THE ONGOING AQUATIC MONITORING PROGRAM

FOR THE GUNSTON COVE AREA

OF THE TIDAL FRESHWATER POTOMAC RIVER

2010

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 Branch, particularly Elaine Schaeffer and Shahram Moshsenin for their advice and cooperation during the study. The Northern Virginia Regional Park Authority facilitated access to the park and boat ramp. Without a dedicated group of field and laboratory workers this project would not have been possible. Thanks go to Beverly Bachman, Alex Graziano, Lara Isdell, Saiful Islam, David Lieu, Sean Lusk, Naghma Malik, Julie McGivern, Shakiba Salehian, and Blake Spady. Claire Buchanan served as a voluntary consultant on plankton identification. Roslyn Cress and Joanne Anderson were vital in handling personnel and procurement functions.

METHODS

A. Profiles and Plankton: Sampling Day

Sampling was conducted on a semimonthly basis at stations representing both Gunston Cove and the Potomac mainstem (Figure 1). One station was located at the center of Gunston Cove (Station 7) and the second was placed in the mainstem tidal Potomac channel off the Belvoir Peninsula just north of the mouth of Gunston Cove (Station 9). Dates for sampling as well as weather conditions on sampling dates and immediately preceding days are shown in Table 1. Gunston Cove is located in the tidal freshwater section of the Potomac about 20 km (13 miles) downstream from Washington, DC.

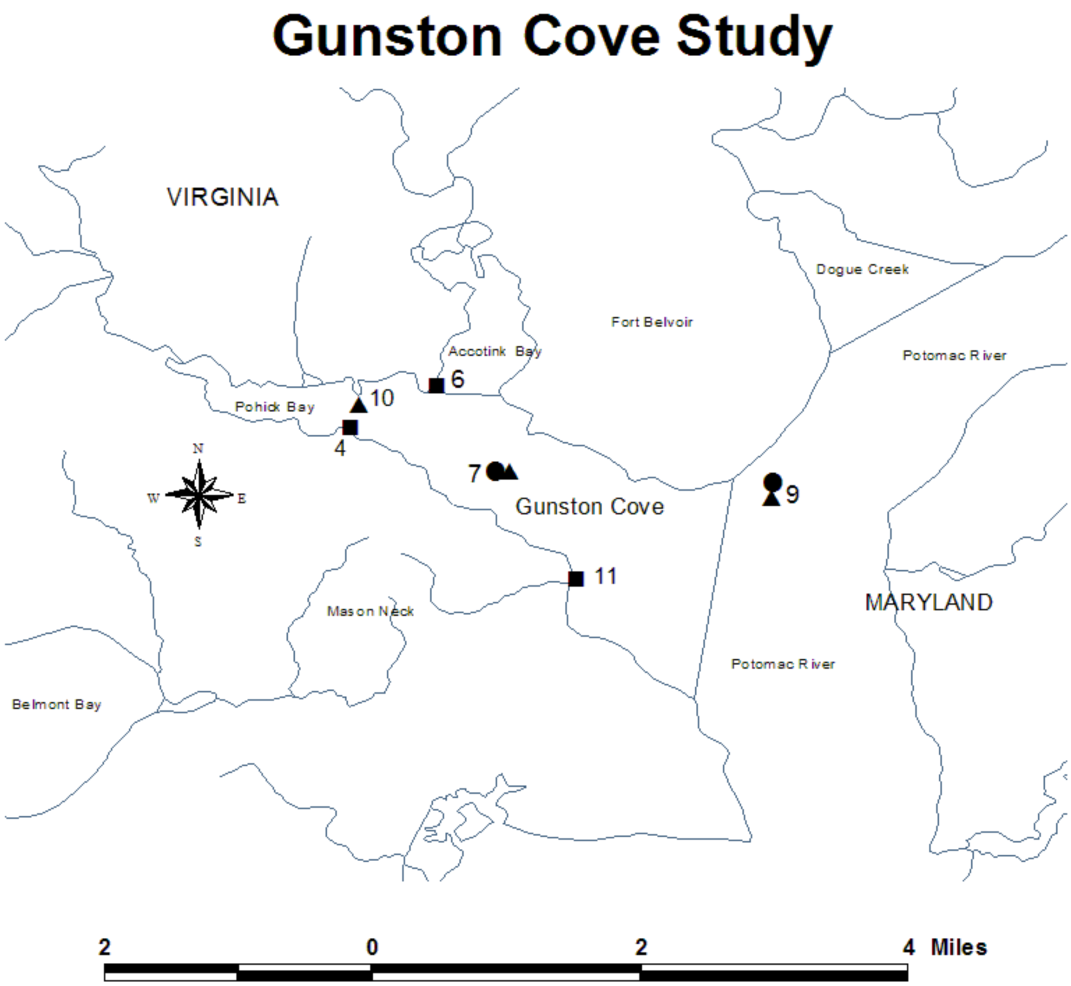


Figure 1. Gunston Cove area of the Tidal Potomac River showing sampling stations. Circles (●) represent Plankton/Profile stations, triangles (▲) represent Fish Trawl stations, and squares (■) represent Fish Seine stations.

Table 1
Sampling Dates and Weather Data for 2010

Date	Type of Sampling G	F	T	S	Avg Daily Temp (°C) 1-Day	3-Day	Precipitation (cm) 1-Day	3-Day
April 9	G	F			11.7	19.3	0.18	1.75
April 13			T	S	11.7	15.2	0.30	0.30
April 20		F*			14.4	12.6	0	0
May 7				S	20.0	21.9	0	0
May 11	G	F			11.1	12.4	0.28	0.29
May 21			T	S	22.2	19.4	0	0
May 25	G				23.3	22.6	0.01	1.65
June 4			T	S	26.7	27.0	0	0.84
June 8	G	F			21.1	23.1	0	0.08
June 18			T	S	24.4	25.4	0	0.05
June 22	G				29.4	29.6	0.64	0.64
June 29		F*			29.4	29.8	0	2.01
July 6	G	F			32.2	29.8	0	0
July 8			T	S	31.1	32.0	0	0
July 20	G				28.9	29.3	0.01	0.10
July 23			T	S	31.1	30.4	0	0.01
July 28		F*			28.9	27.8	0	0
August 3	G	F			26.7	25.2	0	0.14
August 17	G				28.9	27.4	0	0.41
August 20			T	S	27.8	26.3	0	1.32
August 27			T	S	23.9	24.4	0	0
Sept 7	G	F			27.8	24.6	0	0
Sept 15		F*			23.3	23.3	0	0
Sept 20			T	S	22.8	22.0	0	0

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

Sampling was initiated at 10:30 am. Four types of measurements or samples were obtained at each station : (1) depth profiles of temperature, conductivity, dissolved oxygen, pH, and irradiance (photosynthetically active radiation) measured directly in the field; (2) water samples for GMU lab determination of chlorophyll *a* and phytoplankton species composition and abundance; (3) water samples for determination of nutrients, BOD, alkalinity, suspended solids, chloride, and pH by the Environmental Laboratory of the Fairfax County Department of Public Works and Environmental Services; (4) net sampling of zooplankton and ichthyoplankton.

Profiles of temperature, conductivity, and dissolved oxygen were conducted at each station using YSI 6600 datasonde with temperature, conductivity, dissolved oxygen and pH probes. Measurements were taken at 0.3 m, 1.0 m, 1.5 m, and 2.0 m in the cove. In the river measurements were made with the sonde at depths of 0.3 m, 2 m, 4 m, 6 m, 8 m, 10 m, and 12 m. Meters were checked for calibration before and after sampling. Profiles of irradiance (photosynthetically active radiation, PAR) were collected with a LI-COR underwater flat scalar PAR probe. Measurements were taken at 10 cm intervals to a depth of 1.0 m. Simultaneous measurements were made with a terrestrial probe in air during each profile to correct for changes in ambient light if needed. Secchi depth was also determined. The readings of at least two crew members were averaged due to variability in eye sensitivity among individuals.

A 1-liter depth-composited sample was constructed from equal volumes of water collected at each of three depths (0.3 m below the surface, middepth, and 0.3 m off of the bottom) using a submersible bilge pump. A 100-mL aliquot of this sample was preserved immediately with acid Lugol’s iodine for later identification and enumeration of phytoplankton. The remainder of the sample was placed in an insulated cooler with ice. A separate 1-liter sample was collected from 0.3 m using the submersible bilge pump and placed in the insulated cooler with ice for lab analysis of surface chlorophyll *a*. Separate 4-liter samples were collected monthly at each site from just below the surface (0.3 m) and near the bottom (0.3 m off bottom) at each site using the submersible pump. This water was promptly delivered to the nearby Fairfax County Environmental Laboratory for determination of nitrogen, phosphorus, BOD, TSS, VSS, pH, total alkalinity, and chloride.

Microzooplankton was collected by pumping 32 liters from each of three depths (0.3 m, middepth, and 0.3 m off the bottom) through a 44 µm mesh sieve. The sieve consisted of a 12-inch long cylinder of 6-inch diameter PVC pipe with a piece of 44 µm nitex net glued to one end. The 44 µm cloth was backed by a larger mesh cloth to protect it. The pumped water was passed through this sieve from each depth and then the collected microzooplankton was backflushed into the sample bottle. The resulting sample was treated with about 50 mL of club soda and then preserved with formalin containing a small amount of rose bengal to a concentration of 5-10%.

Macrozooplankton was collected by towing a 202 µm net (0.3 m opening, 2 m long) for 1 minute at each of three depths (near surface, middepth, and near bottom). Ichthyoplankton was sampled by towing a 333 µm net (0.5 m opening, 2 m long) for 2 minutes at each of the same depths. In the cove, the boat made a large arc during the tow while in the river the net was towed in a more linear fashion along the channel. Macrozooplankton tows were about 300 m and ichthyoplankton tows about 600 m. Actual distance depended on specific wind conditions and tidal current intensity and direction, but an attempt was made to maintain a constant slow forward speed through the water during the tow. The net was not towed directly in the wake of the engine. A General Oceanics flowmeter, fitted into the mouth of each net, was used to establish the exact towing distance. 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 and ichthyoplankton were preserved immediately with formalin to a concentration of 5-10%. Rose bengal formalin with club soda pretreatment was used for macrozooplankton, but 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. On dates when water samples were not being collected for water quality analysis by the Fairfax County laboratory, benthic macroinvertebrate samples were collected. Three samples were collected at each site using a petite ponar grab. The bottom material was sieved through a 0.5 mm stainless steel sieve and resulting organisms were preserved in rose bengal formalin for lab analysis.

Samples were delivered to the Fairfax County Environmental Services Laboratory by 2 pm on sampling day and returned to GMU by 3 pm. At GMU 10-15 mL aliquots of both depth-integrated and surface samples were filtered through 0.45 µm membrane filters (Gelman GN-6 and Millipore MF HAWP) at a vacuum of less than 10 lbs/in^2 for chlorophyll a and pheopigment determination. During the final phases of filtration, 0.1 mL of $MgCO_3$ suspension (1 g/100 mL water) was added to the filter to prevent premature acidification. Filters were stored in 20 mL plastic scintillation vials in the lab freezer for later analysis. Seston dry weight and seston organic weight were measured by filtering 200-400 mL of depth-integrated sample through a pretared glass fiber filter (Whatman 984AH).

Sampling day activities were normally completed by 5:30 pm.

B. Profiles and Plankton: 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. Fluorescence was determined before and after acidification with 2 drops of 10%

HCl. Chlorophyll a was calculated from the following equation which corrects for pheophytin interference:

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

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

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

Phytoplankton species composition and abundance was determined using the inverted microscope-settling chamber technique (Lund et al. 1958). Ten milliters of well-mixed algal sample were added to a settling chamber and allowed to stand for several hours. The chamber was then placed on an inverted microscope and random fields were enumerated. At least two hundred cells were identified to species and enumerated on each slide. Counts were converted to number per mL by dividing number counted by the volume counted. Biovolume of individual cells of each species was determined by measuring dimensions microscopically and applying volume formulae for appropriate solid shapes. 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 known volume and resuspending it in tap water. This allowed subsample volume to be adjusted to obtain an appropriate number of organisms for counting and for formalin preservative to be purged to avoid fume inhalation during counting. 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:

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

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

Ichthyoplankton samples were sieved through a 333 µm sieve to remove formalin and then reconstituted in ethanol. Larval fish were picked from the reconstituted sample with the aid of a stereo dissecting microscope. Identification of ichthyoplankton was made to family and further to genus and species where possible. If the number of animals in the sample exceeded several hundred, then the sample was split with a plankton splitter and the resulting counts were multiplied by the subsampling factor. The works Hogue et al. (1976), Jones et al. (1978), Lippson and Moran (1974), and Mansueti and Hardy (1967) were used for identification. The number of ichthyoplankton in each sample was expressed as number per 10 m^3 using the following formula:

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

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.

E. Benthic Macroinvertebrates

Benthic macroinvertebrates were sampled using a petite ponar sampler at Stations 7 and 9. Triplicate samples were collected at each site on dates when water samples for Fairfax County lab analysis were not collected.. Bottom samples were sieved on site through a 0.5 mm stainless steel sieve and preserved with rose bengal formalin. In the laboratory benthic samples were rinsed with tap water through a 0.5 mm sieve to remove formalin preservative and resuspended in tap water. All organisms were picked, sorted, identified and enumerated.

F. Data Analysis

Data for each parameter were entered into spreadsheets (Excel or SigmaPlot) for graphing of temporal and spatial patterns. Long term trend analysis was conducted with Systat by plotting data for a given variable by year and then constructing a trend line through the data. For water quality parameters the trend analysis was conducted on data from the warmer months (June-September) since this is the time of greatest microbial activity and greatest potential water quality impact. For zooplankton and fish all data for a given year were used. When graphs are shown with a log axis, zero values have been ignored in the trend analysis. 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

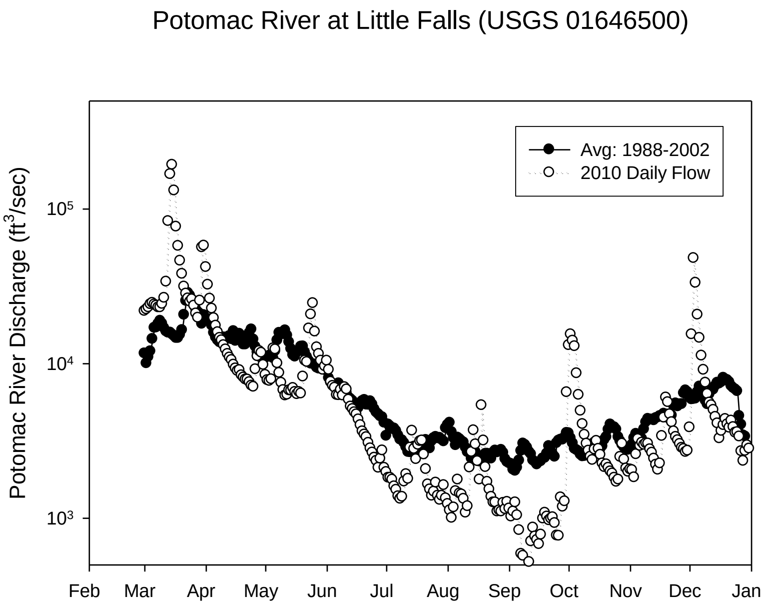
A. Climatic and Hydrologic Factors

In 2010 air temperature was substantially above average for most of the year. All months from March through July were at least 2°C greater than normal (Table 2). July was the warmest month and June had the greatest positive departure from normal. There were 62 days with maximum temperature above 32.2^{o}C (90^{o}F) during 2010 compared with 4 in 2004, 18 in 2005, 29 in 2006, 33 in 2007, 31 in 2008, and 16 days in 2009. Precipitation was well below normal from April through June, above normal in July, and well below normal in August. September exhibited above normal rainfall, but most of this fell in one storm near the end of the month.

Table 2
Meteorological Data for 2010. National Airport. Monthly Summary.

