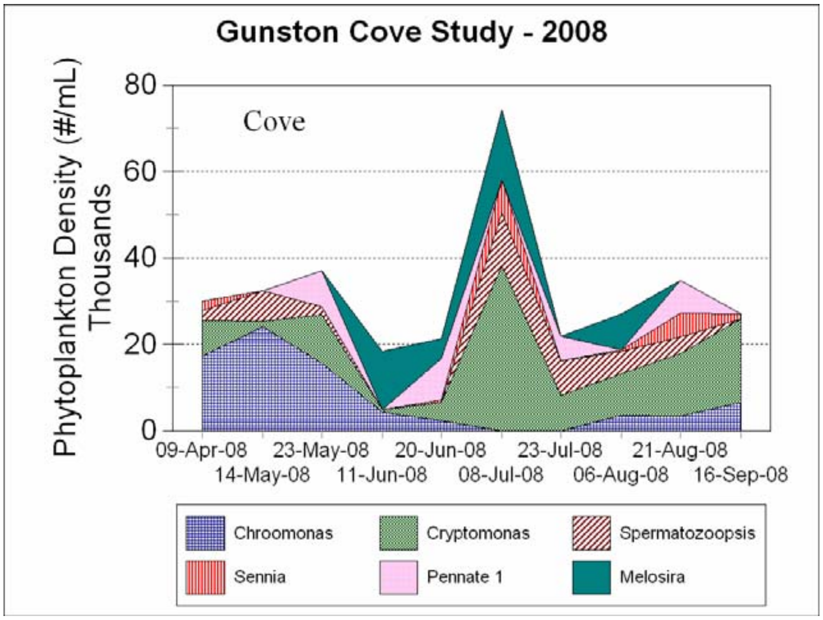


Figure 34. Phytoplankton Density by Dominant Cyanobacteria (cells/mL). River.

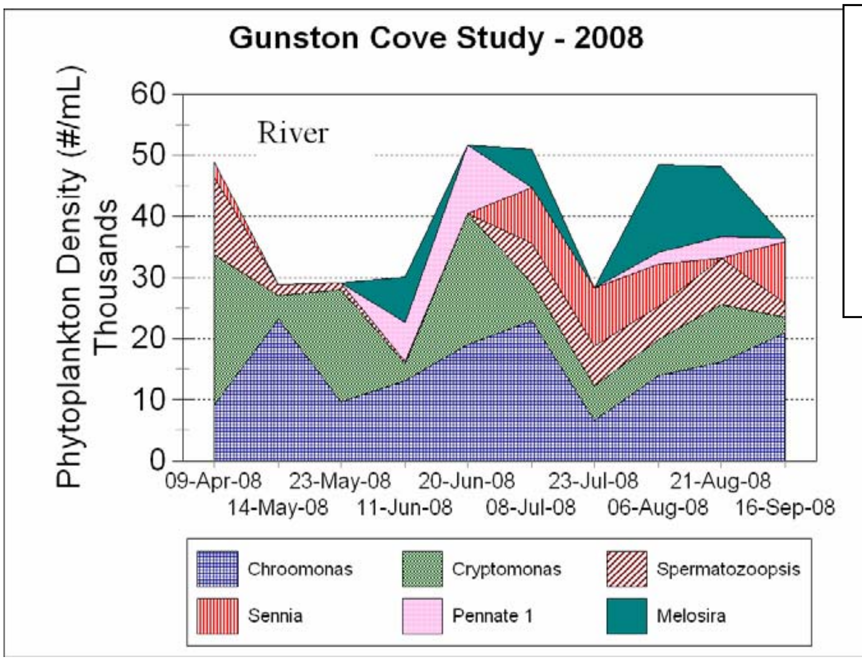


The most numerous non-cyanobacterial phyto-plankton were:

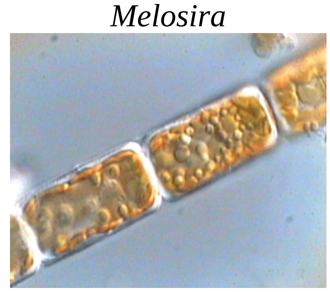
- *Melosira* – a filamentous centric diatom
- Pennate1 – an unidentified pinnate diatom
- *Chroomonas* – a flagellated cryptomonad unicell
- *Spermatozoopsis* – a unicellular green flagellate
- *Ankistrodesmus* – a unicellular lunate green alga
- *Cryptomonas* – an ellip-soidal flagellated unicell

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

In the cove a flagellate, *Chroomonas,* was the most numerous of the noncyanobacterial taxa during April and May (Figure 35). *Melosira* was most numerous in June. The flagellate *Chroomonas* assumed numerical dominance in July and was generally most abundant through the remainder of the year. In the river dominance in abundance was mostly shared by *Chroomonas* and *Cryptomonas* (Figure 36). *Melosira* was most important in August.

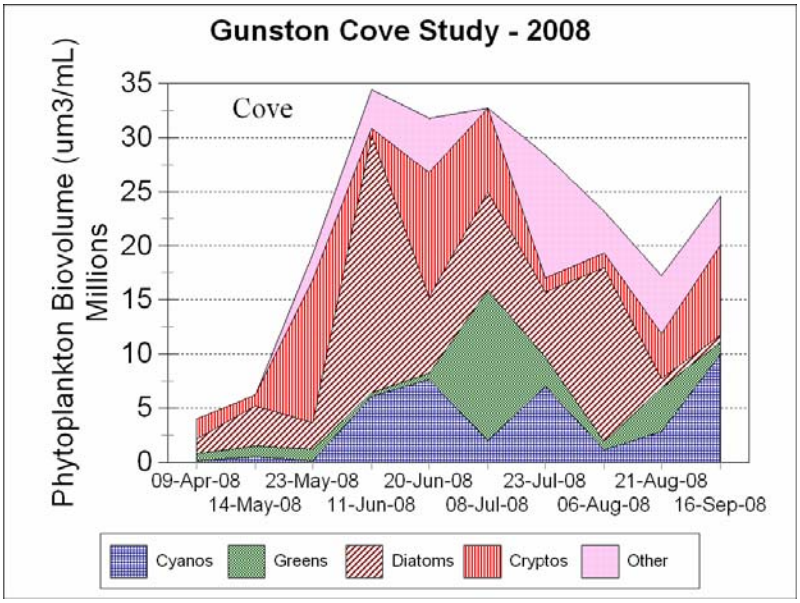


Melosira



Cryptomonas

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

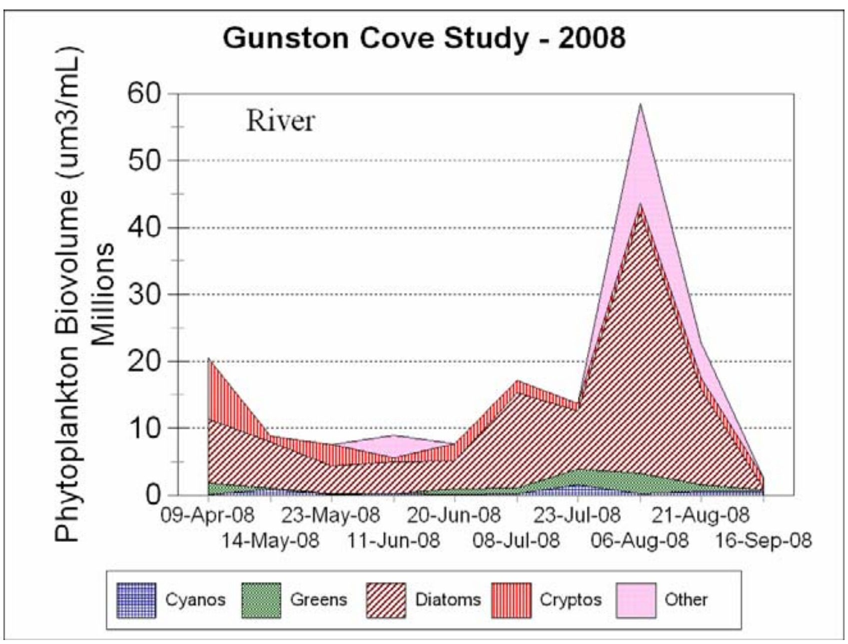


Total phytoplankton biovolume can be broken down into groups:

- **Cyano** – cyanobacteria ("blue-green" algae)
- **Greens** – green algae
- **Diatoms** – includes both centric and pinnate
- **Cryptos** – cryptophytes
- **Other** – includes euglenoids, crysophytes, and dinoflagellates

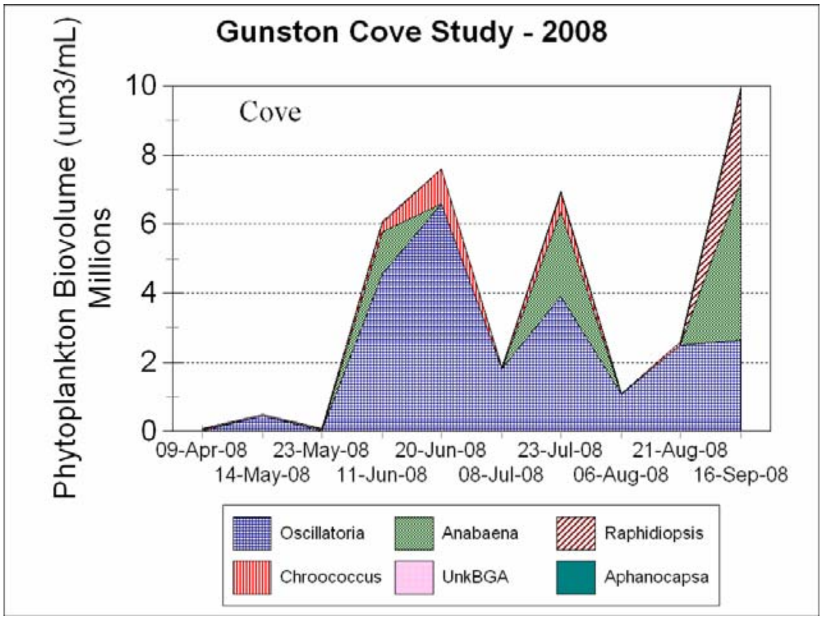
Figure 37. Phytoplankton Biovolume (um^3/mL) by Major Groups. Gunston Cove.

In the cove the relatively low biovolumes in spring were dominated by cryptophytes and diatoms (Figure 37). In early June diatoms were clearly dominant and cyanobacteria were increasing in biovolume. In early July green algae became important and in early August it was back to diatoms. By September cyanobacteria and cryptophytes shared dominance. In the river, diatoms were dominant on all dates (Figure 38). Cryptophytes made a substantial contribution in April and other algae were important in early August.



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

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

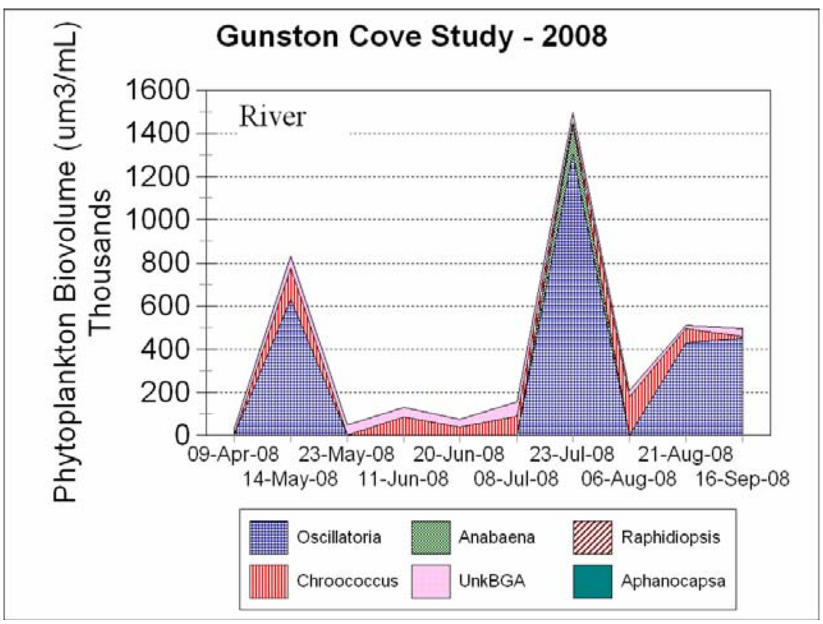


Cyanobacteria are generally most common in late summer and that is when they normally make the largest contribution to phytoplankton biovolume. Important taxa for biovolume which were not on the top list for cell density are:

- *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.

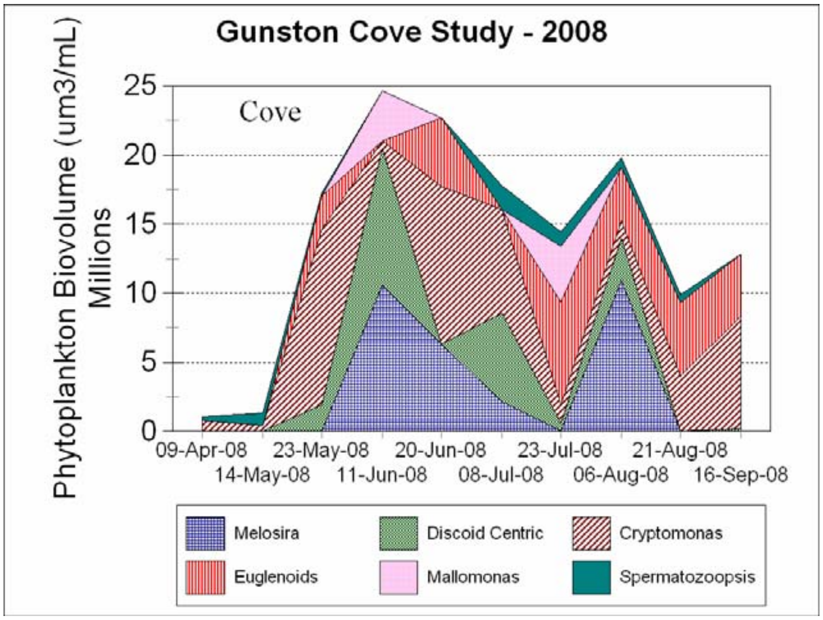
In the cove *Oscillatoria* was the overwhelming dominant cyanobacterium in terms of biovolume for the entire year (Figure 39). Anabaena was important in late July and September. In the river *Oscillatoria* was dominant on those date when cyanobacteria were found in abundance (Figure 40).



Anabaena

Chroococcus

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

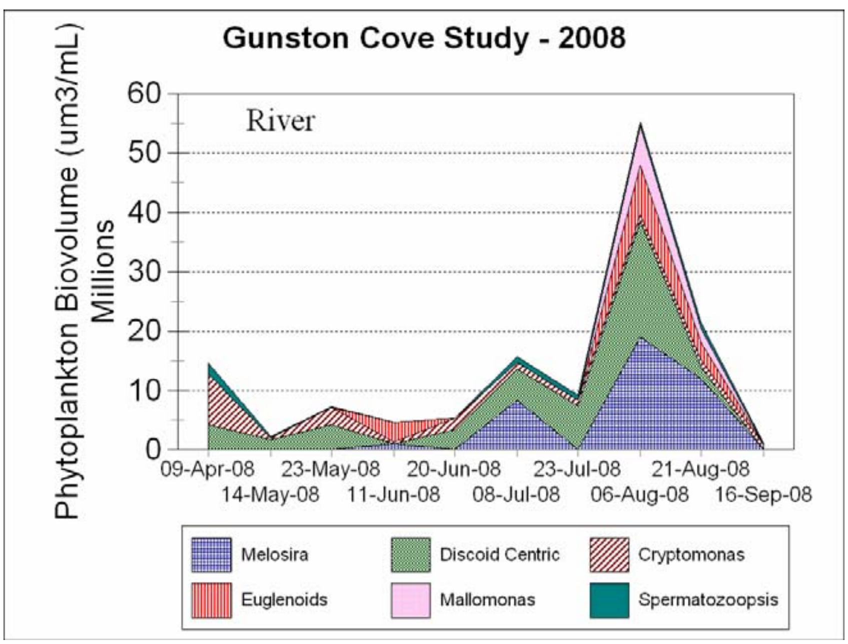


Melosira

Euglena

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

Biovolume of noncyanobacterial phytoplankton varied greatly in the cove (Figure 41). *Cryptomonas* was most abundant in late May followed by *Melosira* and discoid centrics in early June. *Cryptomonas* returned in late June and early July. Euglenoids were most important in late July followed by *Melosira* again in early August. The year ended with dominance by *Cryptomonas* and euglenoids. In the river discoid centrics and *Cryptomonas* were the early dominants with *Melosira* becoming abundant later in the year (Figure 42).



Discoid Centrics

Mallomonas

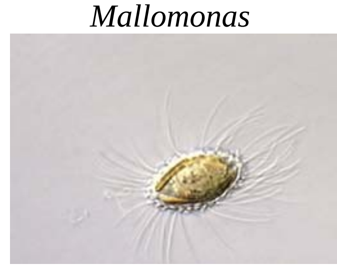
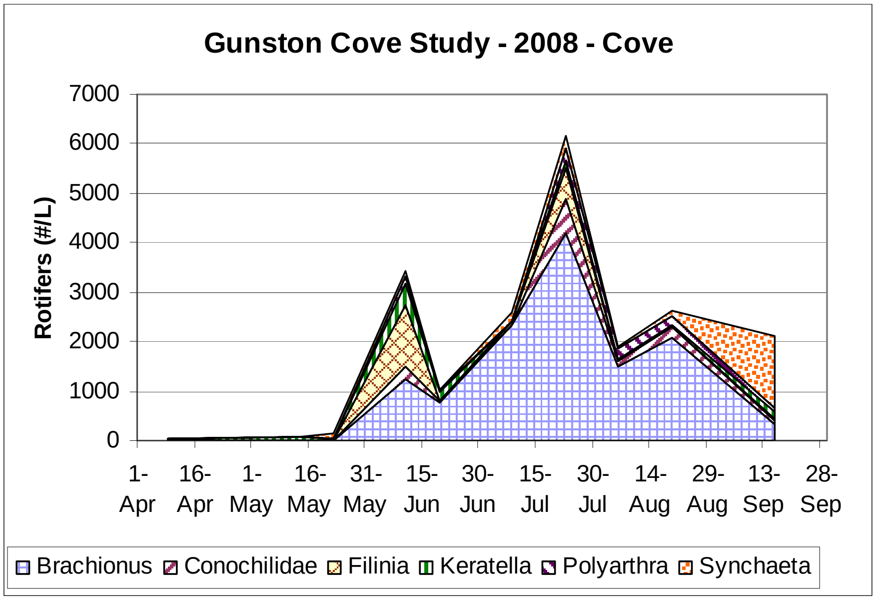


Figure 42. Phytoplankton Biovolume (um^3/mL) by Dominant Taxon. River.

D. Zooplankton – 2008



Rotifers are the most smallest and most abundant metazoan zooplankton in most freshwater systems including the freshwater tidal Potomac River. Rotifers generally grow to maximum numbers in the summer and are scarce in the winter.
Dominant taxa in the cove and river in 2004 include:
Brachionus
Conochilidae
Filinia
Keratella
Polyarthra
Trichocerca
All of these taxa are common in freshwater systems.

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

In the cove, rotifers increased in May and early June to about 3500/L. By late June rotifers dropped to about 1000/L and then increased steadily to a major peak of over 6000/L in late July. A general decline occurred during the remainder of the year reaching 2000/L in mid September (Figure 43). *Filinia* was important in early June and *Synchaeta* was dominant in mid September. In the river rotifers were very low for most of the year. A major pulse occurred in mid August driven by *Synchaeta* and *Brachionus* (Figure 44).

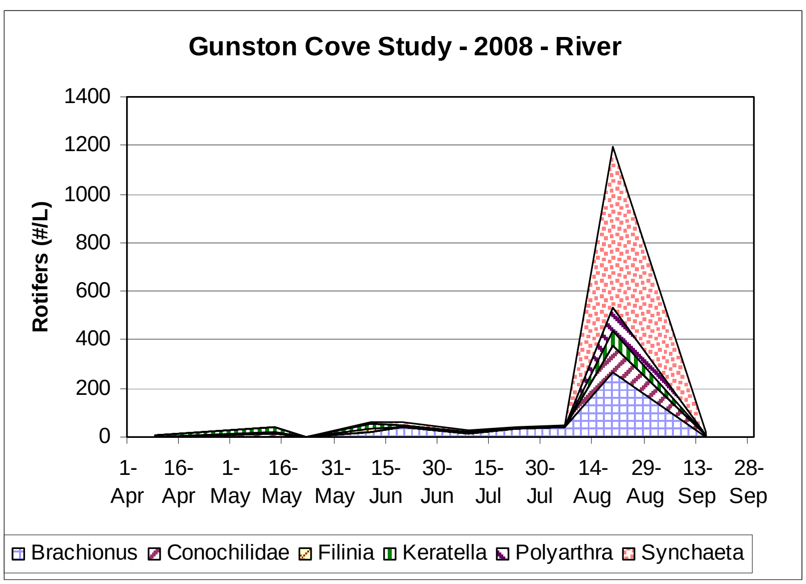
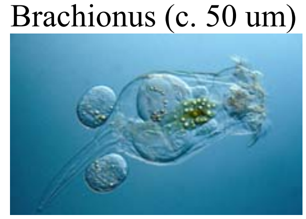
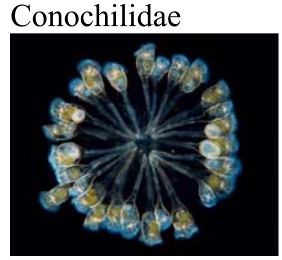


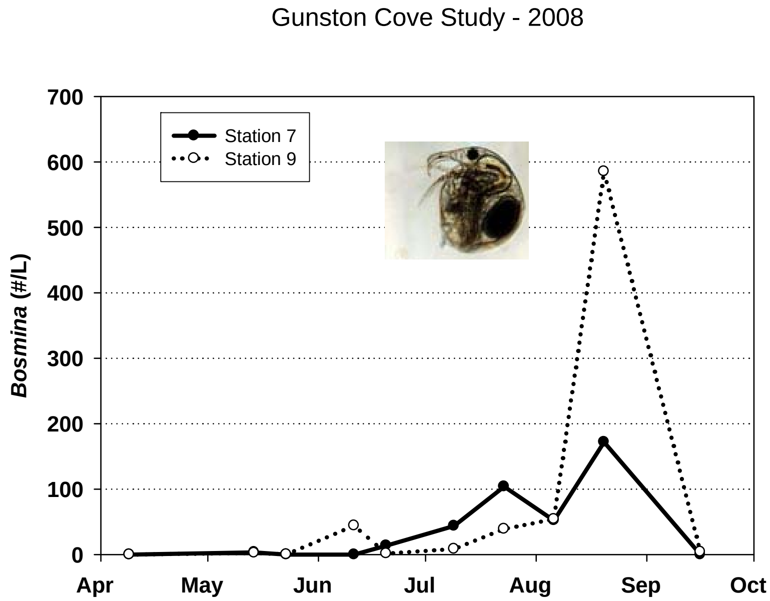
Figure 44. Rotifer Density by Dominant Taxa (#/L). River.