MONTH	Air Temp (^{o}C)		Precipitation (cm)	
March	10.7	(8.1)	9.0	(9.1)
April	16.0	(13.4)	3.8	(7.0)
May	20.7	(18.7)	6.1	(9.7)
June	27.0	(23.6)	4.8	(8.0)
July	28.4	(26.2)	13.1	(9.3)
August	26.7	(25.2)	6.6	(8.7)
September	24.2	(21.4)	15.3	(9.6)
October	16.4	(14.9)	8.6	(8.2)
November	10.3	(9.3)	5.6	(7.7)
December	1.4	(4.2)	4.5	(7.8)

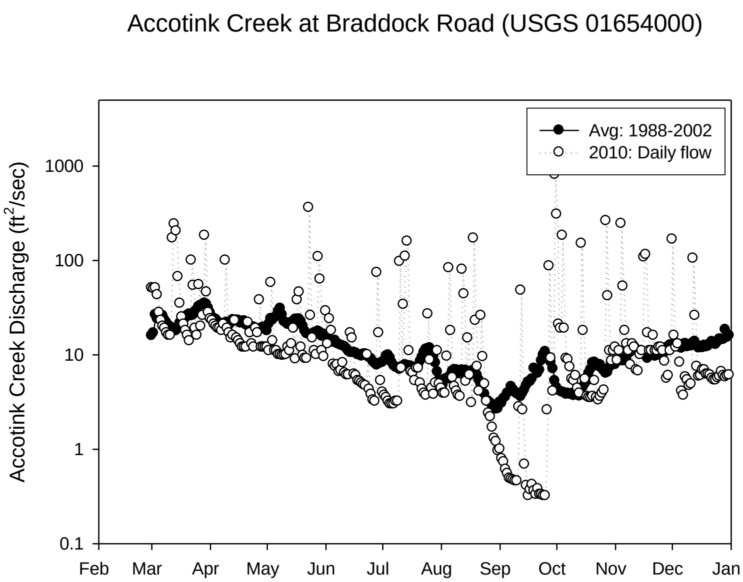
Note: 2010 monthly averages or totals are shown accompanied by long-term monthly averages (1971-2000).
Source: Local Climatological Data. National Climatic Data Center, National Oceanic and Atmospheric Administration.



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 per unit time is referred to as "river discharge" by hydrologists. Note the long term seasonal pattern of higher discharges in winter and spring and lower discharges in summer and fall.

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

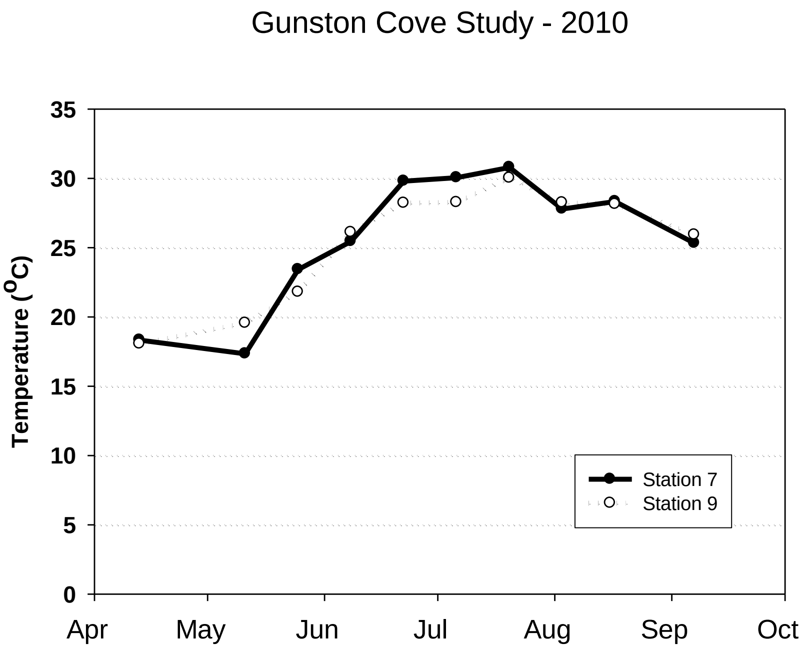
Potomac River discharge during 2010 was generally near average in the spring, but dropped steadily to below normal values in June (Figure 2). A surge in July and a surge in August each brought values back above average, but only for a few days. Most of September was characterized by quite low river discharge. The late September rains brought a surge to well above normal and also seemed to lift the base flows back to near normal. Base flows in Accotink Creek were generally somewhat below normal during most of the year, but dropped to almost nothing during September. The late September rain event and runoff seemed to lift base flows back to near normal levels there as well.



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

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

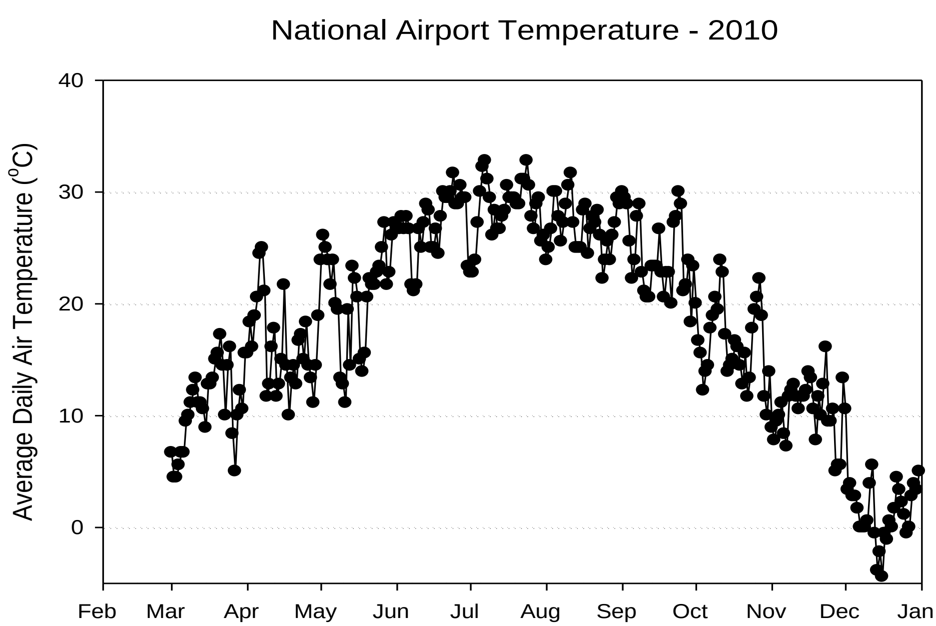
B. Physico-chemical Parameters – 2010



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 (^{o}C). GMU Field Data. Month tick is at first day of month.

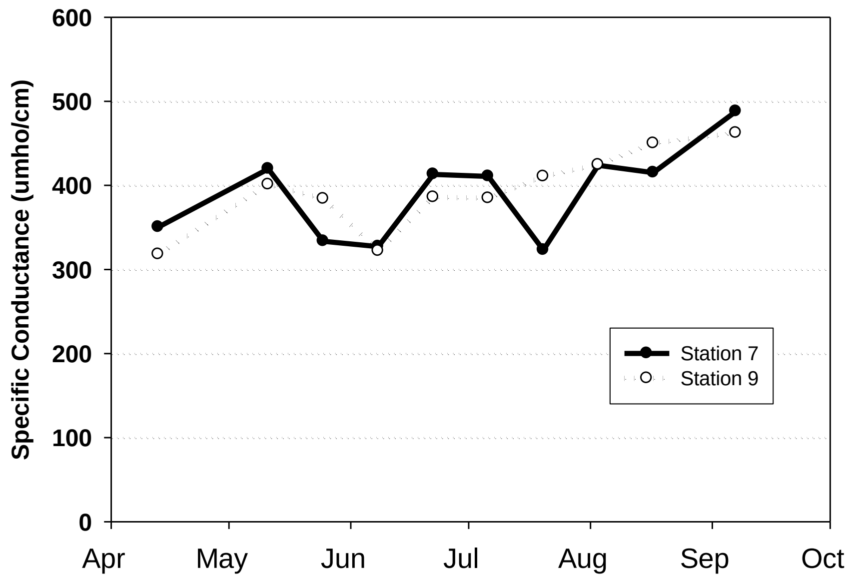
In 2010, water temperature followed the typical seasonal pattern at both sites (Figure 4). Both sites showed a steady increase during the spring and early summer with the cove site (Sta. 7) reaching 30°C in late June while the river site (Sta. 9) attained that value only in late July. For most of the summer, the two stations showed similar air temperatures between 25° and 30° C. Water temperature declined in August and September.



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

Figure 5. Average Daily Air Temperature (^{o}C) at Reagan National Airport.

Gunston Cove Study - 2010

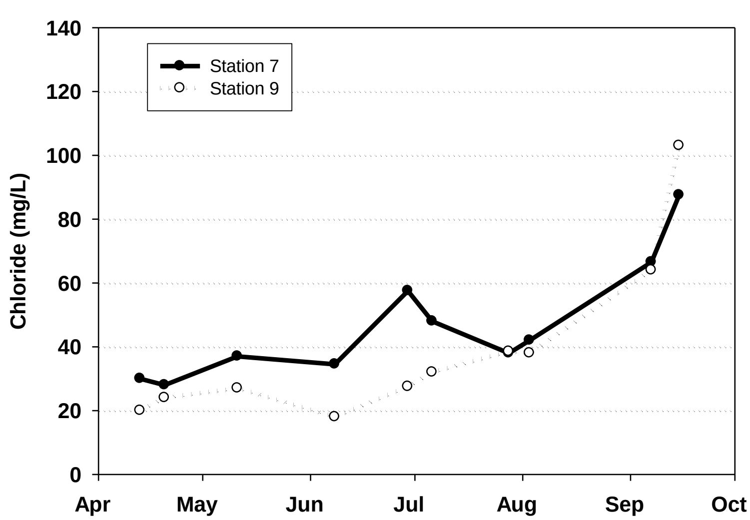


Specific conductance measures the capacity of the water to conduct electricity standardized to 25°C. This is a measure of the concentration of dissolved ions in the water. In freshwater, conductivity is relatively low. Ion concentration generally increases slowly during periods of low freshwater inflow 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.

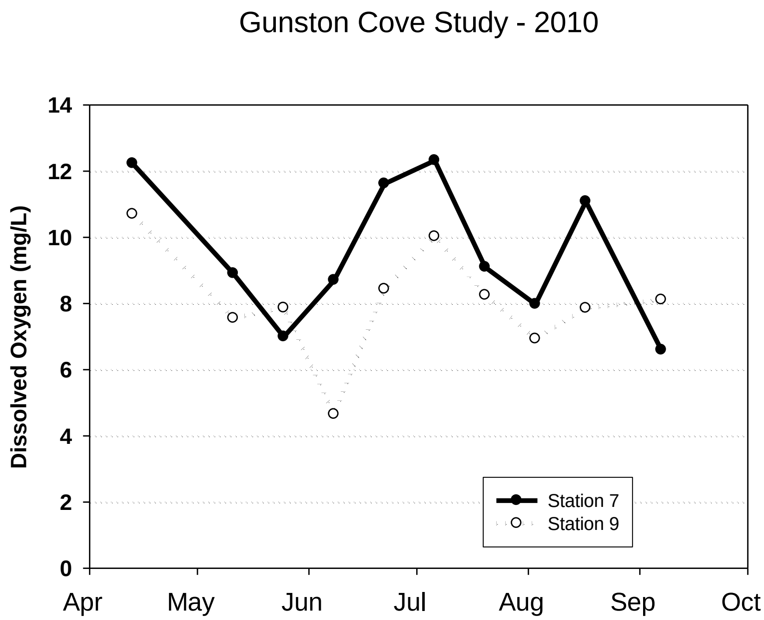
During most of 2010, specific conductance (Figure 6) exhibited similar patterns in the cove (Station 7) and the river (Station 9). Specific conductance remained in the 300-450 range through most of the year with a slight increase in September. Chloride exhibited a similar pattern (Figure 7), but showed a more marked increase in September mainly due to a later reading.

Gunston Cove Study - 2010



Chloride ion (Cl-) is a principal contributor to conductance. Major sources of chloride in the study area are sewage treatment plant discharges, road salt, and brackish water from the downriver portion of the tidal Potomac. Chloride concentrations observed in the Gunston Cove area are very low relative to those observed in brackish, estuarine, and coastal areas of the Mid-Atlantic region. Chloride often peaks markedly in late summer or fall when brackish water from down estuary may reach the cove as freshwater discharge declines.

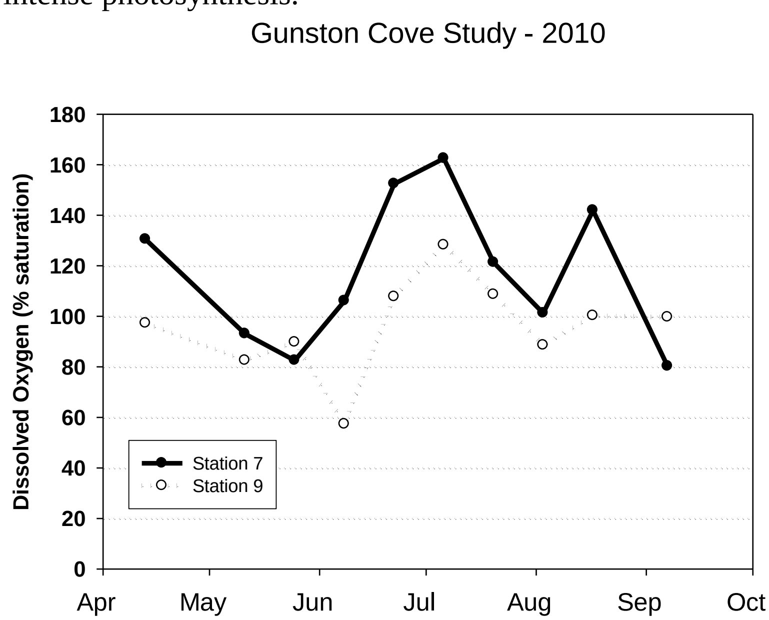
Figure 7. Chloride (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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

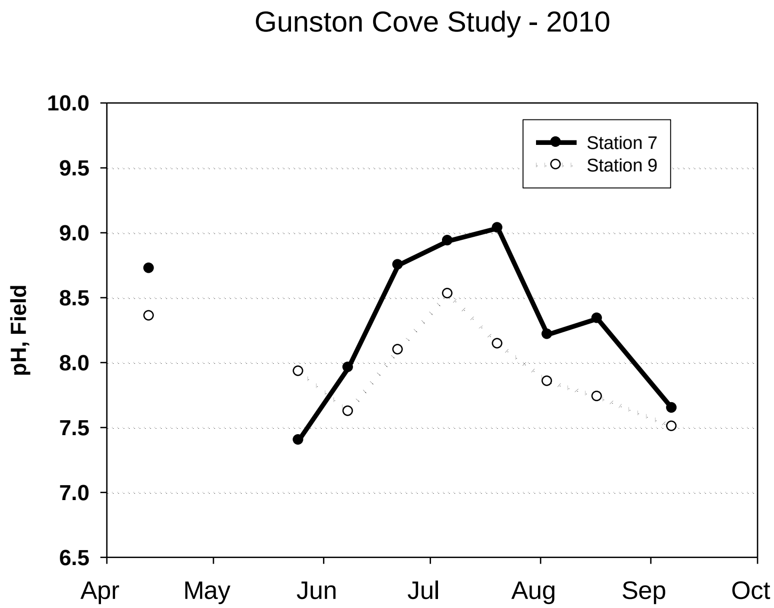
Figure 8. Dissolved Oxygen (mg/L). GMU Field Data. Month tick is at first day of month.

Dissolved oxygen was generally about 1-4 mg/L higher in the cove than in the river (Figure 8). Exceptions were in late May and September when river values were slightly higher. In the cove dissolved oxygen was generally above 100% indicating a general surplus of photosynthesis over respiration (Figure 9). Values above 140%, observed on two occasions in the cove in summer, are indicative of very active photosynthesis. In the river values were generally equal to or less than 100% indicating lower photosynthesis and an excess of respiration. An exception was in early July when DO exceeded 120% indicating moderate to intense photosynthesis.