Brachionus (c. 50 um)



Conochilidae

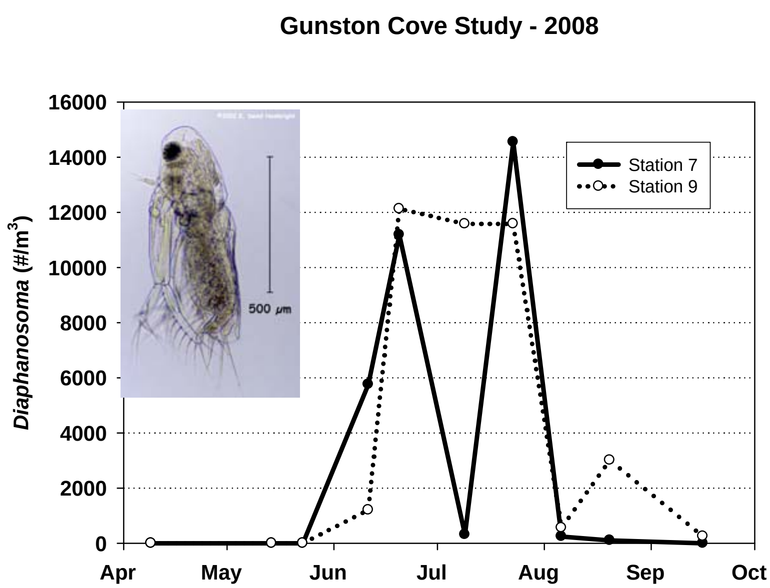




Bosmina is a small-bodied cladoceran, or "waterflea", which is common in lakes and freshwater tidal areas. It is typically the most abundant cladoceran with maximum numbers generally about 100-1000 animals per liter. Due to its small size and relatively high abundances, it is enumerated in the micro-zooplankton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

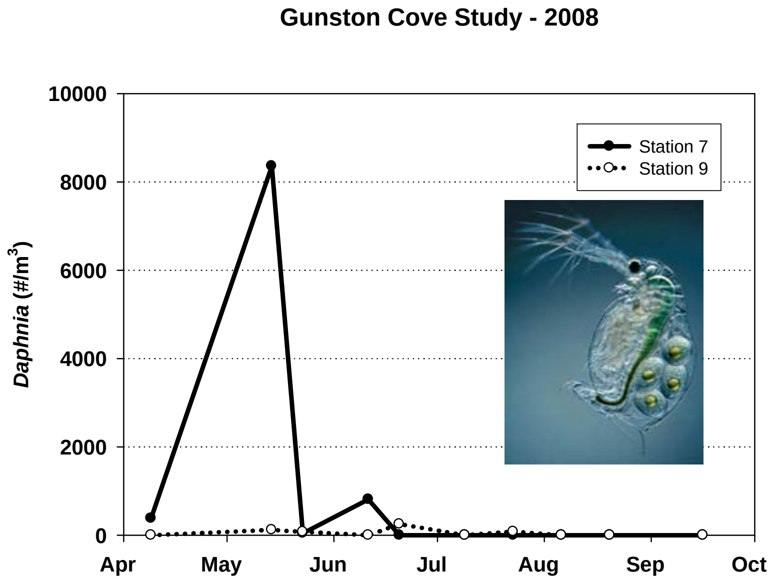
Figure 45. *Bosmina* density by Station (#/L).

In the cove in 2008 *Bosmina* reached a maximum of nearly 180/L in late August (Figure 45). In the river *Bosmina* was generally lower, but exhibited a large pulse in late August reaching nearly 600/L in late August. *Diaphanosoma,* typically the most abundant larger cladoceran in Gunston Cove, exhibited two peaks of over 10,000/m^3 in the cove in June and July (Figure 46). In the river Diaphanosoma was at these elevated levels throughout June and July.



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.

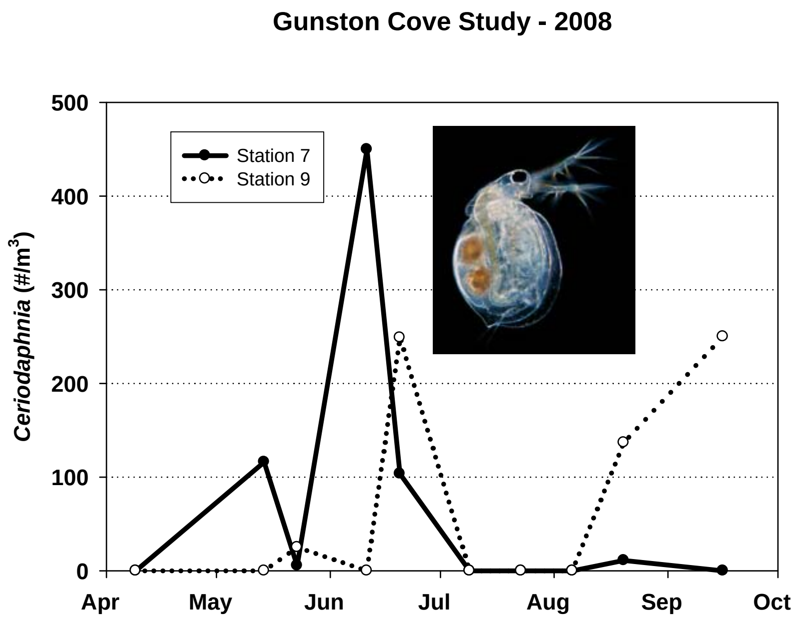
Figure 46. Diaphanosoma density by Station (#/m^3)



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 not as common as *Diaphanosoma*. It is typically most common in spring.

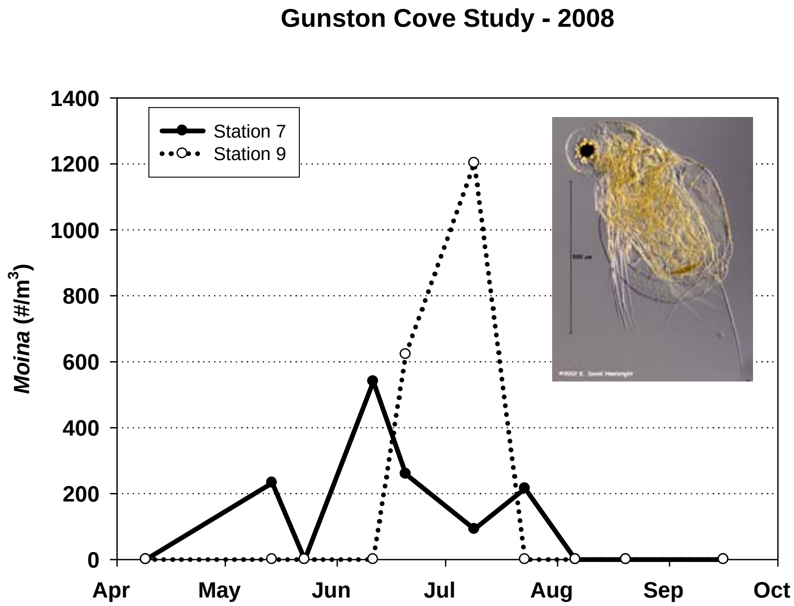
Figure 47. *Daphnia* Density by Station (#/m^3).

Daphnia reached high densities of over 8000/m^3 in the cove in mid May, but otherwise was well below 1000/m^3 at both stations (Figure 47). *Ceriodaphnia* was present at much lower densities in both river and cove reaching a maximum of about 450/m^3 in the cove and 250/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.

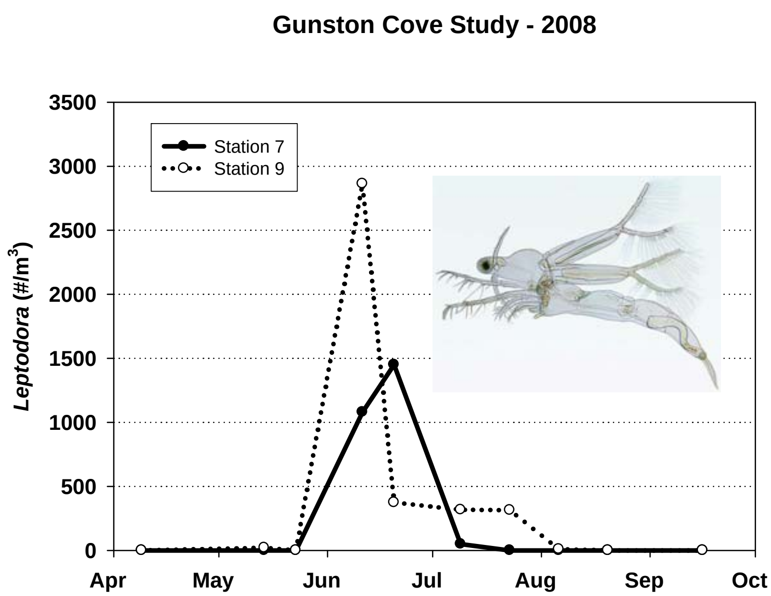
Figure 48. *Ceriodaphnia* Density by Station (#/m^3).



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 in numerous samples from the cove at levels less than 600/m^3 (Figure 49). It was found more rarely in the river, but at somewhat higher levels attaining a maximum of 1200/m^3 in early July. *Leptodora*, the large cladoceran predator, June peaks in both cove and river (Figure 50). In the cove the peak was in late June at 1500/m^3. In the river an early June peak of nearly 3000/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).

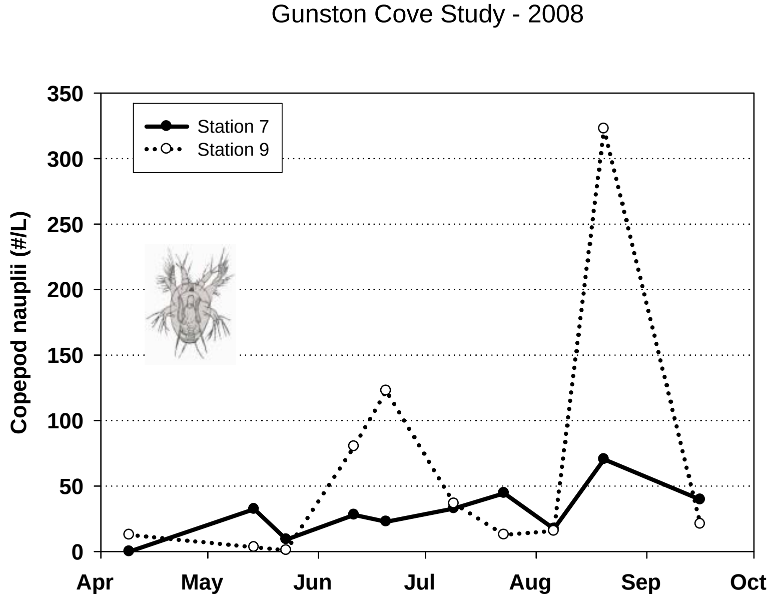


Figure 51. Copepod Nauplii Density by Station (#/L).

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 microzooplankton samples.

Copepod nauplii were generally present at less than 50/L (50,000/m^3) for most of the year (Figure 51). In the cove this value was exceeded only in late August. In the river higher values were observed on two occasions: late June at 125/L and late August at over 300/L. *Eurytemora* exhibited highest densities in mid May in the cove at about 15,000/m^3 (Figure 52). In the river, the highest value was found in early June at about 35,000/m^3.

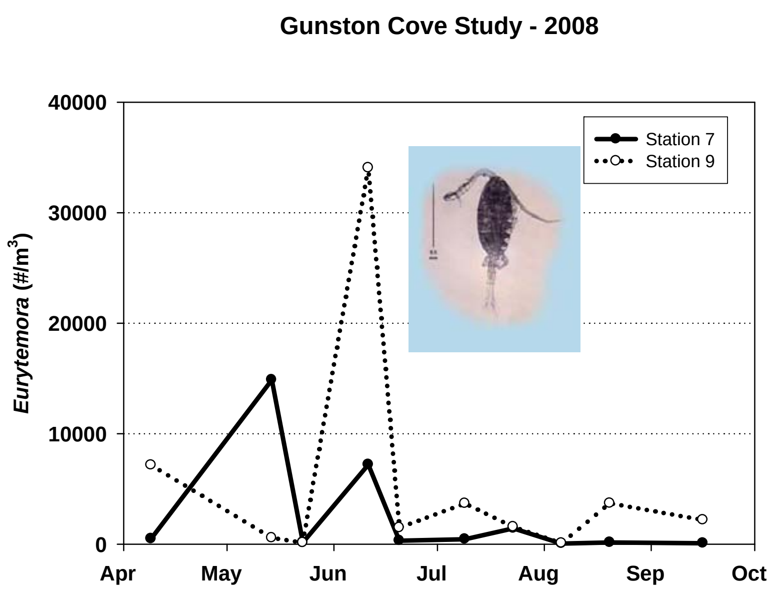
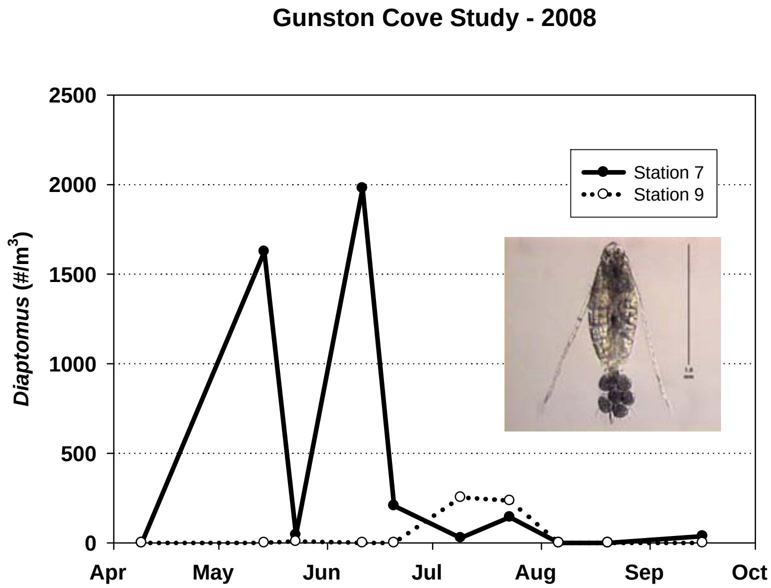


Figure 52. *Eurytemora* Density by Station (#/m^3).

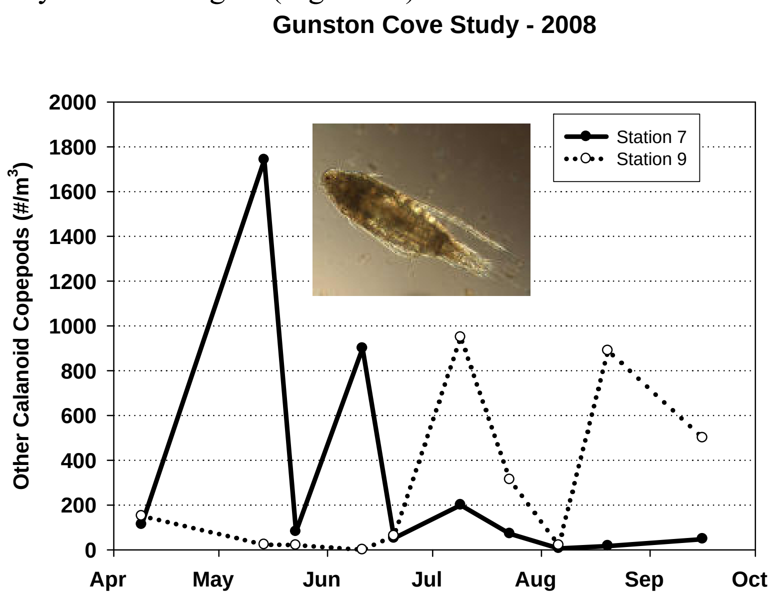
Eurytemora affinis is a large calanoid copepod characteristic of the freshwater and brackish areas of the Chesapeake Bay. *Eurytemora* is a cool water copepod which often reaches maximum abundance in the late winter or early spring. Included in this graph are adults and those copepodids that are recognizable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



Diaptomus pallidus is a calanoid copepod 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*.

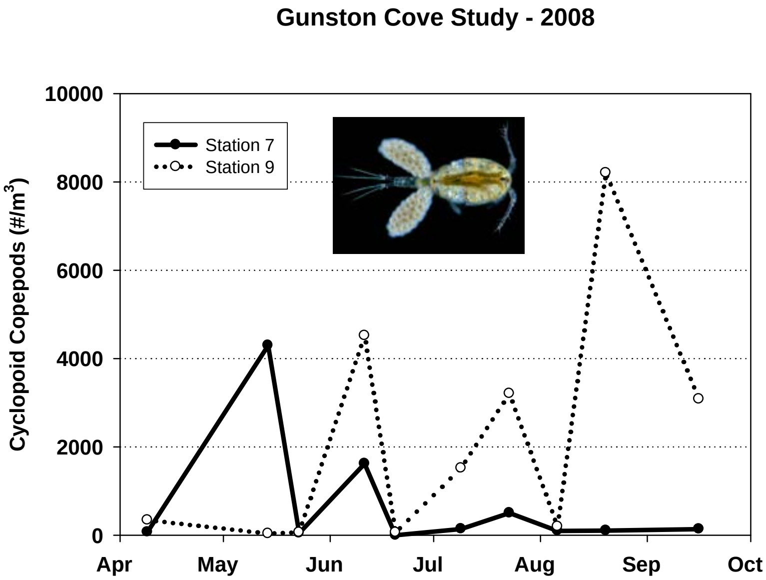
Figure 53. *Diaptomus* Density by Station (#/m^3).

Diaptomus was most common in the cove with peaks in May and June of over 1500/m^3 (Figure 53). In the river *Diaptomus* was much rarer. Other calanoid copepods were highest in early May in the cove reaching nearly 1800/m^3. In the river peaks of about 1000/m^3 were observed in early July and late August (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 reaching maximum densities in the cove in mid May at just over 4000/ m^3 and were much less abundant at other times (Figure 55). In the river there were several periods of abundance with the maximum of 8000/m^3 observed in late August.

E. Ichthyoplankton

Larval fishes are transitional stages in the development of juvenile fishes. They range in development from newly hatched, embryonic fish to a 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 and 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.

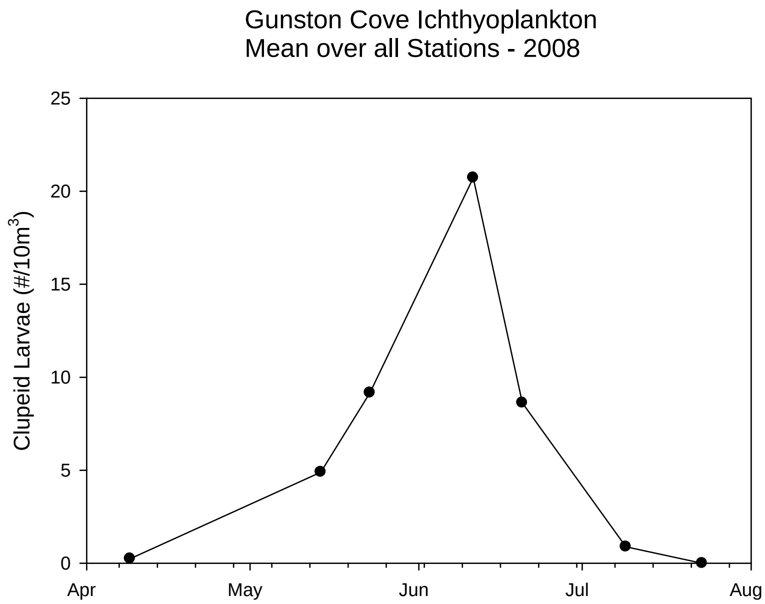
In 2008, we collected 14 samples (7 at each Station), comprising a total of 969 larvae. Of these, approximately twice as many (n=661) were taken at Station 7. The fish larvae are often difficult to distinguish at the species level, thus some of the counts are only to the genera level.

Catches expressed as density are presented in Table 3 below. As is typical, the bulk of the catch (54.2 %) was members of the herring family. Most of these (52.6 %) were larvae of either gizzard shad or threadfin shad. Most, if not all, were probably gizzard shad, since threadfin shad have been extremely rare in our collections of juvenile and adult fishes. Larval white perch were second in rank (44.1 %). Other species were very rare in 2008 with only the shad and river herring (genus *Alosa*) comprising more than 1.6% of the total. *Alosa* larvae are generally more common and this low catch is suggestive of a relatively poor recruitment year.

Table 3. The larval fishes collected in Gunston Cove and the Potomac River in 2008

Table 3
Larval Fishes Collected, by Taxon
Gunston Cove Study – 2008

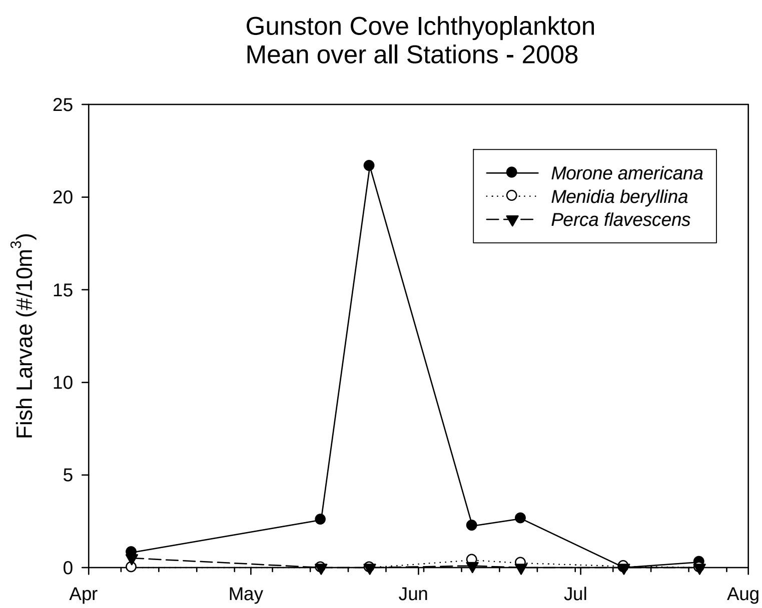
Taxon	Common Name	Number caught Sta 7	Sta 9	Total	% of Total
Alosa sp.	American shad, alewife, hickory shad, or blueback herring	15	0	15	1.6
Dorosoma sp.	gizzard shad or threadfin shad	375	135	510	52.6
Brevortia tyranus	Atlantic menhaden	2	0	2	0.2
Morone americana	white perch	259	168	427	44.1
Perca flavescens	yellow perch	4	2	6	0.6
Menidia beryllina	inland silverside	5	3	8	0.8
Strongylura marina	Atlantic needlefish	1	0	1	0.1
Total		661	308	969	100.0



Ichthyoplankton are defined as larval fishes which are drifting with the currents. In the Gunston Cove area, clupeid fishes (shad and herring) and members of the genus *Morone* (white perch and striped bass) are major contributors to the ichthyoplankton. Many other species such as sunfish and killifish are vastly underrepresented in the ichthyoplankton owing to the fact that they lay eggs in a nest on the bottom where the larvae hatch and develop.

Figure 56. Clupeid Larvae by Date. Month label is at the beginning of the month.

Clupeid larvae include blueback herring, alewife, hickory shad, and gizzard shad. These are difficult to distinguish and have similar spawning patterns so they are lumped into one group for this analysis. Clupeids increased in the study areas through April and May attaining a maximum in early June (Figure 56). By comparison, white perch larval density peaked earlier in late May (Figure 57). Yellow perch (*Perca flavescens*) and inland silverside (*Menidia beryllina*) were captured only sporadically in low numbers and without a clear pattern.