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

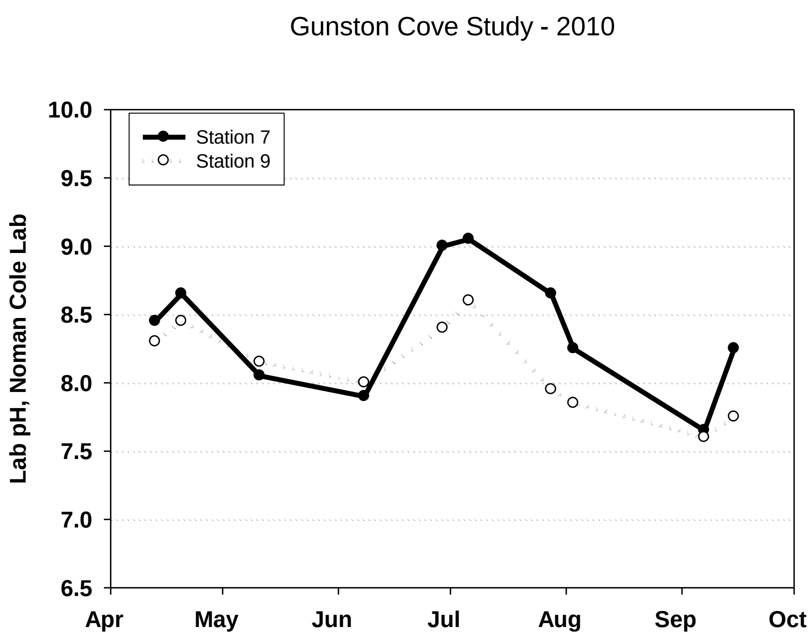
Figure 9. Dissolved Oxygen (% saturation). GMU Field Data. Month tick is at first day of month.



pH is a measure of the concentration of hydrogen ions (H+) in the water. Neutral pH in water is 7. Values between 6 and 8 are often called circumneutral, values below 6 are acidic and values above 8 are termed alkaline. Like DO, pH is affected by photosynthesis and respiration. In the tidal Potomac, pH above 8 indicates active photosynthesis and values above 9 indicate intense photosynthesis.

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

Field pH at the Gunston Cove station was consistently higher than the river station by about 0.5 pH unit (Figure 10). The exception was in late May following a major runoff event from the watershed. Values above 8.5 were typical in the cove during summer while values around 8.0 were found in the river channel. These differences are to be expected given the more intensive photosynthesis in the cove indicated by the dissolved oxygen data. Lab pH showed a similar difference between the two stations (Figure 11).



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.

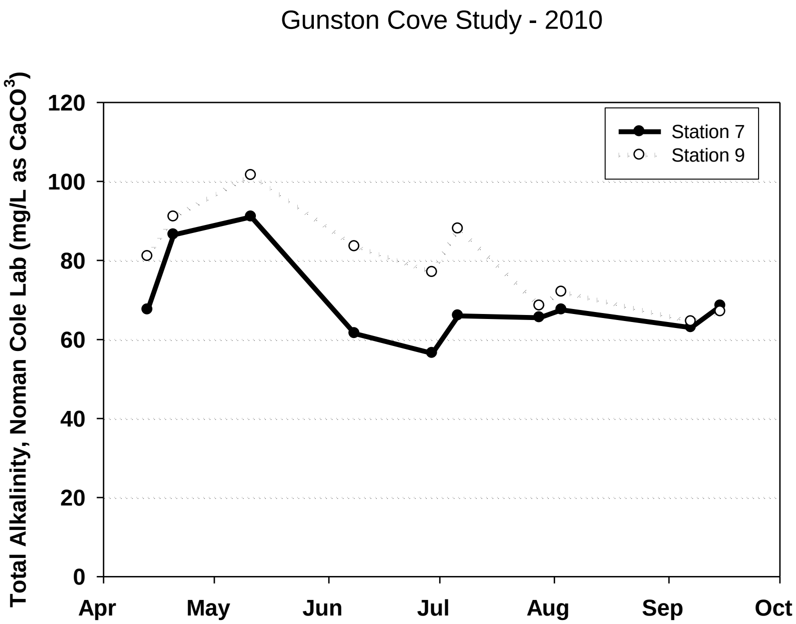
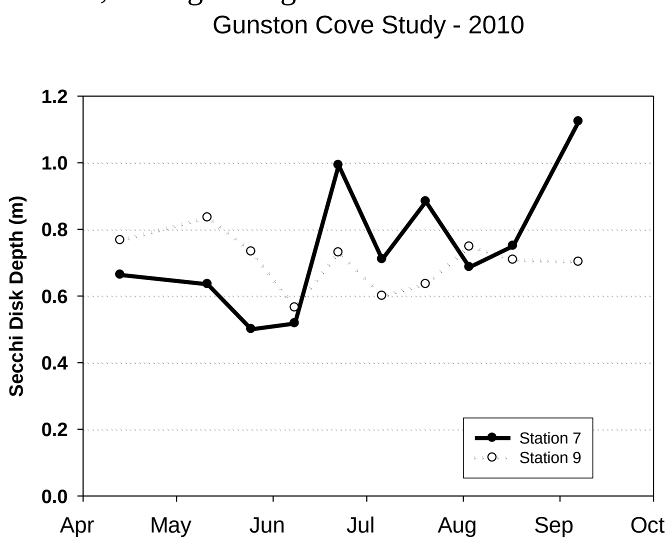


Figure 12. Total Alkalinity (mg/L as $CaCO_3$). Fairfax County Lab data. Month tick is at first day of month.

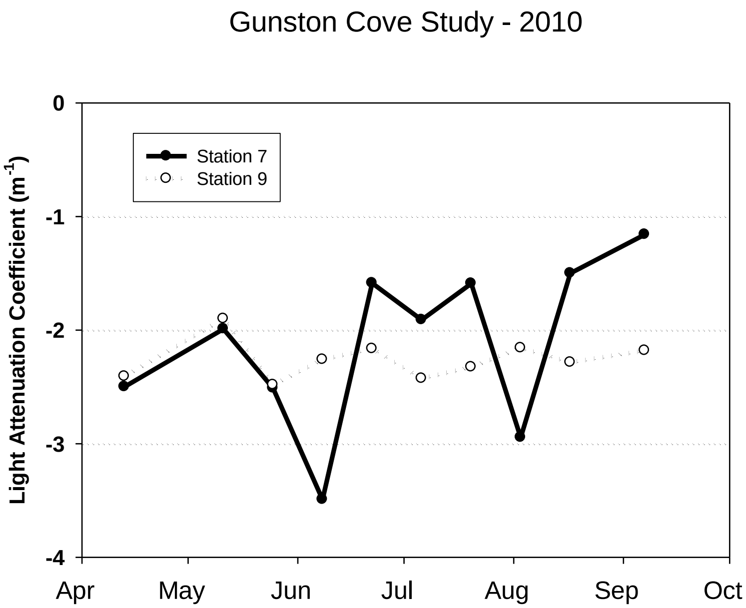
Total alkalinity was generally slightly higher in the river than in the cove (Figure 12). Values peaked in early May and then declined slowly for the rest of the year.

Water clarity as reflected by Secchi disk depth was higher in the river in spring, but in summer, cove water actually cleared so that cove Secchi actually was higher than Secchi in the river (Figure 13). Cove Secchi actually exceeded 1.0 m in September which is highly unusual, but a good sign.



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

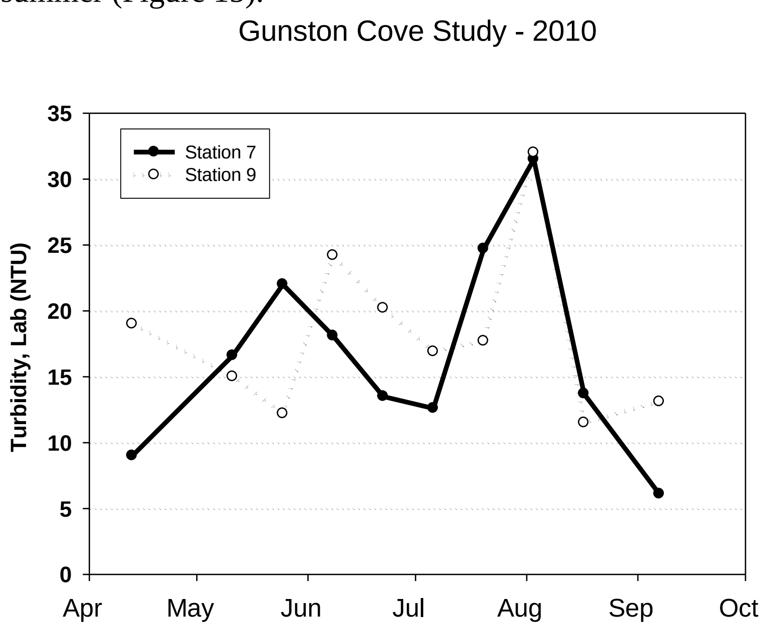
Figure 13. Secchi Disk Depth (m). GMU Field Data. Month tick is at first day of month.



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

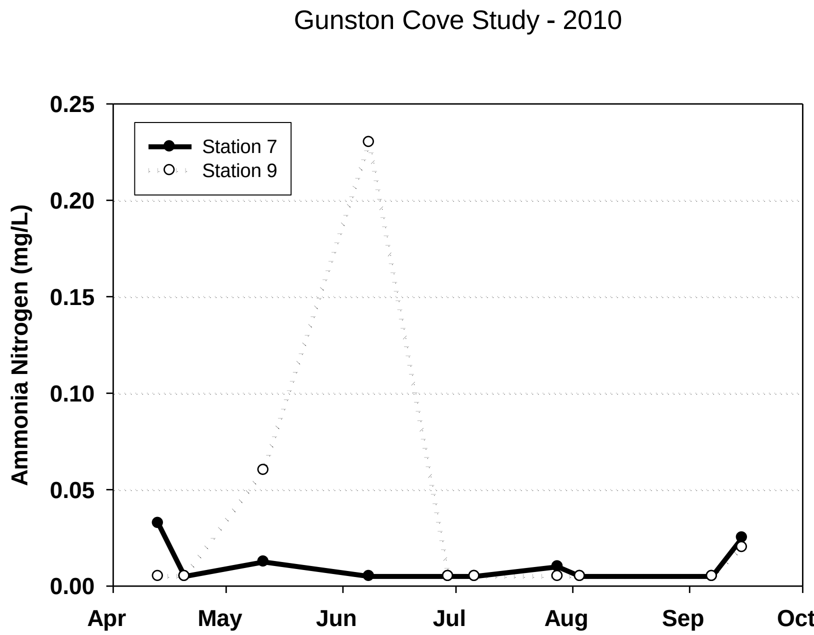
Figure 14. Light Attenuation Coefficient (m^{-1}). GMU Field Data. Month tick is at first day of month.

Light attenuation coefficient data generally fell in the range -1.0 to -2.5 m^{-1} (Figure 14). Temporal and spatial trends were similar to those for Secchi depth. In the cove light attenuation increased substantially (more negative coefficient) in early June and early August in the cove; these were dates of reduced Secchi depth as well. On these dates light attenuation was greater in the cove than in the river. For the rest of the year, Secchi depth in the cove was actually less than or equal to that in the river, which again matched the trend in Secchi depth. In the river light attenuation was much more constant remaining in the -2 to -2.5 m^{-1} range. Turbidity was highest in early August at both stations and lowest in spring and fall the summer (Figure 15).



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

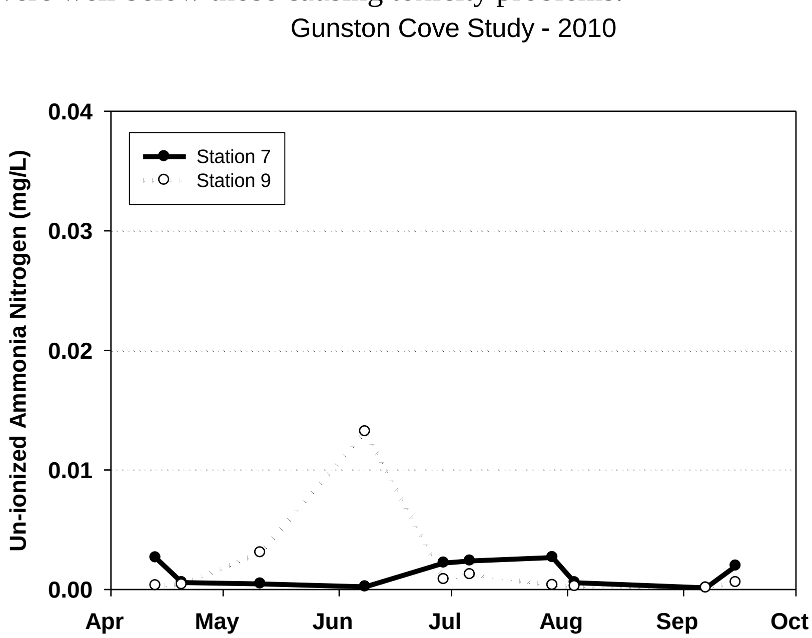
Figure 15. Turbidity (NTU). GMU Lab Data. Month tick is at first day of month.



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

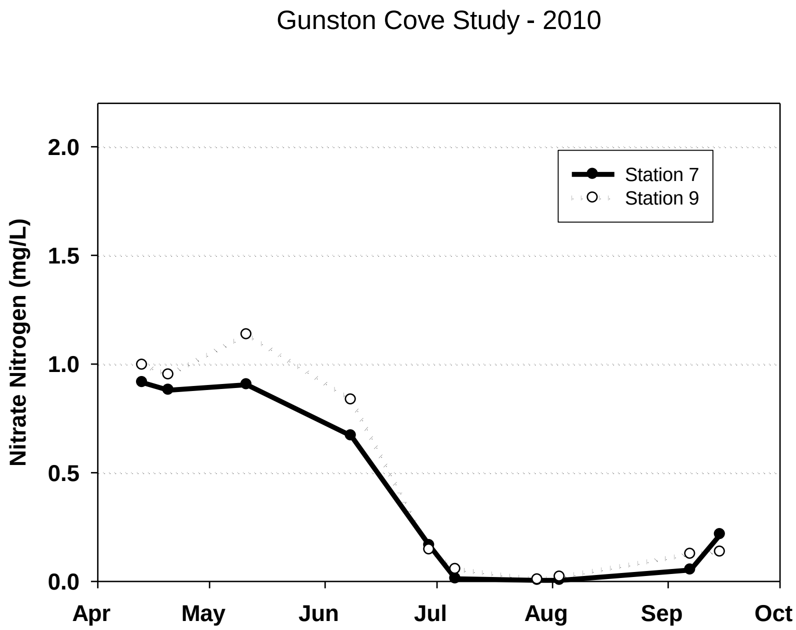
Figure 16. Ammonia Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.

Ammonia nitrogen was consistently very low in the cove for the entire study period (Figure 16). River values were generally also low, but were quite elevated in May and June. Un-ionized ammonia was very low at both stations through the entire year (Figure 17). Values were well below those causing toxicity problems.



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

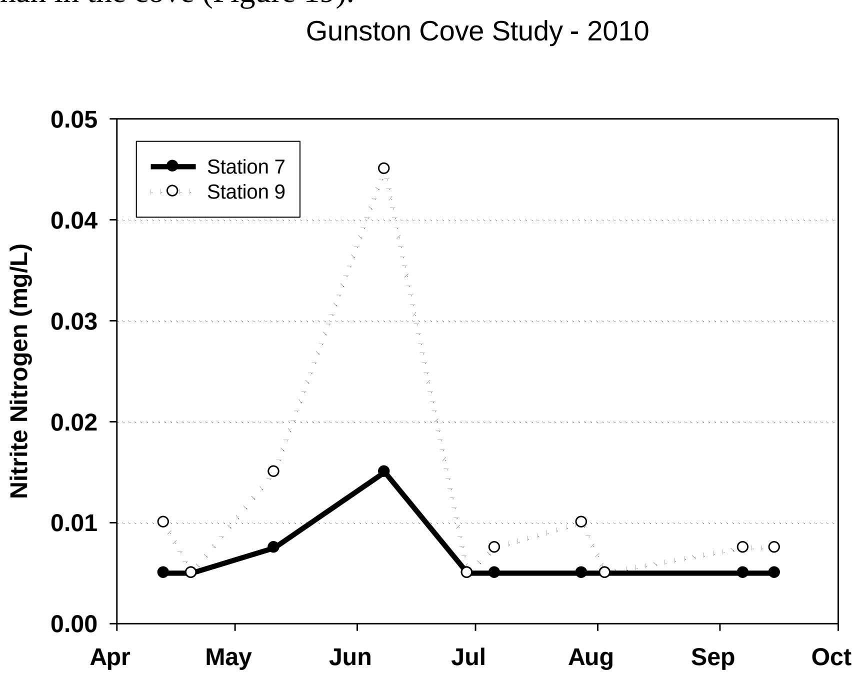
Figure 17. Un-ionized Ammonia Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



Nitrate Nitrogen refers to the amount of N that is in the form of nitrate ion (NO_3^-). Nitrate ion is the most common form of nitrogen in most well oxidized freshwater systems. Nitrate concentrations are increased by input of wastewater, nonpoint sources, and oxidation of ammonia in the water. Nitrate concentrations decrease when algae and plants are actively growing and removing nitrogen as part of their growth.