Herrings, *Morone* spp.. and yellow perch breed during a short interval in the spring of each year. The females broadcast the eggs into the water and the male does the same with its sperm. Hatching from these eggs, the larvae remain in suspension as they develop, first using yolk sac material and then beginning to feed on small zooplankton. Inland silverside larvae are spawned over SAV (sub-mersed aquatic vegetation) beds and generally are found within the SAV rather than in open water where these samples were collected.

Figure 57. Other Fish Larvae by Date. Month label is at the beginning of the month.

E. Adult and juvenile fishes – 2008

Trawls

Trawl sampling was conducted between 25 April and 19 September at three fixed stations (7, 9, and 10) that have been sampled continuously since the inception of the survey. A total of 2363 fishes comprising 31 species were collected (Table 4). The majority (84.7%, numerically) of the fish collected were represented by 4 species: bay anchovy (34.0%), bluegill sunfish and pumpkinseed (32.7%, grouped due to similarity in habitats and body shape), and white perch (17.9%). Other numerically abundant species (annual total >20) included: gizzard shad (3.3%; primarily juveniles taken at station 7 on July 22), spottail shiner (2.2%), redbreast sunfish (1.8%), unidentified sunfish (1.7%; likely bluegill or pumpkinseed, but these were too small to distinguish in the field), and blue catfish (1.2%). The other 23 species were observed sporadically and at low abundances (Table 4, 5A, & 5B).

Seasonal patterns in catches tended to show bimodal patterns, which were driven by reproduction and successful recruitment of the dominant species. Typical of previous years, bay anchovy only appeared in the catches at the end of the sampling season, and are represented almost entirely by one very large catch at station 7 in September (Tables 5B, and 6). Bay anchovy spawn in polyhaline areas and the offspring exhibit up-estuary dispersal into freshwater during late summer and fall. For the two primary sunfish species (and in general for the two sunfish genera, *Lepomis* and *Enneacanthus*), moderate catches in May represented adults in spawning condition and higher catches at the end of July and in August represented primarily young-of-the-year (YOY) individuals that had grown to sizes large enough to be retained by the gear and quantified by the survey. Most of the sunfish catch occurred at station 10, where dense SAV beds develop. These sunfish species associate strongly with SAV beds when available, and this type of habitat has been shown to have a positive influence on survival and growth.

The dominant anadromous species, white perch, was ubiquitous occurring on every sampling date and all stations (Tables 5B and 6). In the spring adult white perch were caught in the nets while later in the summer juveniles dominated.

In total numbers of fish, Stations 9 and 10 were similar, representing 35.7% and 37.2% respectively, but Station 10 had the greatest species richness (21 species compared with only 10 species at Station 7; Table 6). Though not as productive in numbers, Station 9 has species richness that was intermediate (17 species). Catch rates were dominated by bay anchovy and juvenile bluegill sunfish and pumpkinseed, which were concentrated at Stations 9 and 10 (Figure 58). Lower overall catch rates occurred at Station 7 with white perch as the dominant species.

Table 4

Adult and Juvenile Fish Collected by Trawling
Gunston Cove Study - 2008

Anguillidae	*Anguilla rostrata*	American eel	0
Clupeidae	*Alosa aestivalis*	blueback herring	0
	Alosa mediocris	hickory shad	0
	Alosa pseudoharengus	alewife	2
	Alosa sapidissima	American shad	3
	Alosa sp.	herring or shad	0
	Dorosoma cepedianum	gizzard shad	80
	Brevoortia tyrannus	Atlantic menhanden	9
Engraulidae	*Anchoa mitchilli*	bay anchovy	804
Cyprinidae	*Carassius auratus*	goldfish	12
	Cyprinus carpio	common carp	2
	Hybognathus regius	eastern silvery minnow	0
	Notemigonius crysoleucas	golden shiner	0
	Notropis hudsonius	spottail shiner	52
Catostomidae	*Carpiodes cyprinus*	quillback	1
	Catostomus commersoni	white sucker	3
	Erimyzon oblongatus	creek chubsucker	1
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	12
	Ictalurus furcatus	blue catfish	29
	Ictalurus punctatus	channel catfish	1
Belonidae	*Strongylura marina*	Atlantic needlefish	1
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	7
	Fundulus heteroclitus	mummichog	0
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	5
Atherinidae	*Menidia beryllina*	inland silverside	5
Gobiidae	*Gobiosoma bosc*	naked goby	0
Percichthyidae	*Morone americana*	white perch	424
	Morone saxatilis	striped bass	8
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	4
	Lepomis auritus	redbreast sunfish	44
	Lepomis gibbosus	pumpkinseed	140
	Lepomis macrochirus	bluegill	633
	Lepomis microlophus	redear sunfish	3
	Lepomis sp.	sunfish	41
	Micropterus dolomieu	smallmouth bass	12
	Micropterus salmoides	largemouth bass	6
	Pomoxis nigromaculatus	white crappie	7
Percidae	*Etheostoma olmstedi*	tessellated darter	8
	Perca flavescens	yellow perch	3
Soleidae	*Trinectes maculatus*	hogchoker	1
TOTAL			2363

Table 5A

Adult and Juvenile Fish Collected by Trawling
Gunston Cove Study - 2008

			25-Apr	15-May	27-May	6-Jun	23-Jun	8-Jul	22-Jul
Anguillidae	*Anguilla rostrata*	American eel	0	0	0	0	0	0	0
Clupeidae	*Alosa aestivalis*	blueback herring	0	0	0	0	0	0	0
	Alosa mediocris	hickory shad	0	0	0	0	0	0	0
	Alosa pseudoharengus	alewife	1	0	0	0	1	0	0
	Alosa sapidissima	American shad	0	0	0	0	3	0	0
	Alosa sp.	herring or shad	0	0	0	0	0	0	0
	Dorosoma cepedianum	gizzard shad	0	0	0	0	0	0	75
	Brevoortia tyrannus	Atlantic menhaden	0	9	0	0	0	0	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	0	0	0	0	0
Cyprinidae	*Carassius auratus*	goldfish	2	1	0	2	0	1	4
	Cyprinus carpio	common carp	1	0	1	0	0	0	0
	Hybognathus regius	eastern silvery minnow	0	0	0	0	0	0	0
	Notemigonius crysoleucas	golden shiner	0	0	0	0	0	0	0
	Notropis hudsonius	spottail shiner	20	2	8	3	5	0	3
Catostomidae	*Carpiodes cyprinus*	quillback	0	0	1	0	0	0	0
	Catostomus commersoni	white sucker	3	0	0	0	0	0	0
	Erimyzon oblongatus	creek chubsucker	1	0	0	0	0	0	0
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	1	1	3	1	2	1	2
	Ictalurus furcatus	blue catfish	0	0	0	1	0	0	12
	Ictalurus punctatus	channel catfish	0	0	1	0	0	0	0
Belonidae	*Strongylura marina*	Atlantic needlefish	0	0	0	0	0	0	1
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	3	0	0	0	1	0	0
	Fundulus heteroclitus	mummichog	0	0	0	0	0	0	0
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	5	0	0	0	0	0	0
Atherinidae	*Menidia beryllina*	inland silverside	5	0	0	0	0	0	0
Gobiidae	*Gobiosoma bosc*	naked goby	0	0	0	0	0	0	0
Percichthyidae	*Morone americana*	white perch	18	9	18	3	10	7	59
	Morone saxatilis	striped bass	4	0	0	0	0	0	1
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	0	0	0	0	0	0	0
	Lepomis auritus	redbreast sunfish	1	0	0	0	0	0	1
	Lepomis gibbosus	pumpkinseed	27	7	14	4	6	0	43
	Lepomis macrochirus	bluegill	28	20	16	8	11	0	1
	Leopmis microlophus	redear sunfish	0	0	0	0	0	0	0
	Lepomis sp.	sunfish	0	0	0	0	0	0	0
	Micropterus dolomieu	smallmouth bass	12	0	0	0	0	0	0
	Micropterus salmoides	largemouth bass	3	1	1	0	0	0	0
	Pomoxis nigromaculatus	white crappie	0	0	1	0	5	0	0
Percidae	*Etheostoma olmstedi*	tessellated darter	2	3	0	0	1	0	0
	Perca flavescens	yellow perch	1	1	0	0	0	0	1
Soleidae	*Trinectes maculatus*	hogchoker	0	1	0	0	0	0	0
TOTAL			138	55	64	22	45	8	589

Table 5B

Adult and Juvenile Fish Collected by Trawling
Gunston Cove Study - 2008

			5-Aug	19-Aug	19-Sep
Anguillidae	*Anguilla rostrata*	American eel	0	0	0
Clupeidae	*Alosa aestivalis*	blueback herring	0	0	0
	Alosa mediocris	hickory shad	0	0	0
	Alosa pseudoharengus	alewife	0	0	0
	Alosa sapidissima	American shad	0	0	0
	Alosa sp.	herring or shad	0	0	0
	Dorosoma cepedianum	gizzard shad	0	0	5
	Brevoortia tyrannus	Atlantic menhaden	0	0	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	1	0	803
Cyprinidae	*Carassius auratus*	goldfish	2	0	0
	Cyprinus carpio	common carp	0	0	0
	Hybognathus regius	eastern silvery minnow	0	0	0
	Notemigonius crysoleucas	golden shiner	0	0	0
	Notropis hudsonius	spottail shiner	2	5	4
Catostomidae	*Carpiodes cyprinus*	quillback	0	0	0
	Catostomus commersoni	white sucker	0	0	0
	Erimyzon oblongatus	creek chubsucker	0	0	0
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	2	1	0
	Ictalurus furcatus	blue catfish	12	1	3
	Ictalurus punctatus	channel catfish	0	0	0
Belonidae	*Strongylura marina*	Atlantic needlefish	0	0	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	1	2	0
	Fundulus heteroclitus	mummichog	0	0	0
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0	0	0
Atherinidae	*Menidia beryllina*	inland silverside	0	0	0
Gobiidae	*Gobiosoma bosc*	naked goby	0	0	0
Percichthyidae	*Morone americana*	white perch	77	103	120
	Morone saxatilis	striped bass	0	0	3
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	2	2	0
	Lepomis auritus	redbreast sunfish	0	42	0
	Lepomis gibbosus	pumpkinseed	5	21	13
	Lepomis macrochirus	bluegill	171	130	50
	Lepomis microlophus	redear sunfish	2	0	1
	Lepomis sp.	sunfish	0	41	0
	Micropterus dolomieu	smallmouth bass	0	0	0
	Micropterus salmoides	largemouth bass	1	0	0
	Pomoxis nigromaculatus	white crappie	1	0	0
Percidae	*Etheostoma olmstedi*	tessellated darter	1	0	1
	Perca flavescens	yellow perch	0	0	0
Soleidae	*Trinectes maculatus*	hogchoker	0	0	0
TOTAL			280	348	1003