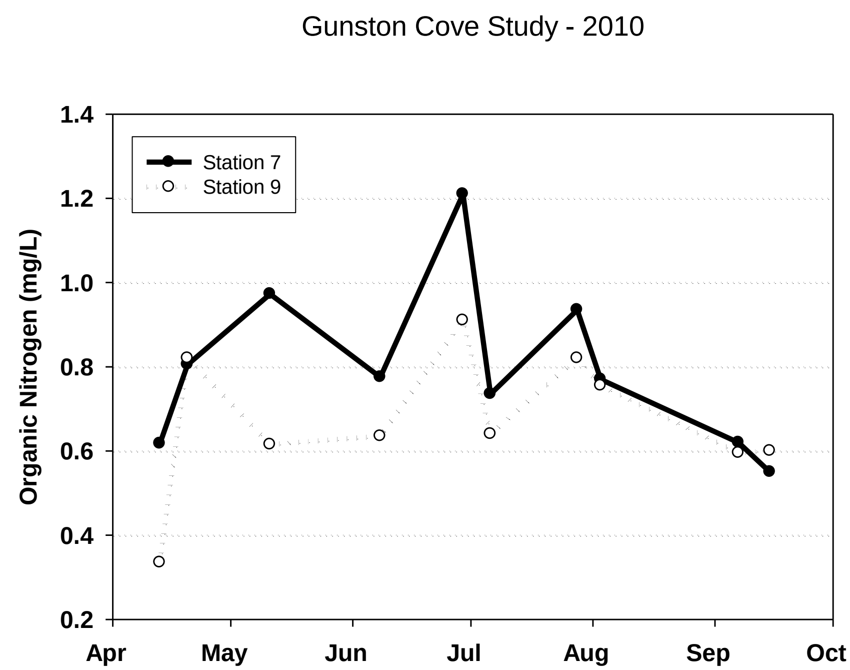
Figure 18. Nitrate Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.

Nitrate nitrogen levels were closely matched in cove and river throughout the year (Figure 18). Nitrate levels were elevated from April to early June and exhibited a strong decline during late June to very low values which were maintained through the rest of the year Nitrite nitrogen remained very low throughout the year, was consistently higher in the river than in the cove (Figure 19).



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

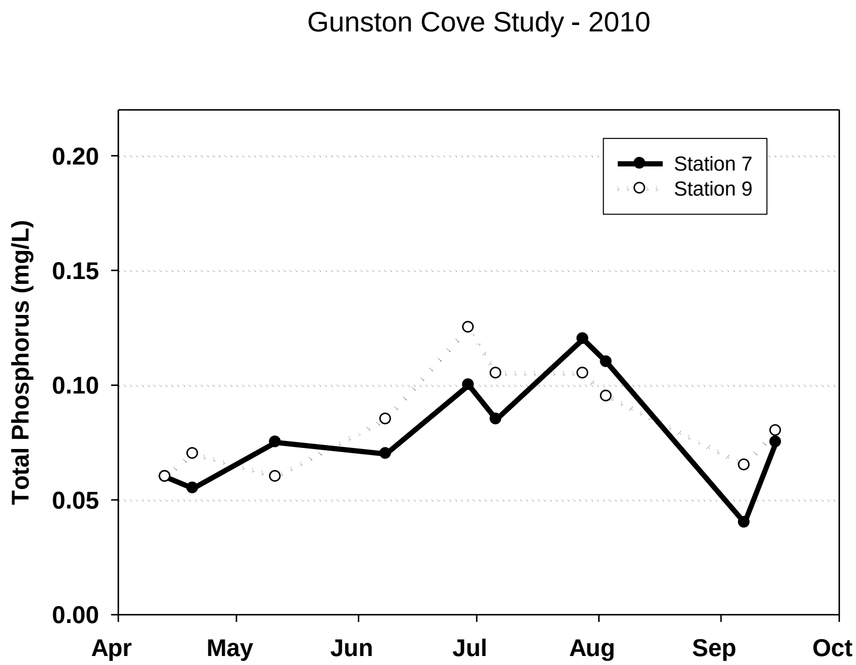
Figure 19. Nitrite Nitrogen (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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

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

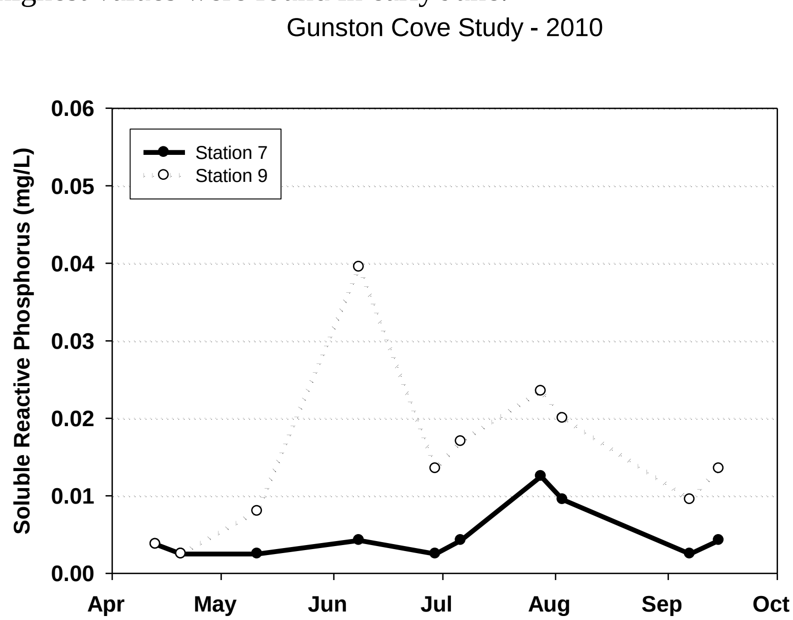
Organic nitrogen was generally higher in the cove than in the river with maximum of 1.2 mg/L in late June (Figure 20). In the river values peak value was about 0.9 mg/L.



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.

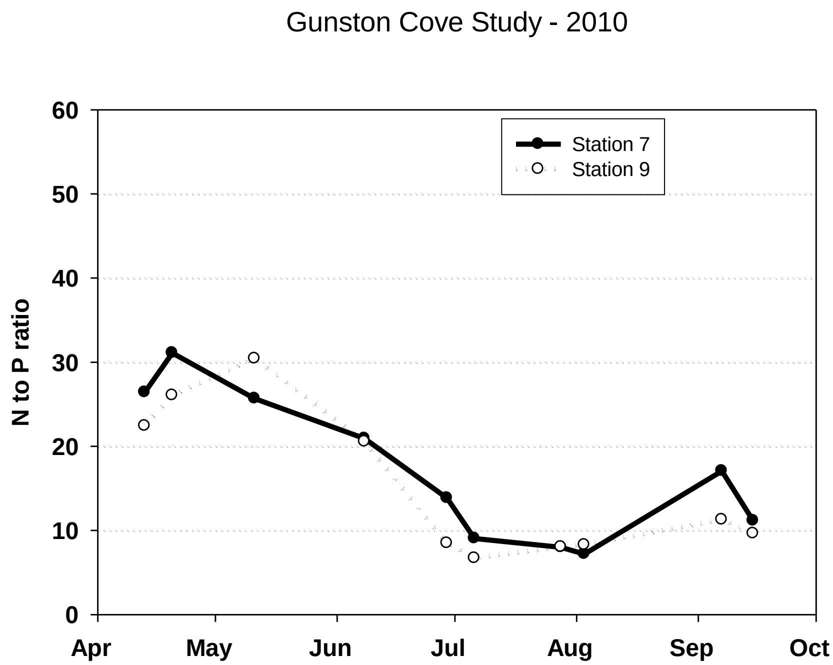
Figure 21. Total Phosphorus (mg/L). Fairfax County Lab Data. Month tick is at first day of month.

Total phosphorus exhibited a clear seasonal increase at both stations, reaching a peak in late June in the cove and late July in the river (Figure 21). Soluble reactive phosphorus was consistently higher in the river than in the cove (Figure 22). In the cove values were in the range 0.002-0.012 mg/L, while in the river values were generally 0.010-0.040. In the river highest values were found in early June.



Soluble reactive phosphorus (SRP) is a measure of phosphate ion (PO_4^{-3}). Phosphate ion is the form in which P is most available to primary producers such as algae and aquatic plants in freshwater. However, SRP is often inversely related to the activity of primary producers because they tend to take it up so rapidly. So, higher levels of SRP indicate either a local source of SRP to the waterbody or limitation by a factor other than P.

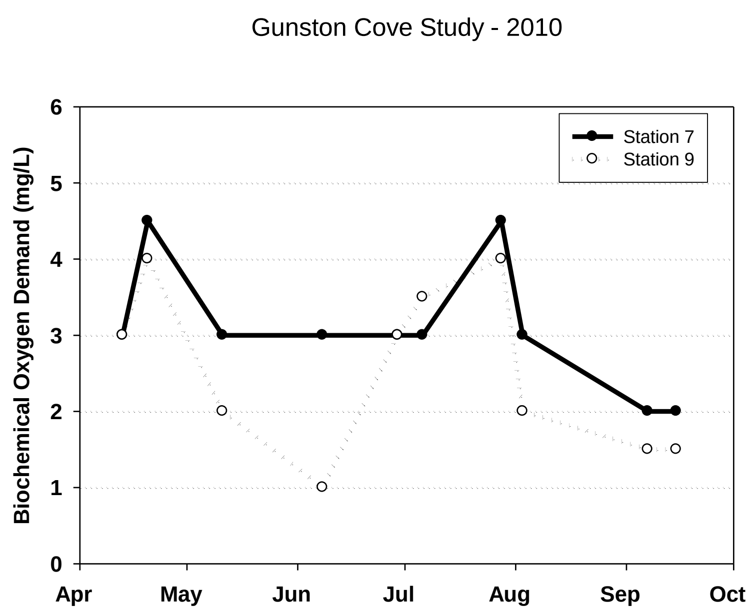
Figure 22. Soluble Reactive Phosphorus (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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

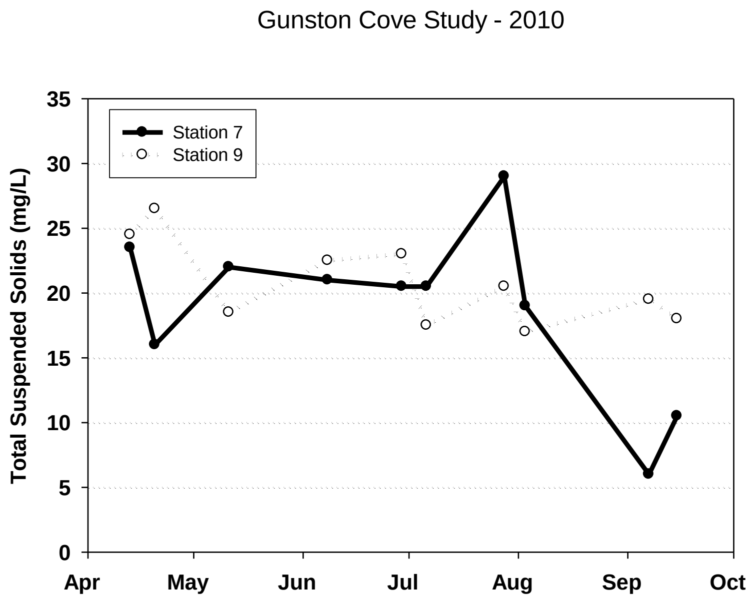
Figure 23. N/P Ratio (by mass). Fairfax County Lab Data. Month tick is at first day of month.

N/P ratio exhibited a clear seasonal pattern that was similar at both sites (Figure 23). High readings in April and early May declined steadily through early July to below 10 and remained low through July and August. During this period readings hovered around or just above 7.2 the point at which algae shift from P to N limitation. Biochemical oxygen demand (BOD) was consistently higher in the cove than in the river (Figure 24). In the cove values were generally 3-5 mg/L whereas most river values were generally lower.



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

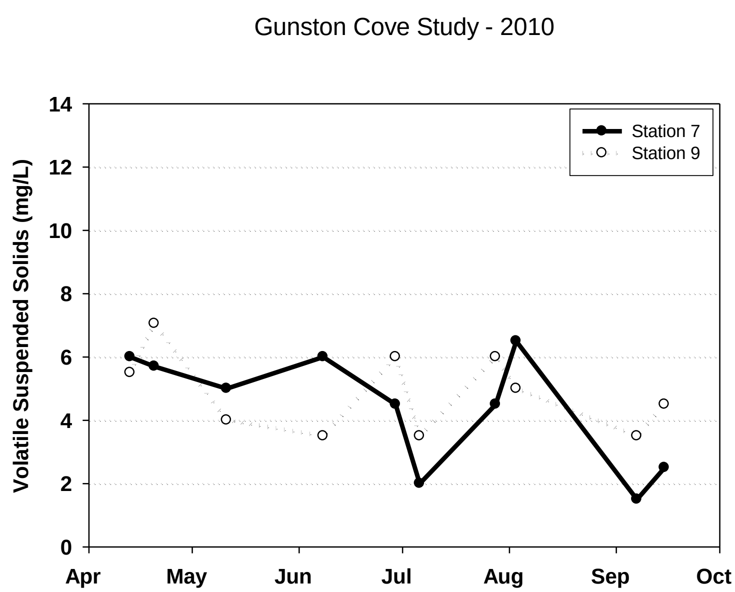
Figure 24. Biochemical Oxygen Demand (mg/L). Fairfax County Lab Data. Month tick is at first day of month.



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

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

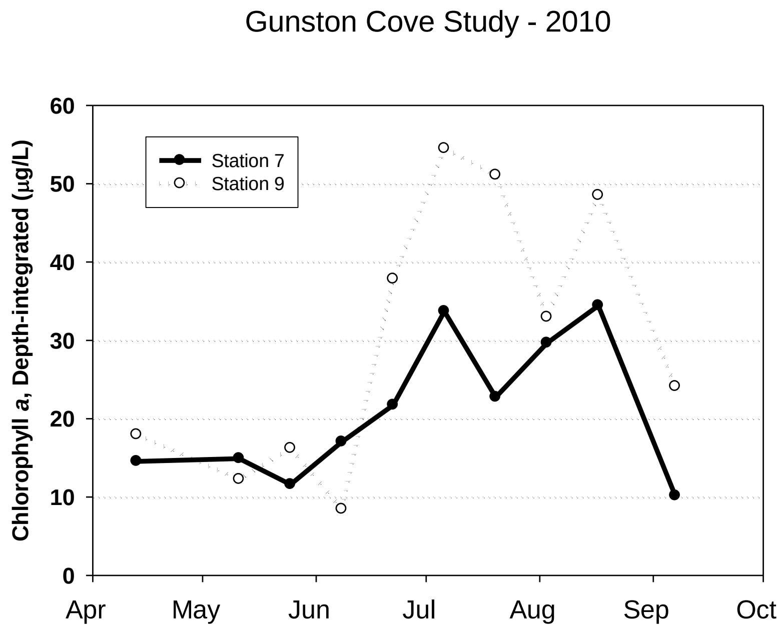
Total suspended solids was generally in the range 15-25 mg/L at both stations (Figure 25). TSS was elevated in late July in the cove, but decreased and dropped to very low levels in early September. In the river values were a bit more consistent. Volatile suspended solids were similar at both stations and showed a tendency to decline somewhat over the study period (Figure 26).



Volatile suspended solids (VSS) is determined by taking the filters used for TSS and then ashing them to combust (volatilize) the organic matter. The organic component is then determined by difference. VSS is a measure of organic solids in a water sample. These organic solids could be bacteria, algae, or detritus. Origins include sewage effluent, algae growth in the water column, or detritus produced within the waterbody or from tributaries. In summer in Gunston Cove a chief source is algal (phytoplankton) growth.

Figure 26. Volatile Suspended Solids (mg/L). Fairfax County Lab Data. Month tick is at first day of month.

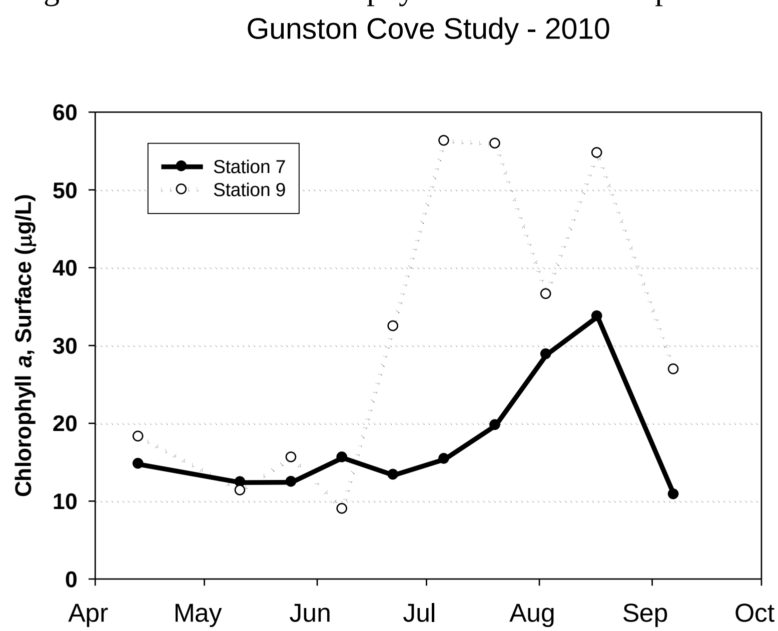
C. Phytoplankton -2010



Chlorophyll *a* is a measure of the amount of algae growing in the water column. These suspended algae are called phytoplankton, meaning “plant wanderers”. In addition to the true algae (greens, diatoms, cryptophytes, etc.) the term phytoplankton includes cyanobacteria (sometimes known as “blue-green” algae). Both depth-integrated and surface chlorophyll values are measured due to the capacity of phytoplankton to aggregate near the surface under certain conditions.

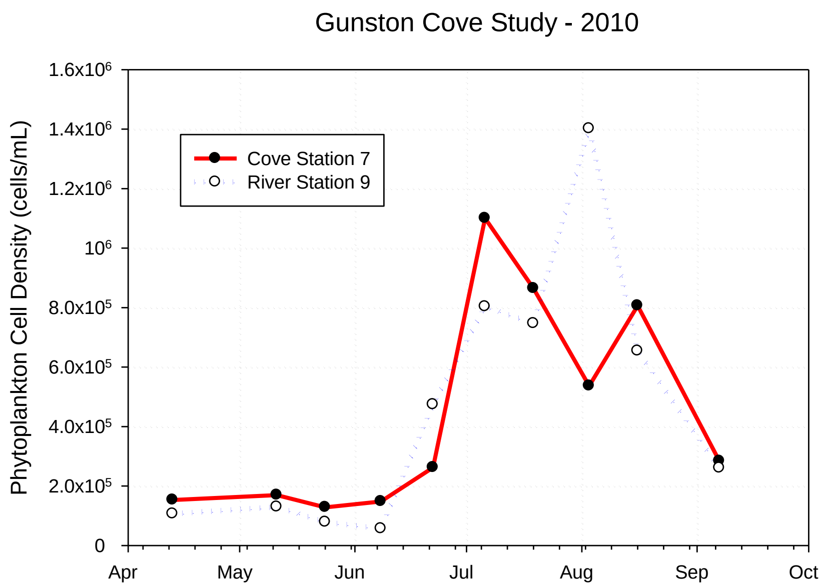
Figure 27. Chlorophyll *a* (ug/L). Depth-integrated. GMU Lab Data. Month tick is at the first day of month.

Chlorophyll *a* exhibited a clear seasonal pattern at both sites with values increasing in June and remaining elevated through August (Figure 27). In the cove values increased from about 15 ug/L in the spring to about 30 ug/L for the summer months. In the river, chlorophyll *a* levels exhibited an even stronger increase with most summer values near 50 ug/L. Depth-integrated and surface chlorophyll showed similar spatial and temporal patterns (Figure 28).



In the Gunston Cove, there is very little difference in surface and depth-integrated chlorophyll levels because tidal action keeps the water well-mixed which overcomes any potential surface aggregation by the phytoplankton. Summer chlorophyll concentrations above 30 ug/L are generally considered characteristic or eutrophic conditions.

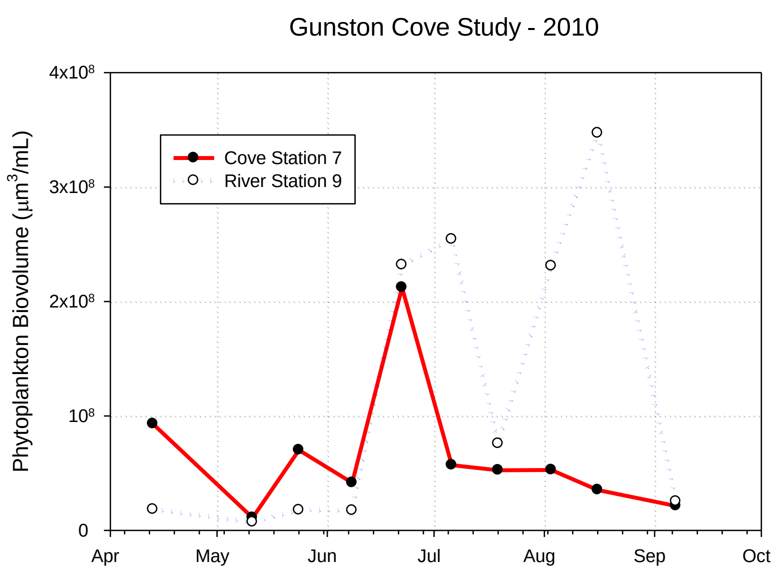
Figure 28. Chlorophyll *a* (ug/L). Surface. GMU Lab Data. Month tick is at first day of month.



Phytoplankton cell density provides a measure of the number of algal cells per unit volume. This is a rough measure of the abundance of phytoplankton, but does not discriminate between large and small cells. Therefore, a large number of small cells may actually represent less biomass (weight of living tissue) than a smaller number of large cells. However, small cells are typically more active than larger ones so cell density is probably a better indicator of activity than of biomass. The smaller cells are mostly cyanobacteria.

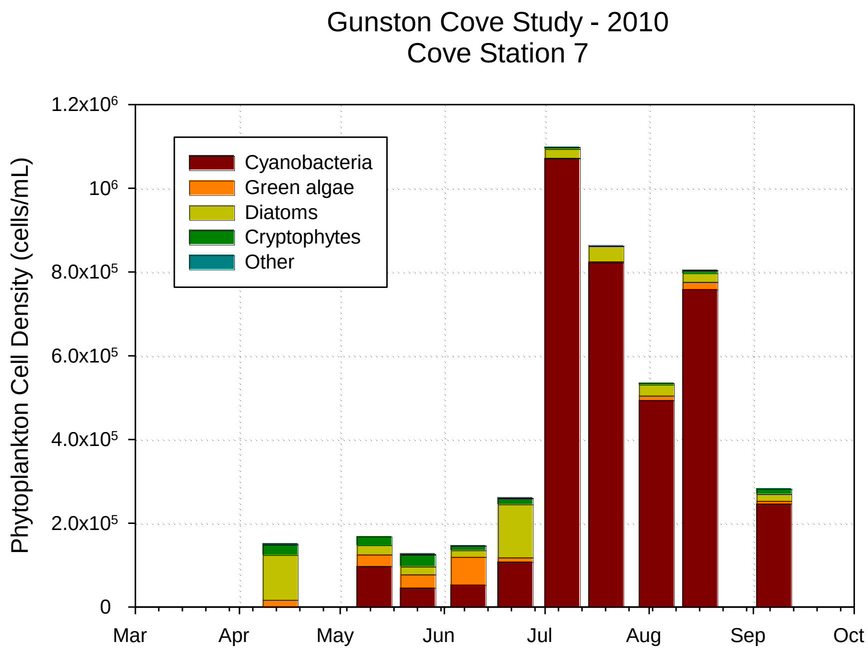
Figure 29. Phytoplankton Density (cells/mL).

Phytoplankton density was generally low from April through early June in both cove and river (Figure 29). At both stations density increased strongly in early June to higher summer values. In the cove, values peaked in early July at about 1.1 x 10^6 cells/mL. Values stayed above 0.5 x 106 through August, but dropped markedly in September. In the river densities increased a little more slowly, but reached a higher peak of about 1.4 x 10^6 cells/mL in early August before declining for the remainder of the year. Total biovolume showed a somewhat similar seasonal pattern in the cove (Figure 30). Cove biovolume increased in through the spring reaching about a peak of 2 x 10^8 um^3/mL in late June. In the river a similar maximum was found in late June and early July, but a second maximum of 3.5 x 10^8 um^3/mL was attained in mid August.



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.

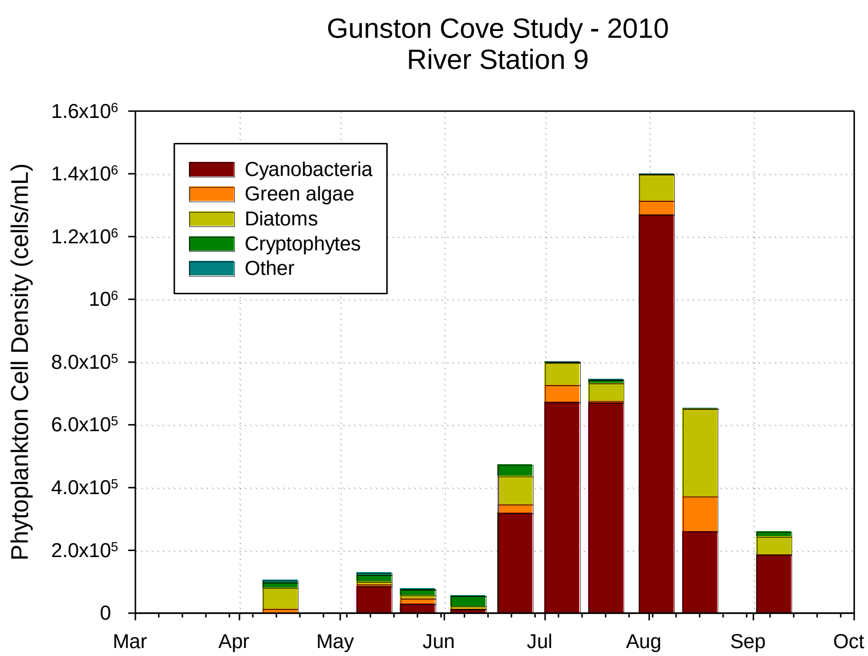
Figure 30. Phytoplankton Biovolume (um^3/mL).



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.

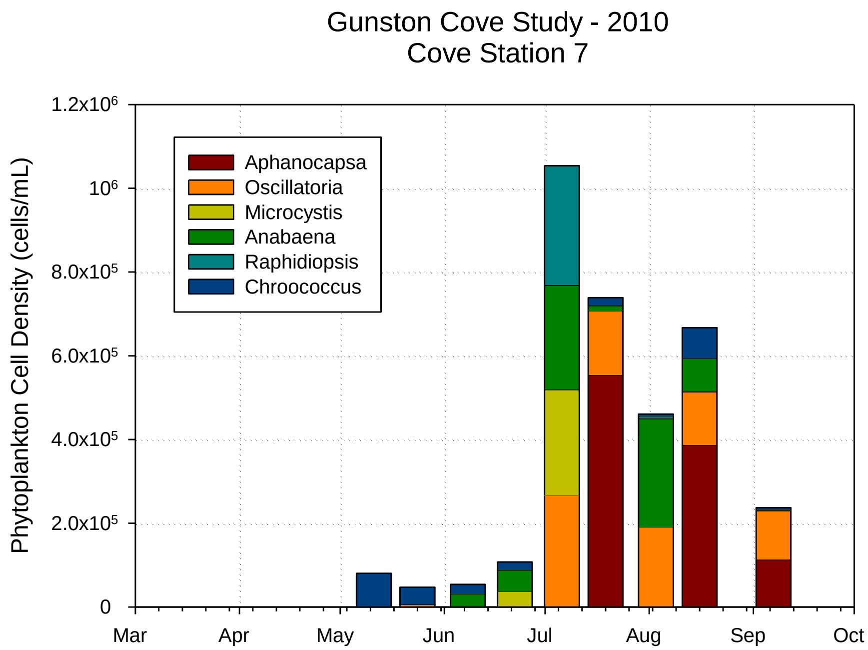
Figure 31. Phytoplankton Density by Major Group (cells/mL). Gunston Cove.

Phytoplankton density in the cove fairly evenly divided among the major groups in spring and early summer, but in July and August was overwhelmingly dominated by cyanobacteria (Figure 31). During this period diatoms were a distant second. In the river cyanobacterial dominance began in late June (Figure 32). Diatoms were somewhat more abundant than in the cove.



In the river cyanobacteria normally follow similar patterns as in the cove, but attaining lower abundances. This is probably due to the deeper water column which leads to lower effective light levels and greater mixing. Other groups such as diatoms and green algae tend to be more important on a relative basis than in the cove.

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



The dominant cyanobacteria on a numerical basis were:

Aphanocapsa -- small sphere

Oscillatoria – a filament with cylindrical cells

Microcystis – an irregular colony of spherical cells

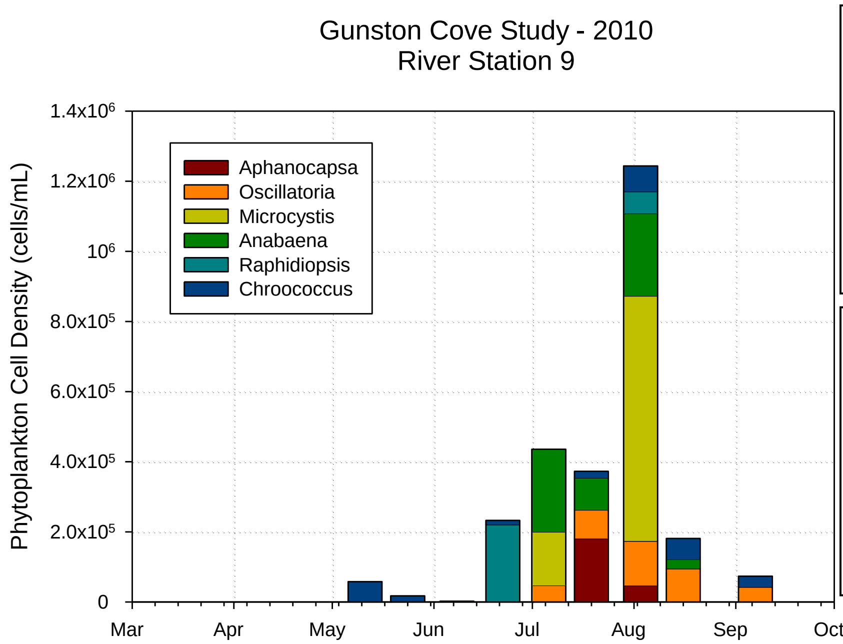
Anabaena – a filament with bead-like cells & heterocysts

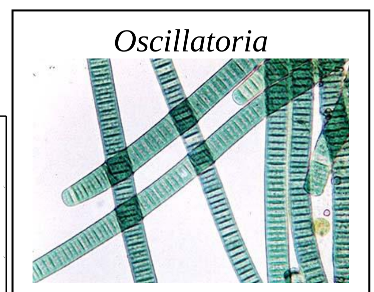
Raphidiopsis -- a filament with cylindrical cells

Chroococcus – individual spherical cells

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

In the cove the low spring levels were dominated early by *Chroococcus* and later by *Anabaena* and *Microcystis* (Figure 33). The greatly increased summer levels were dominated intitially by these same taxa as well as *Oscillatoria* and *Raphidiopsis*. In late July *Aphanocapsa* became most important. Early August returned to *Oscillatoria* and *Anabaena* dominance. In the river the dominants were similar, but Aphanocapsa was much reduced and Microcystis was greatly increased especially in early August (Figure 34).