Table 6

Adult and Juvenile Fish Collected by Trawling
Gunston Cove Study - 2008

		Station	7	9	10
Anguillidae	*Anguilla rostrata*	American eel	0	0	0
Clupeidae	*Alosa aestivalis*	blueback herring	0	0	0
	Alosa mediocris	hickory shad	0	0	0
	Alosa pseudoharengus	alewife	1	1	0
	Alosa sapidissima	American shad	2	1	0
	Alosa sp.	herring or shad	0	0	0
	Dorosoma cepedianum	gizzard shad	79	0	1
	Brevoortia tyrannus	Atlantic menhaden	0	0	9
Engraulidae	*Anchoa mitchilli*	bay anchovy	5	799	0
Cyprinidae	*Carassius auratus*	goldfish	0	0	12
	Cyprinus carpio	common carp	0	0	2
	Hybognathus regius	eastern silvery minnow	0	0	0
	Notemigonius crysoleucas	golden shiner	0	0	0
	Notropis hudsonius	spottail shiner	32	1	19
Catostomidae	*Carpiodes cyprinus*	quillback	0	0	1
	Catostomus commersoni	white sucker	3	0	0
	Erimyzon oblongatus	creek chubsucker	0	0	1
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	2	0	10
	Ictalurus furcatus	blue catfish	4	25	0
	Ictalurus punctatus	channel catfish	1	0	0
Belonidae	*Strongylura marina*	Atlantic needlefish	0	0	1
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	0	0	7
	Fundulus heteroclitus	mummichog	0	0	0
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0	5	0
Atherinidae	*Menidia beryllina*	inland silverside	0	0	5
Gobiidae	*Gobiosoma bosc*	naked gobi	0	0	0
Percichthyidae	*Morone americana*	white perch	305	100	19
	Morone saxatilis	striped bass	3	5	0
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	0	0	4
	Lepomis auritus	redbreast sunfish	2	0	42
	Lepomis gibbosus	pumpkinseed	37	1	102
	Lepomis macrochirus	bluegill	14	0	619
	Lepomis microlophus	redear sunfish	0	0	3
	Lepomis sp.	sunfish	0	0	41
	Micropterus dolomieu	smallmouth bass	0	12	0
	Micropterus salmoides	largemouth bass	0	0	6
	Pomoxis nigromaculatus	white crappie	6	0	1
Percidae	*Etheostoma olmstedi*	tessellated darter	2	0	6
	Perca flavescens	yellow perch	1	0	2
Soleidae	*Trinectes maculatus*	hogchoker	0	0	0
TOTAL			501	949	913

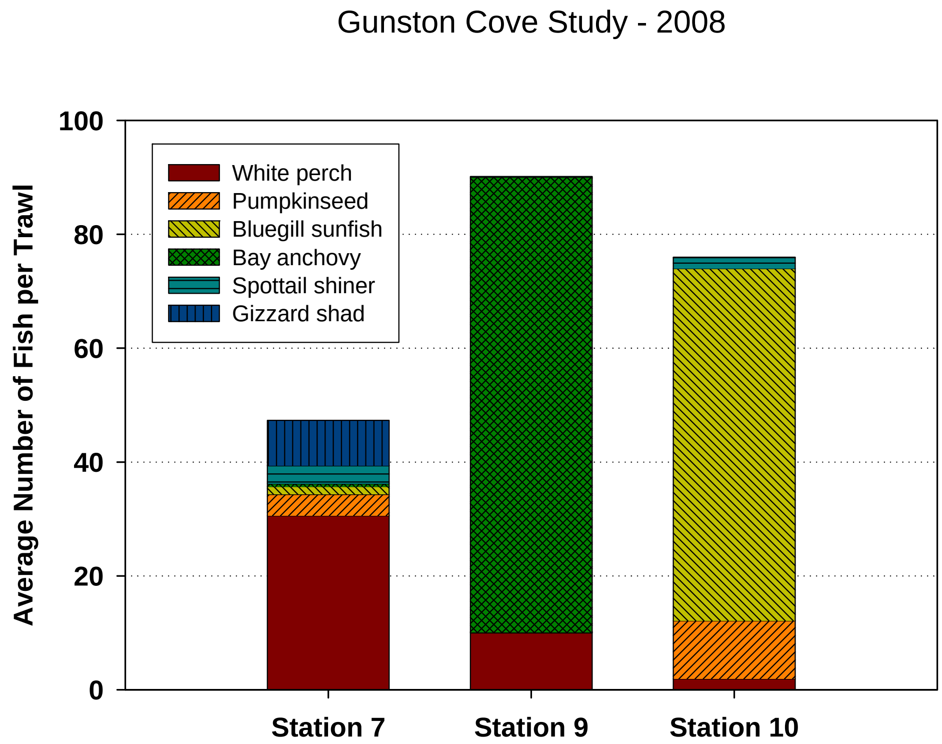


Figure 58. Adult and Juvenile Fishes Collected by Trawling. Dominant Species by Station.

The six most abundant species varied in representation across stations with a single large catch of bay anchovy dominating the pattern at station 9 (Figure 58). High numbers of juvenile bluegill sunfish and pumpkinseed followed by juvenile redbreast sunfish (primarily late in the season) dominated the catch rates at station 10. Consistent catches of white perch throughout the year and a single large catch of gizzard shad dominated the pattern at station 7.

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.

Bay anchovy (*Anchoa mitchilli*), is not commercially valuable, but is a significant link between the plankton community and large fish like white perch and striped bass. They reproduce in small batches throughout the warmer months. They grow to a maximum of 9 cm. In Gunston Cove this species is frequently very abundant, but its occurrence is erratic.

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

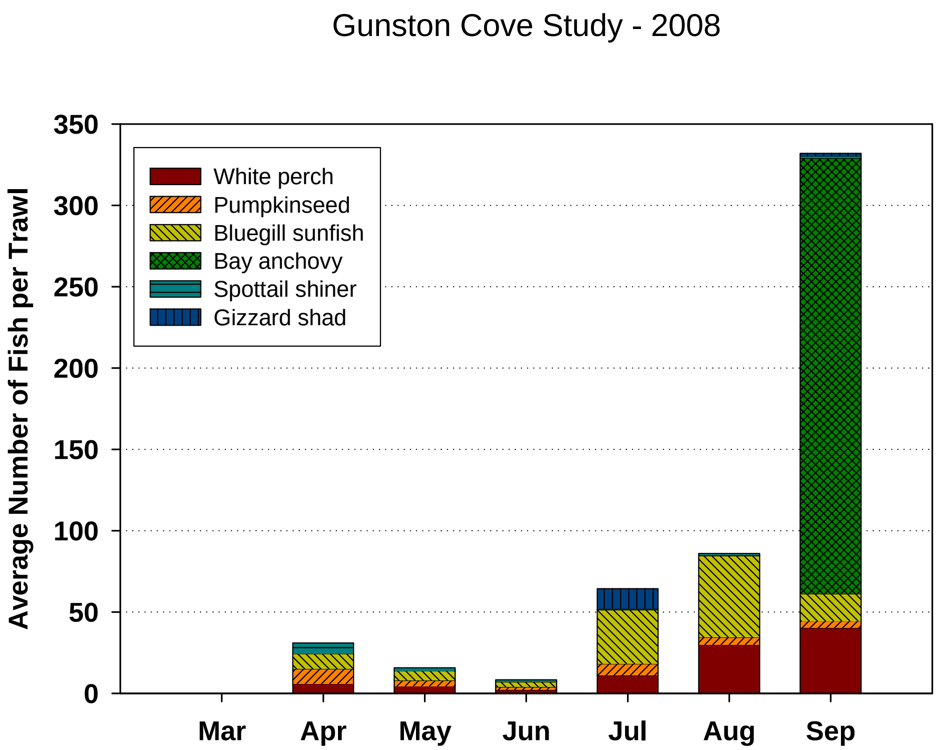


Figure 59. Adult and Juvenile Fishes Collected by Trawling. Dominant Species by Month.

Disregarding large single catches of gizzard shad (in July) and bay anchovy (in September), white perch, bluegill sunfish and pumpkinseed were the most common species that were present throughout the sampling season (Figure 59). The bimodal pattern represented by higher catch rates early and late during the season, reflects adults that tend to be captured more frequently during April and May (spawning season), and annual cohorts of juveniles that are more variable from year-to-year and tend to occur in trawl catches during late July, August, and September.

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 cat (*Ictalurus punctatus*) is an introduced 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 24 April and 12 September. Three of these stations (4, 6, 11) have been sampled continuously since 1984 and the fourth ancillary station (4A) was added in recent years as a substitute for station 4 when dense SAV impeded seining. Station 4A was 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 2008, regardless of SAV density, station 4A was sampled concurrently with station 4 so that catch composition could be compared. Note, on April 25th, use of the canoe launch area by private citizens prohibited sampling at the exact location for 4A; therefore, we sampled an immediately adjacent habitat 50 (shoreline) yards away with similar substrate.

A total of 40 seine samples were conducted, comprising 7628 fishes and 35 species (Table 7). The most abundant specie in seine catches was gizzard shad (44.2%), followed by banded killifish (26.7%), white perch (8.4%), tessellated darter (7.8%), and bluegill sunfish and pumpkinseed (4.9%, combined). Several other species occurred at moderate abundances (>20 total) including: spottail shiner, American shad, largemouth bass, redbreast sunfish, quillback, eastern silvery minnow, Atlantic menhaden, tessellated darter, and striped bass (Table 7). Other species occurred sporadically at low abundances. We captured a single northern snakehead (first occurrence on the survey), but note that this fish was caught on April 25th at the location adjacent to station 4A, and we have not recorded this new invasive at any of the standard long-term monitoring stations. Though at moderate abundances, American shad (all juveniles) still featured prominently in our catches, which continues a pattern first observed 2 years ago, coincident with increased larval stocking efforts at Pohick Regional Park. Also continuing a recent trend were moderate catches of (primarily juvenile) largemouth bass, which reflects relatively high recruitment success in both 2007 and 2008. Two species observed in 2008 that have been recorded only a few times previous on the survey were redear sunfish and smallmouth bass.

Seasonal patterns were variable, but the recruitment of large numbers of juveniles of gizzard shad, inland silversides, white perch, and common sunfish species (bluegill and pumpkinseed) resulted in increased catches during July and August (Tables 8 A,B). Other species exhibited little trend in total abundance across the season. For example, the banded killifish was captured on every sampling round (Tables 8 A,B), and other than a decline in total catch during July sampling trips, numbers varied around a mean of 241 per sampling date.

The productivity of catches at each site varied approximately three-fold from n=933 fish at station 4 to n=3031 at station 6 (Table 9). A few high abundance species dominated this pattern, but particular dominants varied by site. At sites 4 and 4A, banded killifish was most abundant, whereas gizzard shad dominated at site 6 and to a lesser degree at site 11. In contrast, species richness at each site was very similar ranging from 20 species at site 6 to 22 species at site 4 (and 4A). Site 4 and its comparison site (4A) shared 16 species in common, but varied 2 fold in total numbers with more than twice as many fish at 4A (Table 9).

Table 7

Adult and Juvenile Fish Collected by Seining
Gunston Cove Study - 2008

Lepisosteidae	*Lepisosteus osseus*	longnose gar	2
Anguillidae	*Anguilla rostrata*	American eel	0
Clupeidae	*Alosa aestivalis*	blueback herring	13
	Alosa mediocris	hickory shad	0
	Alosa pseudoharengus	alewife	3
	Alosa sapidissima	American shad	86
	Dorosoma cepedianum	gizzard shad	3373
	Brevoortia tyrannus	Atlantic menhaden	40
Engraulidae	*Anchoa mitchilli*	bay anchovy	2
Cyprinidae	*Carassius auratus*	goldfish	2
	Cyprinella analostana	satinfin shiner	1
	Cyprinus carpio	common carp	1
	Hybognathus regius	eastern silvery minnow	48
	Notemigonus crysoleucas	golden shiner	10
	Notropis hudsonius	spottail shiner	97
Catastomidae	*Carpiodes cyprinus*	quillback	53
	Catostomus commersoni	white sucker	5
	Erimyzon oblongatus	creek chubsucker	0
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	4
Belonidae	*Strongylura marina*	Atlantic needlefish	6
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	2033
	Fundulus heteroclitus	mummichog	5
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	10
Atherinidae	*Menidia beryllina*	inland silverside	596
Percichthyidae	*Morone americana*	white perch	639
	Morone saxatilis	striped bass	24
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	6
	Lepomis auritus	redbreast sunfish	55
	Lepomis gibbosus	pumpkinseed	170
	Lepomis macrochirus	bluegill	206
	Lepomis microlophus	redear sunfish	3
	Lepomis sp.	sunfish	20
	Micropterus dolomieu	smallmouth bass	1
	Micropterus salmoides	largemouth bass	64
	Pomoxis nigromaculatus	crappie	1
Percidae	*Etheostoma olmstedi*	tessellated darter	39
	Perca flavescens	yellow perch	9
Channoidea	*Channa argus*	northern snakehead	1
TOTAL		7628	