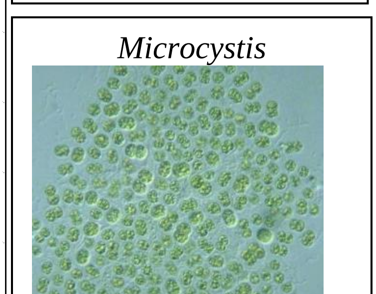
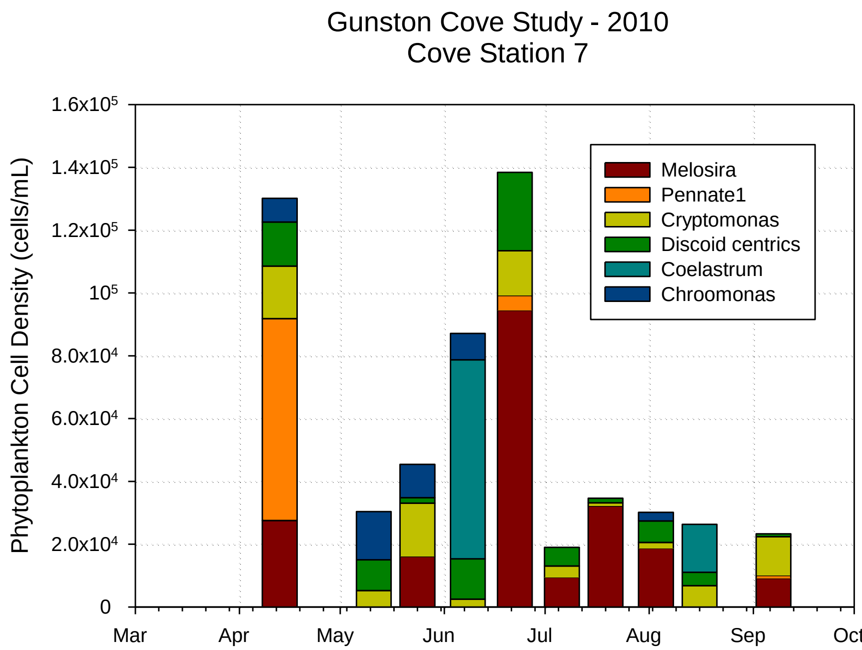


Figure 34. Phytoplankton Density by Dominant Cyanobacteria (cells/mL). River.

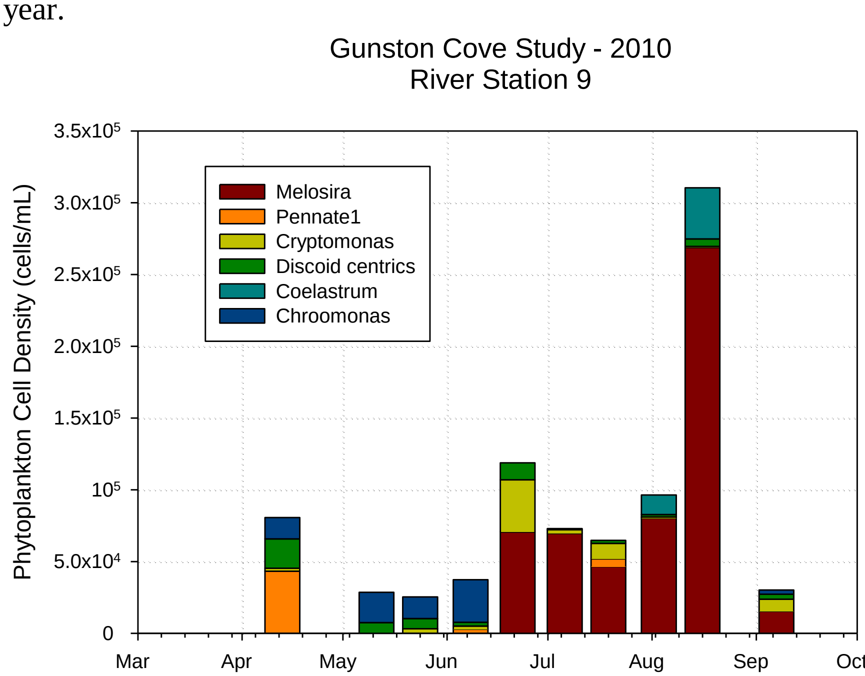


The most numerous non-cyanobacterial phyto-plankton were:

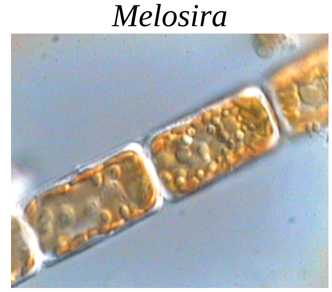
- *Melosira* – a filamentous centric diatom
- Pennate1 – an unidentified pinnate diatom
- *Cryptomonas* – an ellip-soidal, flagellated unicell
- *Discoid centrics* – a group of similar unicellular disk-shaped diatoms
- *Coelastrum* – a green algale colony
- *Chroomonas* – a flagellated cryptomonad unicell

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

In the cove two flagellates, diatoms (Melosira, Pennate 1, and discoid centrics) were generally the most numerous of the eukaryotic algae (Figure 35). *Cryptomonas* was present in most samples and *Coelastrum* was especially common in early June. In the river dominance in spring was distributed among Pennate 1, Chroomonas, and discoid centrics (Figure 36). In late June *Melosira* appeared on the scene and was strongly dominant for the remainder of the year.

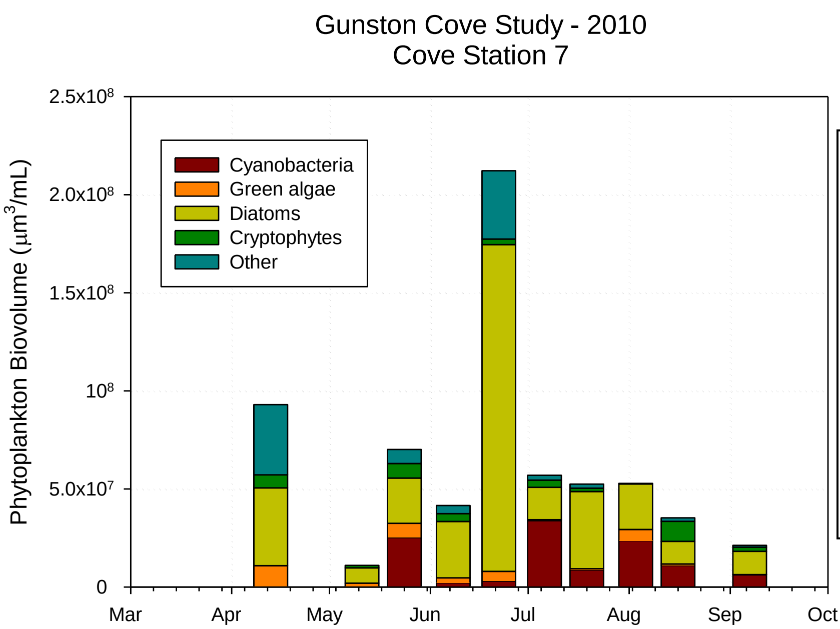


Melosira



Cryptomonas

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

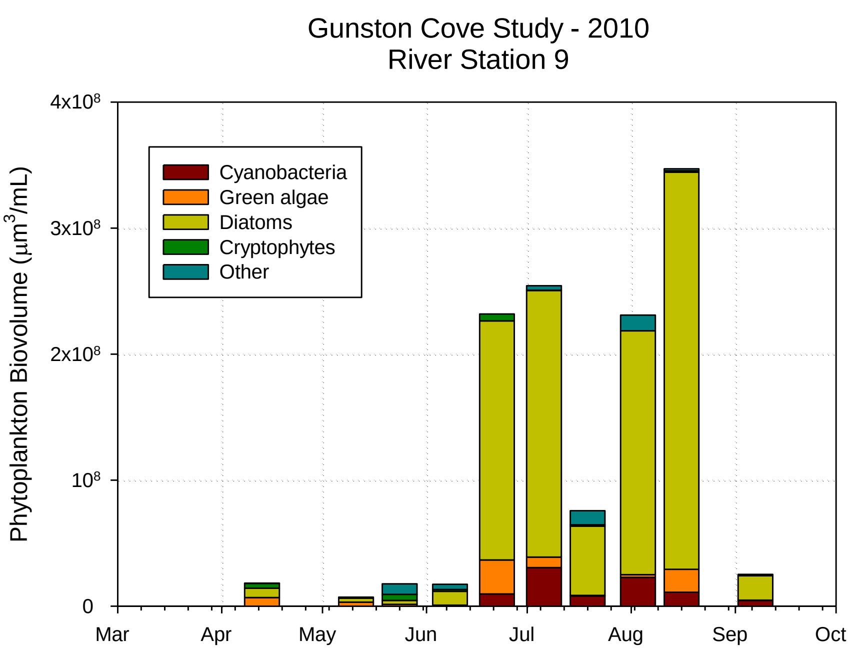


Total phytoplankton biovolume can be broken down into groups:

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

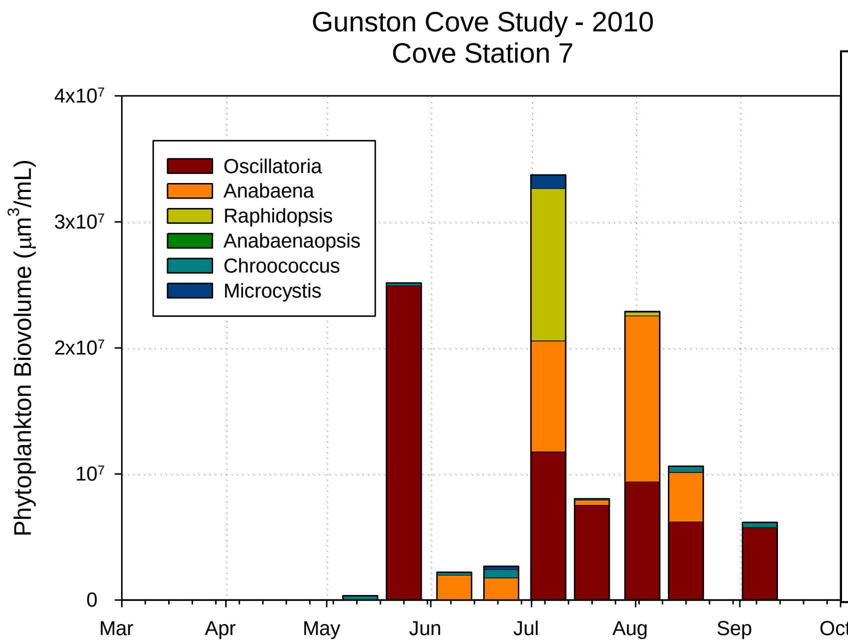
Figure 37. Phytoplankton Biovolume (um^3/mL) by Major Groups. Gunston Cove.

In the cove diatoms were dominant in biovolume in almost all samples (Figure 37). Cryptophytes maintained a presence on almost all dates. Cyanobacteria were substantial to biovolume only in early July and early August. Other algae were important in April and late June. In the river, diatoms were again the overwhelming dominants during the summer (Figure 38). Cyanobacteria had a presence in the summer; other groups were very minor.



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.

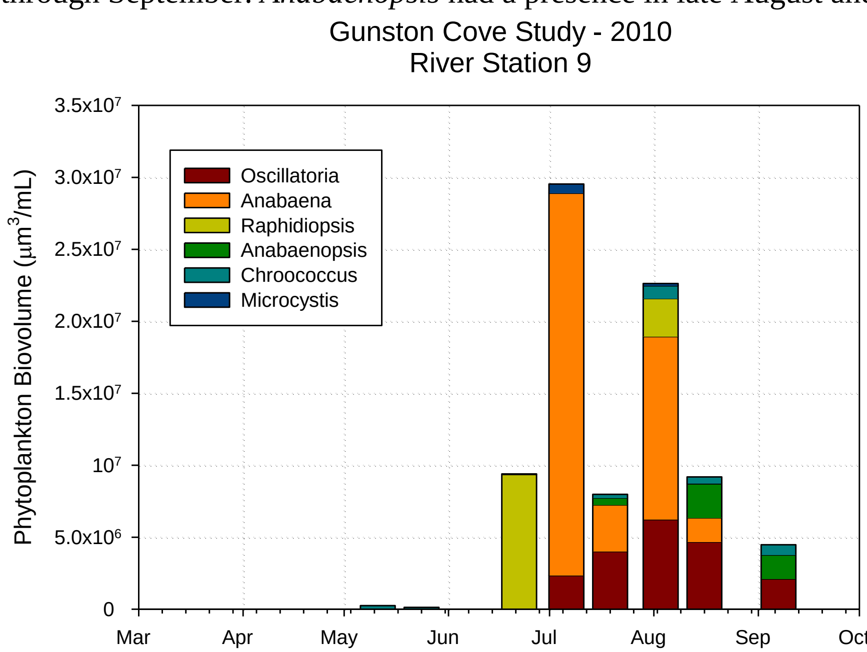


Cyanobacteria are generally most common in late summer and that is when they normally make the largest contribution to phytoplankton biovolume. Important taxa for biovolume which were not on the top list for cell density are:

- *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 most of the year (Figure 39). *Anabaena* was also important in summer and *Raphidiopsis* was codominant in early July. In the river cyanobacterial biovolume was very low through early June (Figure 40). In late June *Raphidiopsis* showed a clear presence and then *Anabaena* took over in July and August. *Oscillatoria* was also important from July through September. *Anabaenopsis* had a presence in late August and September.



Anabaena

Chroococcus

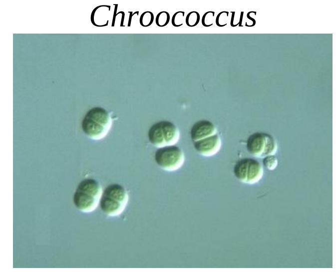
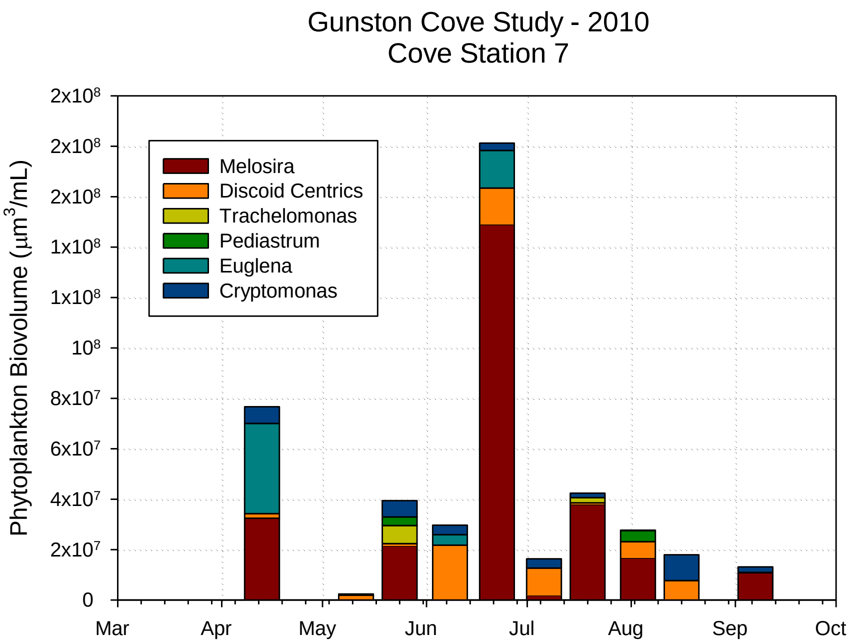


Figure 40. Phytoplankton Biovolume (um^3/mL) by Cyanobacterial Taxa. River.