Table 8A

Adult and Juvenile Fish Collected by Seining

Gunston Cove Study - 2008

			25-Apr	15-May	27-May	6-Jun	23-Jun	8-Jul
Lepisosteidae	*Lepisosteus osseus*	longnose gar	0	0	0	1	0	1
Anguillidae	*Anguilla rostrata*	American eel	0	0	0	0	0	0
Clupeidae	*Alosa aestivalis*	blueback herring	0	0	0	0	0	0
	Alosa mediocris	hickory shad	0	0	0	0	0	0
	Alosa pseudoharengus	alewife	0	0	0	0	0	0
	Alosa sapidissima	American shad	0	0	0	0	0	1
	Dorosoma cepedianum	gizzard shad	0	2	0	0	0	2188
	Brevoortia tyrannus	Atlantic menhaden	0	37	1	0	2	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	1	0	0	1	0	0
Cyprinidae	*Carassius auratus*	goldfish	0	1	0	0	0	1
	Cyprinella analostana	satinfin shiner	0	0	0	0	0	0
	Cyprinus carpio	common carp	0	0	1	0	0	0
	Hybognathus regius	eastern silvery minnow	1	1	0	1	1	5
	Notemigonus crysoleucas	golden shiner	2	2	1	1	0	0
	Notropis hudsonius	spottail shiner	7	2	12	4	25	3
Catastomidae	*Carpiodes cyprinus*	quillback	0	0	0	0	27	21
	Catostomus commersoni	white sucker	2	1	1	1	0	0
	Erimyzon oblongatus	creek chubsucker	0	0	0	0	0	0
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	0	0	0	0	4	0
Belonidae	*Strongylura marina*	Atlantic needlefish	0	0	0	0	4	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	182	126	427	275	469	52
	Fundulus heteroclitus	mummichog	0	0	0	0	0	0
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0	4	1	0	3	0
Atherinidae	*Menidia beryllina*	inland silverside	10	23	31	8	33	47
Percichthyidae	*Morone americana*	white perch	9	31	20	9	2	246
	Morone saxatilis	striped bass	0	0	0	0	0	0
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	0	0	0	0	5	0
	Lepomis auritus	redbreast sunfish	9	0	10	1	1	0
	Lepomis gibbosus	pumpkinseed	6	3	53	4	2	1
	Lepomis macrochirus	bluegill	16	3	17	2	2	0
	Lepomis microlophus	redear sunfish	0	0	0	0	0	0
	Lepomis sp.	sunfish	0	0	0	0	0	3
	Micropterus dolomieu	smallmouth bass	0	0	1	0	0	0
	Micropterus salmoides	largemouth bass	11	5	4	8	8	10
	Pomoxis nigromaculatus	crappie	0	0	0	0	0	0
Percidae	*Etheostoma olmstedi*	tessellated darter	1	0	10	1	1	7
	Perca flavescens	yellow perch	1	3	3	0	1	0
Channoidea	*Channa argus*	northern snakehead	1	0	0	0	0	0
TOTAL			259	244	593	317	590	2586

Table 8B

Adult and Juvenile Fish Collected by Seining
Gunston Cove Study - 2008

			22-July	5-Aug	19-Aug	19-Sept
Lepisosteidae	*Lepisosteus osseus*	longnose gar	0	0	0	0
Anguillidae	*Anguilla rostrata*	American eel	0	0	0	0
Clupeidae	*Alosa aestivalis*	blueback herring	0	0	0	13
	Alosa mediocris	hickory shad	0	0	0	0
	Alosa pseudoharengus	alewife	3	0	0	0
	Alosa sapidissima	American shad	1	13	2	69
	Dorosoma cepedianum	gizzard shad	887	59	236	1
	Brevoortia tyrannus	Atlantic menhaden	0	0	0	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	0	0
Cyprinidae	*Carassius auratus*	goldfish	0	0	0	0
	Cyprinella analostana	satinfin shiner	0	0	1	0
	Cyprinus carpio	common carp	0	0	0	0
	Hybognathus regius	eastern silvery minnow	12	4	19	4
	Notemigonus crysoleucas	golden shiner	0	0	0	4
	Notropis hudsonius	spottail shiner	5	9	16	12
Catastomidae	*Carpiodes cyprinus*	quillback	5	0	0	0
	Catostomus commersoni	white sucker	0	0	0	0
	Erimyzon oblongatus	creek chubsucker	0	0	0	0
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	0	0	0	0
Belonidae	*Strongylura marina*	Atlantic needlefish	0	2	0	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	55	136	149	162
	Fundulus heteroclitus	mummichog	0	1	4	0
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0	0	1	1
Atherinidae	*Menidia beryllina*	inland silverside	70	29	335	10
Percichthyidae	*Morone americana*	white perch	17	13	248	44
	Morone saxatilis	striped bass	14	8	1	1
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	0	0	0	1
	Lepomis auritus	redbreast sunfish	2	1	30	1
	Lepomis gibbosus	pumpkinseed	0	52	40	9
	Lepomis macrochirus	bluegill	11	95	43	17
	Lepomis microlophus	redear sunfish	0	3	0	0
	Lepomis sp.	sunfish	0	0	17	0
	Micropterus dolomieu	smallmouth bass	0	0	0	0
	Micropterus salmoides	largemouth bass	2	7	8	1
	Pomoxis nigromaculatus	crappie	0	0	1	0
Percidae	*Etheostoma olmstedi*	tessellated darter	2	0	17	0
	Perca flavescens	yellow perch	1	0	0	0
Channoidea	*Channa argus*	northern snakehead	0	0	0	0
TOTAL			1087	432	1170	350

Table 9

Adult and Juvenile Fish Collected by Seining

Gunston Cove Study - 2008

			4	6	11	4A
Lepisosteidae	*Lepisosteus osseus*	longnose gar	1	1	0	0
Anguillidae	*Anguilla rostrata*	American eel	0	0	0	0
Clupeidae	*Alosa aestivalis*	blueback herring	0	0	13	0
	Alosa mediocris	hickory shad	0	0	0	0
	Alosa pseudoharengus	alewife	0	0	1	2
	Alosa sapidissima	American shad	0	2	19	65
	Dorosoma cepedianum	gizzard shad	1	2222	490	660
	Brevoortia tyrannus	Atlantic menhaden	0	37	2	1
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	2	0
Cyprinidae	*Carassius auratus*	goldfish	1	0	1	0
	Cyprinella analostana	satinfin shiner	0	0	0	1
	Cyprinus carpio	common carp	0	1	0	0
	Hybognathus regius	eastern silvery minnow	6	2	18	22
	Notemigonus crysoleucas	golden shiner	5	4	1	0
	Notropis hudsonius	spottail shiner	34	9	19	35
Catastomidae	*Carpiodes cyprinus*	quillback	0	0	42	11
	Catostomus commersoni	white sucker	1	1	1	2
	Erimyzon oblongatus	creek chubsucker	0	0	0	0
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	4	0	0	0
Belonidae	*Strongylura marina*	Atlantic needlefish	2	0	4	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	581	367	147	938
	Fundulus heteroclitus	mummichog	4	0	0	1
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	9	0	0	1
Atherinidae	*Menidia beryllina*	inland silverside	33	94	413	56
Percichthyidae	*Morone americana*	white perch	24	27	420	168
	Morone saxatilis	striped bass	0	5	1	18
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	6	0	0	0
	Lepomis auritus	redbreast sunfish	5	47	0	3
	Lepomis gibbosus	pumpkinseed	62	84	1	23
	Lepomis macrochirus	bluegill	117	70	0	19
	Lepomis microlophus	redear sunfish	3	0	0	0
	Lepomis sp.	sunfish	0	20	0	0
	Micropterus dolomieu	smallmouth bass	0	0	1	0
	Micropterus salmoides	largemouth bass	27	20	1	16
	Pomoxis nigromaculatus	crappie	0	1	0	0
Percidae	*Etheostoma olmstedi*	tessellated darter	4	12	3	20
	Perca flavescens	yellow perch	3	5	0	1
Channoidea	*Channa argus*	northern snakehead	0	0	0	1
TOTAL			933	3031	1600	2064

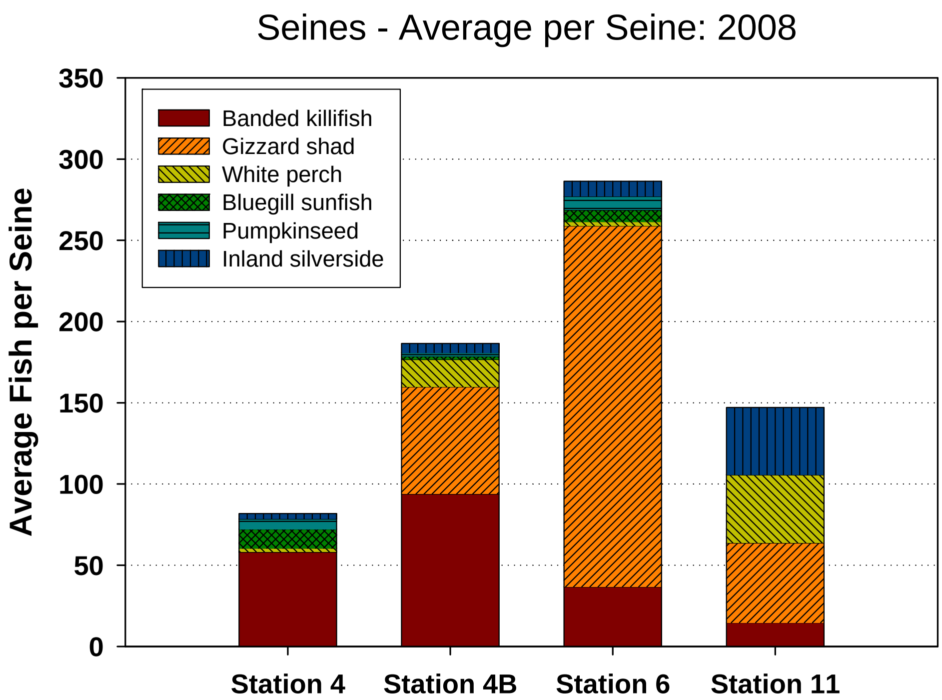


Figure 60. Adult and Juvenile Fish Collected by Seining. Dominant Species by Station.

Typical of shallow littoral zone habitats in Gunston Cove during the past decade, the 6 dominant species ranked by catch rate included banded killifish and white perch, which were present at every station (Figure 60). Other common species included bluegill sunfish, pumpkinseed, and inland silverside. Gizzard shad (predominantly juveniles) were not present at station 4, but were the first or second highest ranking species at the other stations. The high abundance of juvenile gizzard shad indicates a particularly strong year-class – a result that has only been observed sporadically on the survey.

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

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

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.

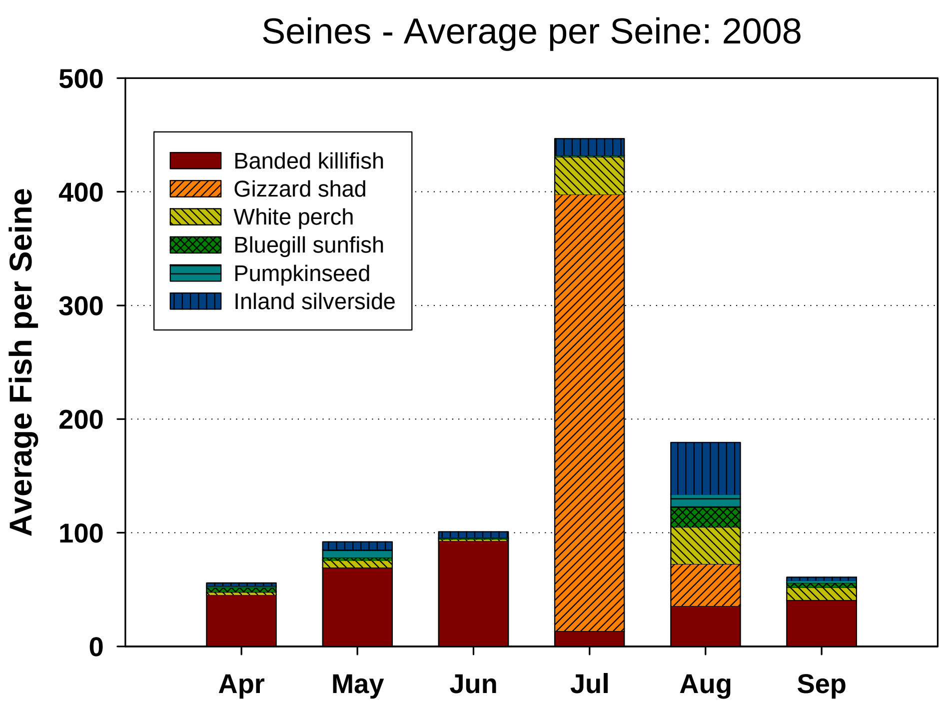


Figure 61. Adult and Juvenile Fish Collected by Seining. Dominant Species by Month.