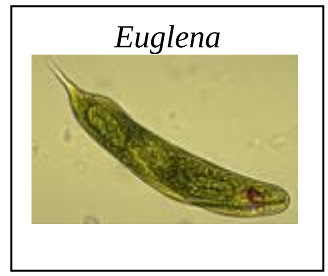
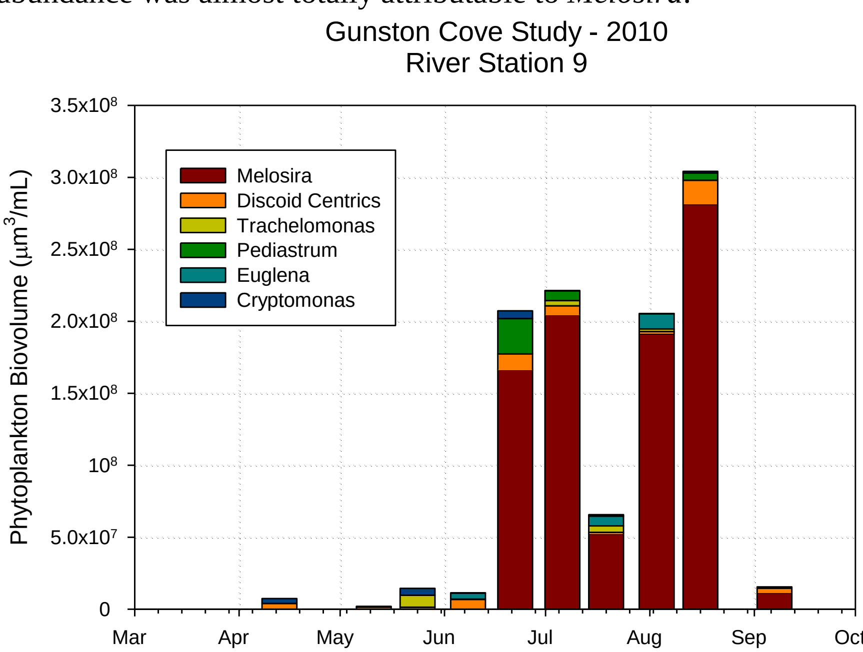


Figure 41. Phytoplankton Biovolume (um^3/mL) by Dominant Noncyanobacterial Taxa. Gunston Cove.

Melosira and discoid centrics were the most important components of noncyanobacterial biovolume in the cove for most of the year (Figure 41). *Melosira* was chiefly responsible for the major peak in late June. In April and late June Euglena made substantial contributions. In the river biovolume was low through mid June (Figure 42). The summer period of high abundance was almost totally attributable to *Melosira*.



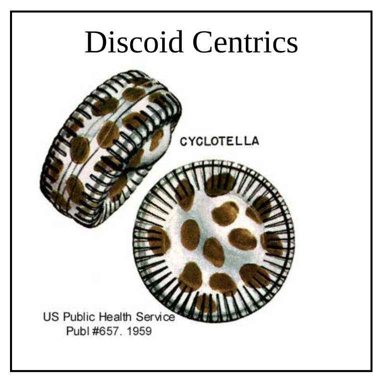


Figure 42. Phytoplankton Biovolume (um^3/mL) by Dominant Taxon. River.

D. Zooplankton – 2010

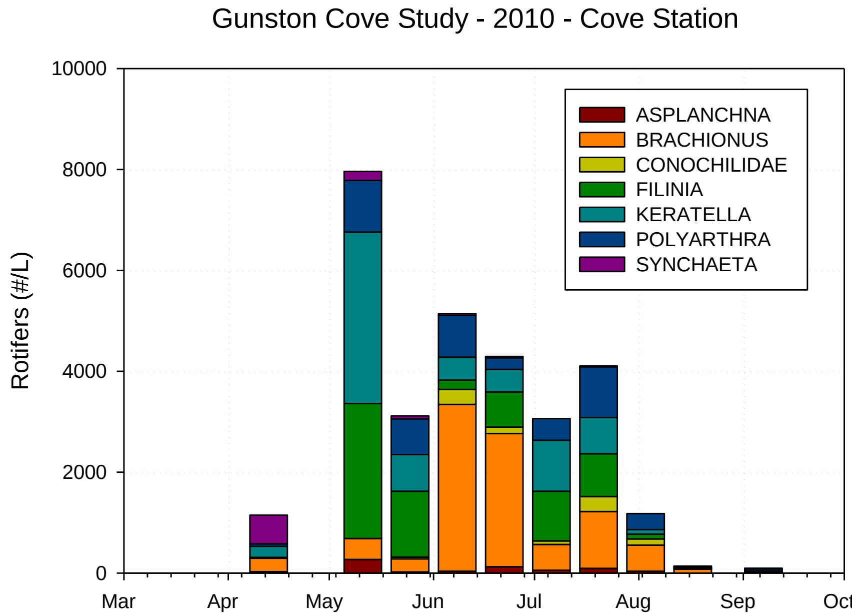
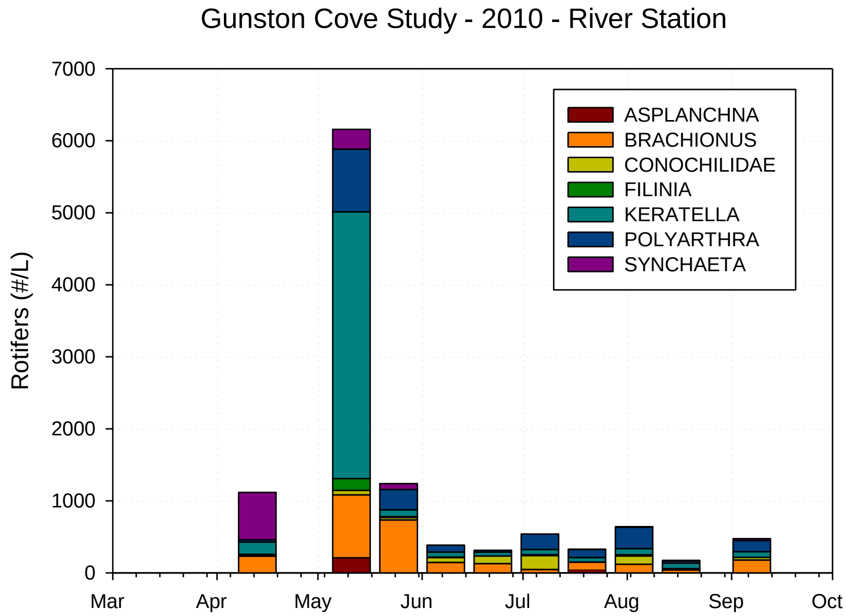
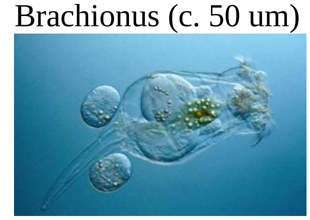


Figure 43. Rotifer Density by Dominant Taxa (#/L). Cove.

In the cove, rotifers increased in spring to an early May peak of about 8000/L. Densities declined somewhat by late May, but remained above 3000/L through July (Figure 43). *Brachionus* and *Filinia* were most important during most of the year, but Keratella was very abundant in early May. In the river rotifers were generally less abundant with the exception of a large peak in early May of over 6000/L led by *Keratella* (Figure 44). Values above 1000/L were observed in April and late May, but otherwise levels were generally below 500/L.



Brachionus (c. 50 um)



Conochilidae

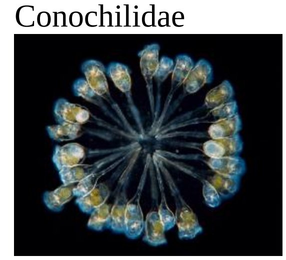
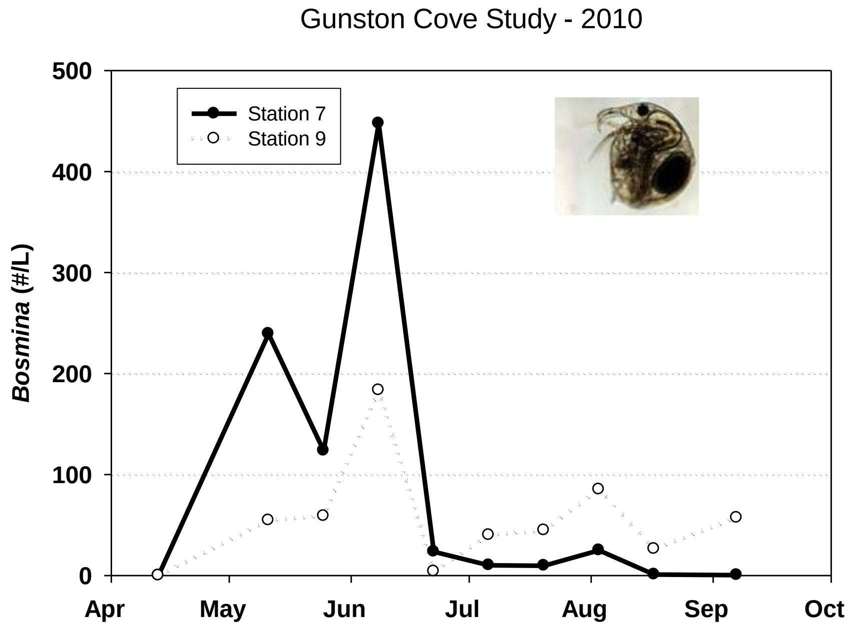


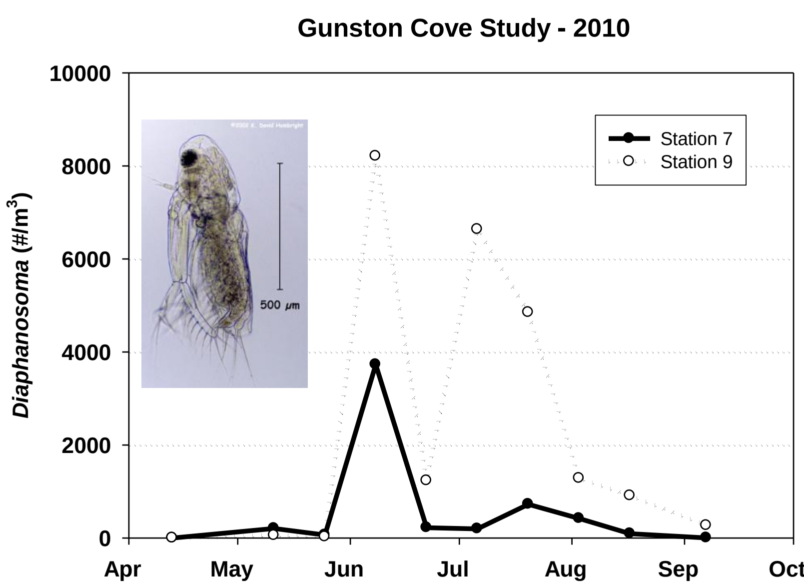
Figure 44. Rotifer Density by Dominant Taxa (#/L). River.



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

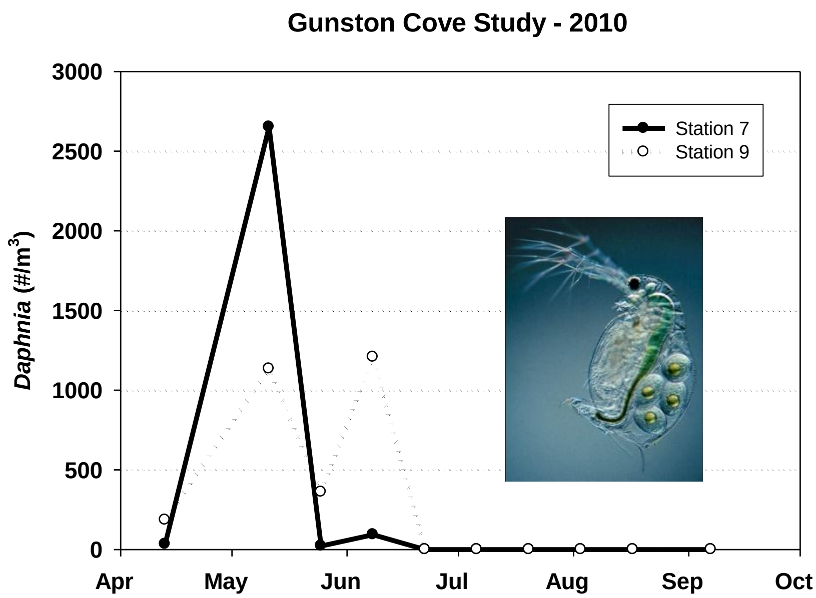
Figure 45. *Bosmina* Density by Station (#/L).

In 2010 the small cladoceran *Bosmina* increased during May and June to a peak of about 450/L in early June (Figure 45). Its levels then declined to less than 20/L for the remainder of the year. In the river *Bosmina* exhibited a similar spring increase reaching a maximum of nearly 20/L in early June. *Diaphanosoma*, typically the most abundant larger cladoceran in Gunston Cove, exhibited one peaks at both sites and a second peak in the river (Figure 46). The early June peak exceeded 8,000/m^3 in the river and was about half of that in the cove. The second river peak was slightly lower attaining 7000/m^3.



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

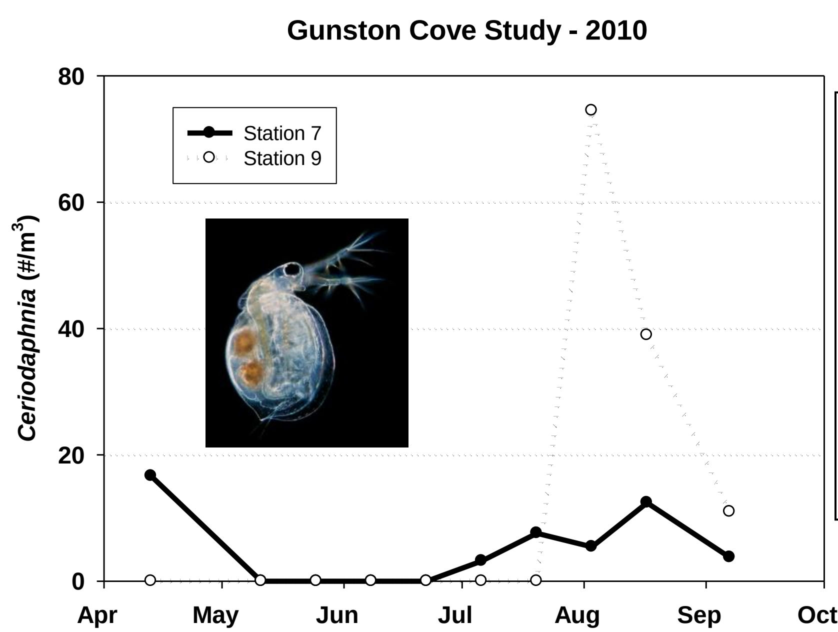
Figure 46. *Diaphanosoma* Density by Station (#/m^3)



Daphnia, the common waterflea, is one of the most efficient grazers of phytoplankton in freshwater ecosystems. In the tidal Potomac River it is present, but not as common as *Diaphanosoma*. It is typically most common in spring.

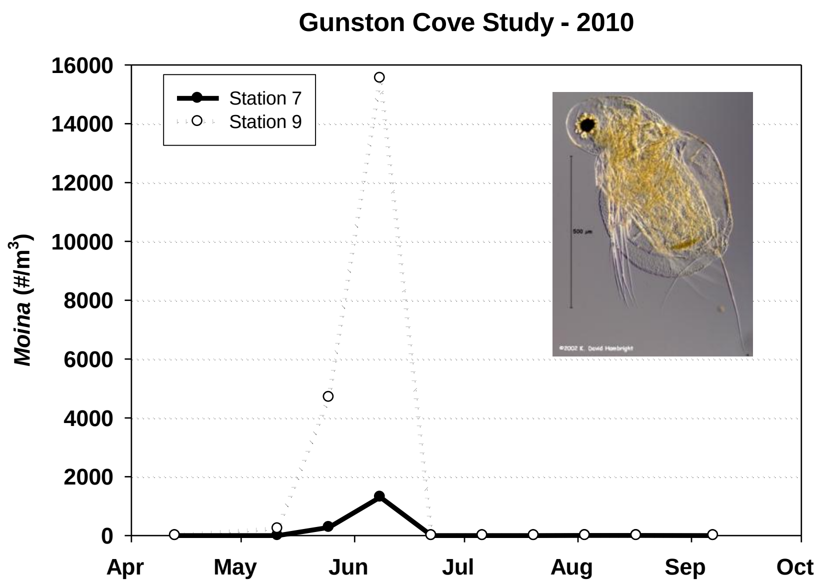
Figure 47. *Daphnia* Density by Station (#/m^3).