Examination of mean catch rates by month emphasized the occurrence of juvenile gizzard shad in seine catches during July (Figure 61), and the trawl catches reflected this pattern, too (Figure 59). In addition, juvenile white perch occurred in relatively high density during July and August. Part of the explanation for this pattern is that both gizzard shad and white perch are anadromous, spring spawning species that typically recruit to shallow water habitats of Gunston Cove during July and August. In other months, banded killifish dominated catch rates, followed by inland silversides (particularly in August).

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.

Mummichog (*Fundulus heteroclitus*) is a close relative of the dominant seine fish, banded killifish, who it closely resembles. Individuals become sexually mature in their second year and grow to a maximum length of 10 cm. Mummichog is very common in shallow bay waters and is an important food for larger fishes.

Inland silverside (*Menidia beryllina*) is a small fish which is collected sporadically in the Gunston Cove seines. This species is characteristic of brackish water conditions, but often enters tidal freshwater to feed. Adults may reach 7 cm long. Spawning occurs throughout the warmer months. Food consists almost exclusively of zooplankton. It is food for larger fishes and shoreline birds like egrets.

Drop-ring Sampling of Fish

We selected 28 sites using a stratified random sampling routine with equal probability of sampling any SAV-colonized location in Pohick or Accotink Bays (Figure 62). The 28 drop ring samples contained a total of 126 juvenile fishes for a nominal fish density of 4.8 individuals per sample. Here we compare 2008 results with a subset of 2007 data (n=24 samples, 170 total individual fish) from Pohick and Accotink Bays (a full report with all 2007 data can be found as a separate chapter of this report).

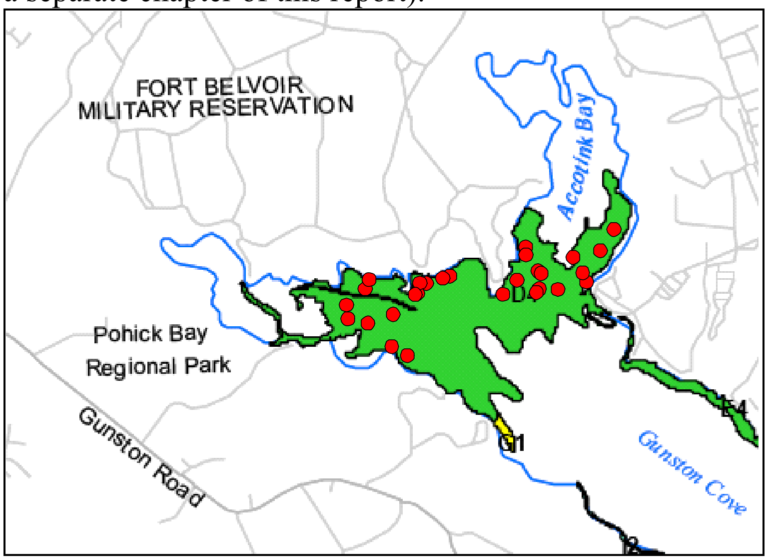


Figure 62 Map of Gunston Cove demonstrating extent of SAV beds in Pohick and Accotink Bays (preliminary 2008 data from aerial surveys; see www.vims.edu/bio/sav). The red dots are locations sampled with the drop ring in 2008.

The species richness in drop ring samples was similar between years (9 in 2008, and 10 in 2007) with 6 species common to both years. Banded killifish had the highest density in both years and density was significantly higher in 2007 (Figure 63). Tessellated darter density was also significantly higher in 2007 and declined by approximately 75% in drop ring samples for 2008. In general, fish density was higher in 2007, with the exception of the dominant sunfish species in the cove (bluegill sunfish and pumpkinseed). In particular, bluegill sunfish were more frequently encountered in 2008 (present in 42% of samples versus 17% in 2007) and had nearly 4-fold higher mean density, which is also reflected in higher catch rates observed in seines and trawls. White perch, brown bullhead, mummichog and blue spotted sunfish were only observed in 2007, and eastern mosquitofish, redear sunfish, and inland silverside were only observed in 2008.

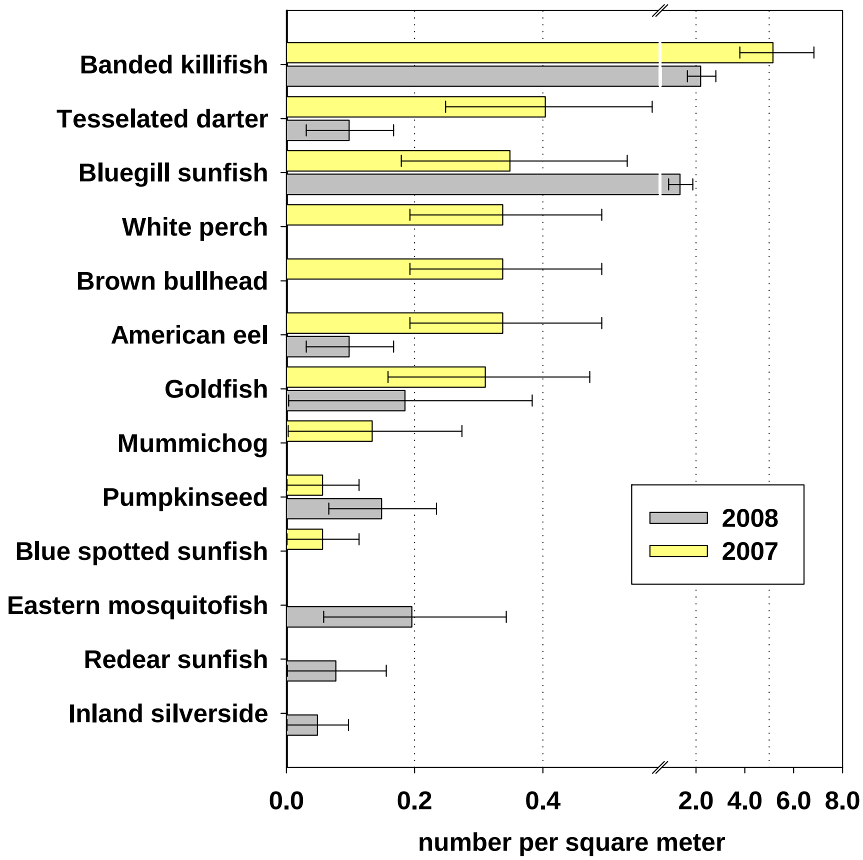
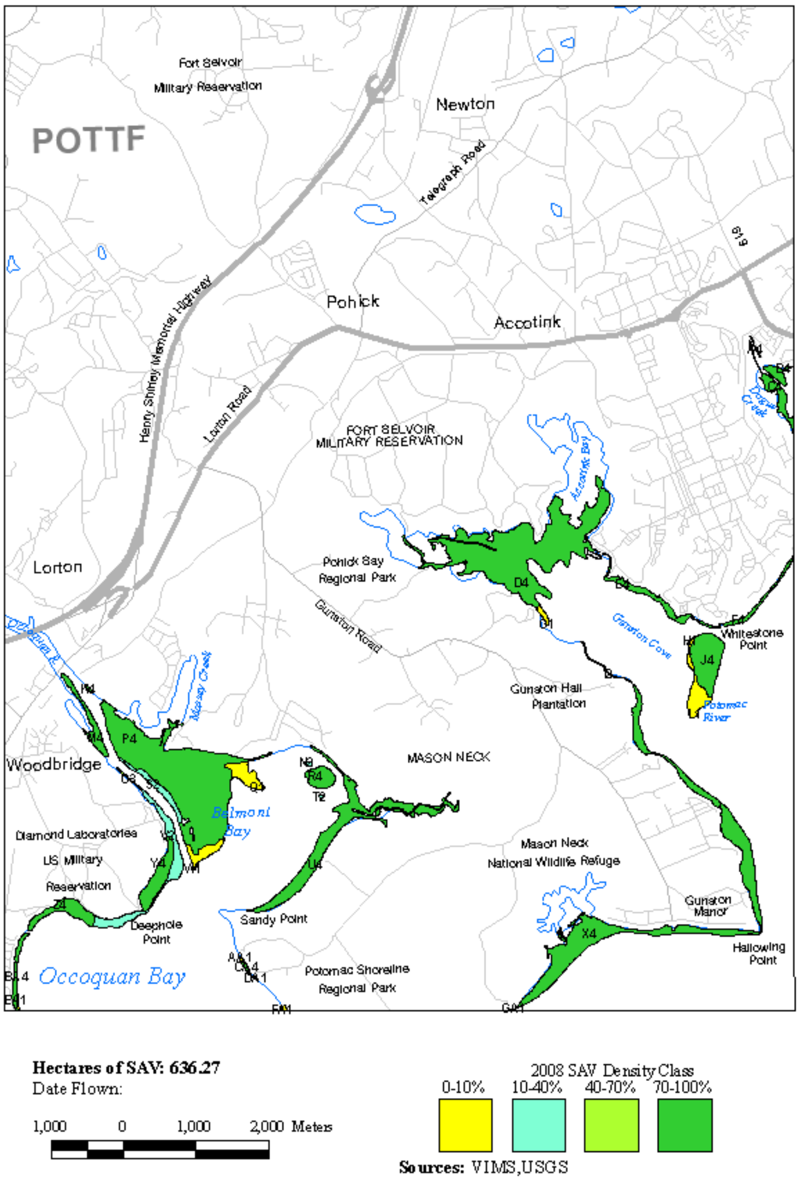


Figure 63. Geometric mean density of juvenile fishes in drop ring samples from SAV beds in Gunston Cove. Means are compared between 2007 and 2008, and corresponding asymmetric confidence intervals (95%) are plotted. Note that the horizontal axis scale is broken in order to show the range of density values more clearly. Geometric mean was used due to the high frequency of zero catches (calculations were made with ln(x+1) transformed data that were back-transformed for graphing). The geometric mean approaches the arithmetic mean when data are normally distributed and is lower than the arithmetic mean when data are right-skewed (e.g., when there are many zeros).

F. Submersed Aquatic Vegetation – 2008

The distribution of submersed aquatic vegetation (SAV) in the Gunston Cove area in fall 2008 as determined by the annual VIMS aerial photography survey is shown in Figure 64. SAV was present at high densities in both Pohick and Accotink Bays and had spread into the inner portions of Gunston Cove. Coverage was not quite as extensive as in 2005, but imagery was taken later and some dieback had probably already occurred. The fringing beds continued to be found along much of the shoreline and the bed of SAV has intensified along the sill at the mouth of the cove. Species data for 2008 was not available for Gunston Cove from the VIMS website.



Valisneria americana
Water celery

Hydrilla verticillata
Hydrilla

Figure 64. Distribution and Density of Submersed Aquatic Vegetation in the Gunston Cove area. 2008. VIMS (http://www.vims.edu/bio/sav/index.html).