Daphnia was common mainly in May and June being most abundant in the cove where it reached 2700/m^3 in early May (Figure 47). In the river two smaller peaks of about 1200/m^3 were observed in early May and early June. *Ceriodaphnia* was present sporadically at low densities in both river and cove reaching a maximum of about 75/m^3 in the river in early August (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.

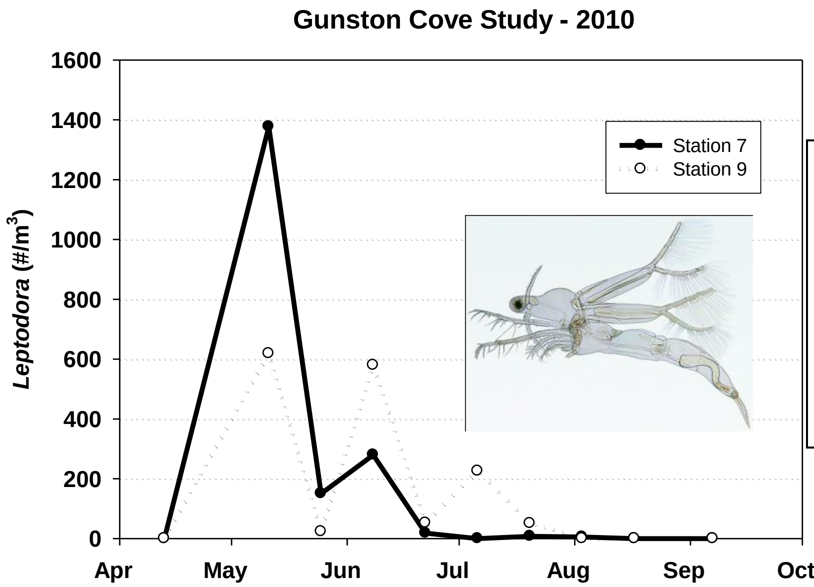
Figure 48. *Ceriodaphnia* Density by Station (#/m^3).



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.

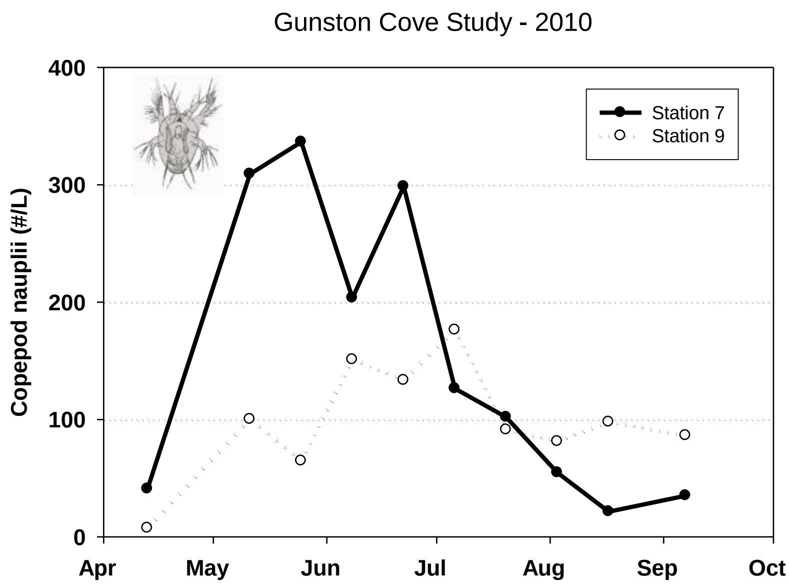
Figure 49. *Moina* Density by Station (#/m^3).

Moina was exhibited a strong peak in early June in the river when a value of over 15,000/m^3 was reached (Figure 49). The cove saw a much smaller coincident peak. For the rest of the year, *Moina* was rare at both stations. *Leptodora*, the large cladoceran predator, was consistently present in May and June in both cove and river (Figure 50). In the cove the peak was in early May at 1400/m^3, but values remained relatively high through early June. In the river an early May peak of about 600/m^3 was followed by a second early June peak at a similar density.



Leptodora is substantially larger than the other cladocera mentioned. Also different is its mode of feeding – it is a predator on other zooplankton. It normally occurs for brief periods in the late spring or early summer.

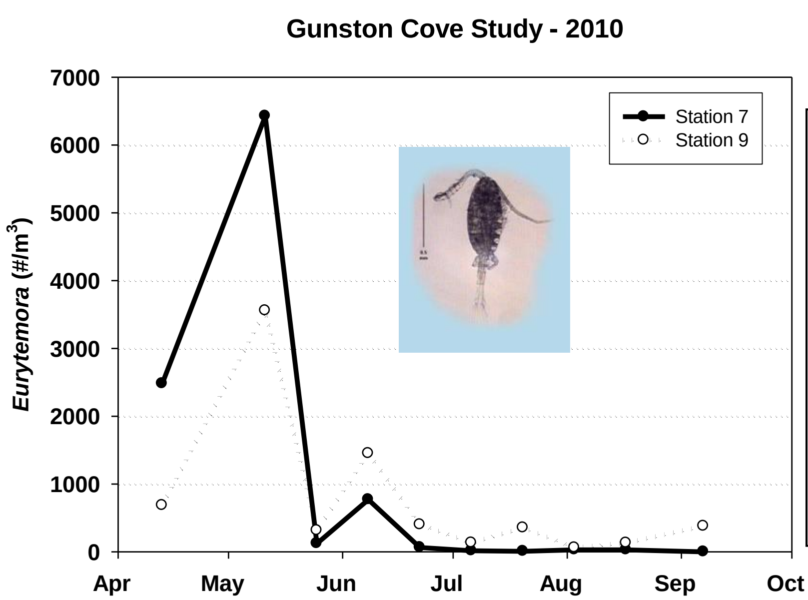
Figure 50. *Leptodora* Density by Station (#/m^3).



Copepod eggs hatch to form an immature stage called a nauplius. The nauplius is a larval stage that does not closely resemble the adult and the nauplii of different species of copepods are not easily distinguished so they are lumped in this study. Copepods go through 5 naupliar molts before reaching the copepodid stage which is morpho-logically very similar to the adult. Because of their small size and high abundance, copepod nauplii are enumerated in the micro-zooplankton samples.

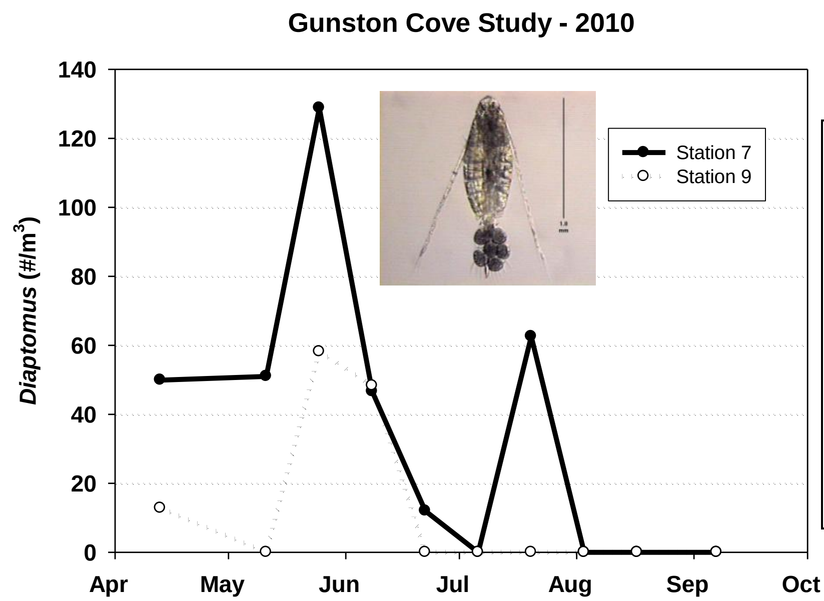
Figure 51. Copepod Nauplii Density by Station (#/L).

Copepod nauplii increased from levels of less than 50/L in April reaching nearly 350/L (350,000/m^3) in late May in the cove (Figure 51). Nauplii densities in the cove gradually declined thorough the rest of the summer. In the river a steady increase from April through early July resulted in a peak of 180/L in late June. *Eurytemora* exhibited highest densities in early May at both sites (Figure 52). Maximum values were about 6500/m^3 in the cove and 3,500/m^3 in the river. *Eurytemora* declined in early summer to values of less than 500/m^3 at both sites.



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

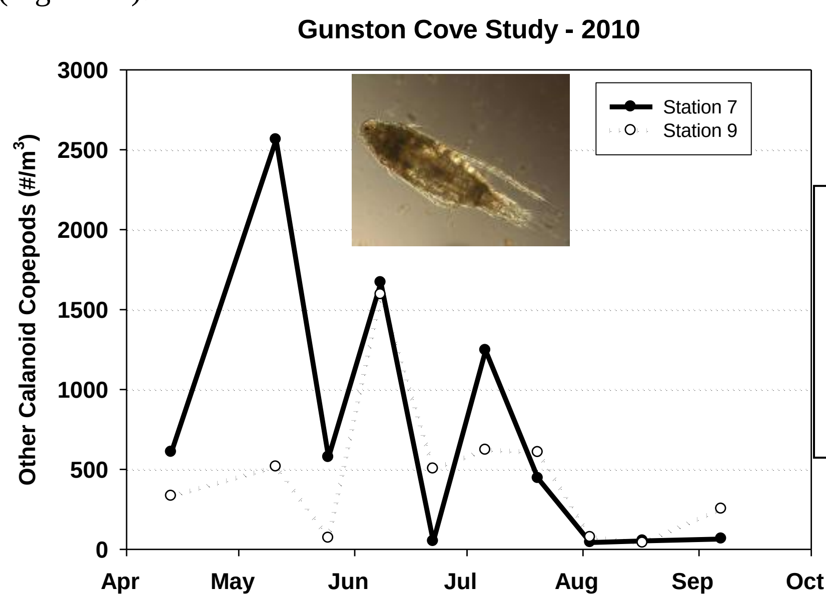
Figure 52. *Eurytemora* Density by Station (#/m^3).



Diaptomus pallidus is a calanoid copepod 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 abundant at both sites in late May, but levels were much lower than in recent years (Figure 53). Other calanoid copepods were highest in early May in the cove reaching nearly 2600/m^3. In the river peak of about 1600/m^3 wa observed in early June (Figure 54).



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

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

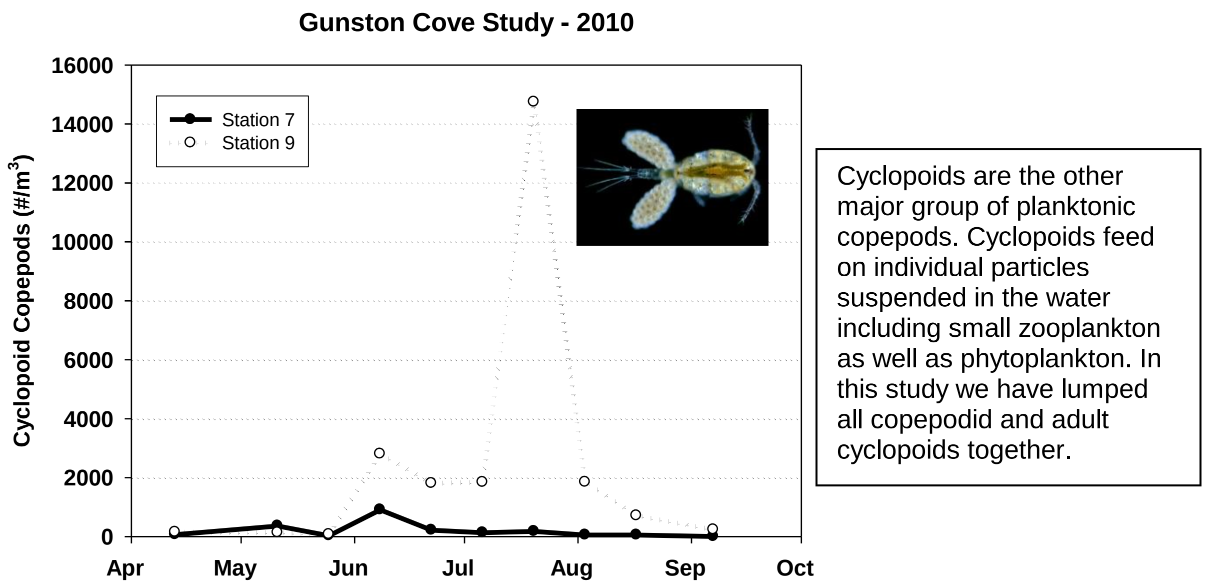


Figure 55. Cyclopoid Copepods by Station (#/m^3).

Cyclopoid copepods were relatively rare all year in the cove, but were common in the river in summer reaching a peak of over 14,000/m^3 in late July (Figure 55).

E. Ichthyoplankton – 2010

Larval fishes are transitional stages in the development of juvenile fishes. They range in development from newly hatched, embryonic fish to juvenile fish with morphological features similar to those of an adult. Many fishes such as clupeids (herring family), white perch, striped bass, and yellow perch disperse their eggs and sperm into the open water 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.

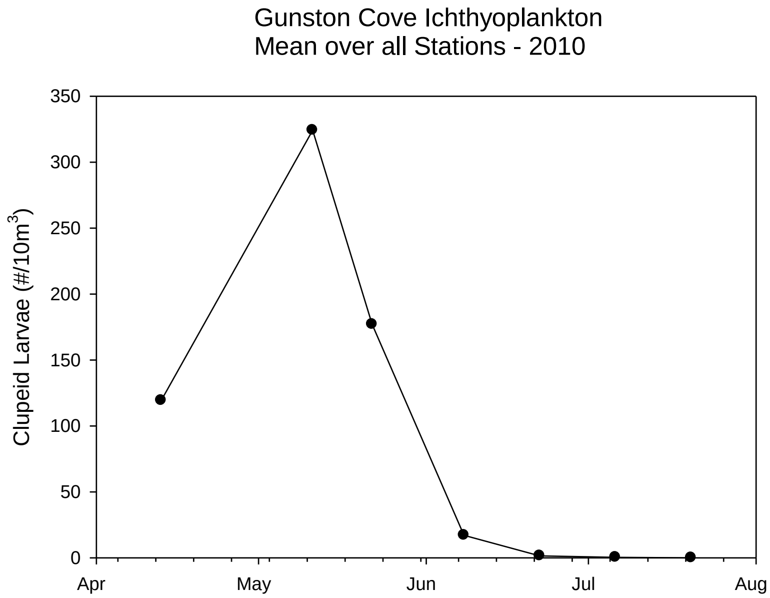
In 2010, we collected 14 samples (7 at each Station) during the months April through July and obtained a total of 7856 larvae (Table 3). The fish larvae are often difficult to distinguish at the species level, thus some of the counts are only to the genus level. The fish larvae are often difficult to distinguish at the species level, thus some of the counts are only to the genus level. Nearly ¾ of the total catch was from Station 9. About ½ of the total catch was obtained on one date, May 11.

Catches expressed as abundance are presented in Table 3. As is typical, the bulk of the catch (91.4 %) was comprised of members of the herring family. Most of these (74.4 %) were larvae of either gizzard shad or threadfin shad. Most, if not all of these, were probably gizzard shad, since threadfin shad have been extremely rare in our collections of juvenile and adult fishes. Larval white perch were second in rank (6.4 %). Yellow perch and inland silversides larvae were somewhat more common than usual, each comprising about 1.1% of total collections. Other species were very rare in 2010 with only one sunfish larvae being represented.

Table 3. The larval fishes collected in Gunston Cove and the Potomac River in 2010

Table 3
Larval Fishes Collected, by Taxon
Gunston Cove Study – 2010

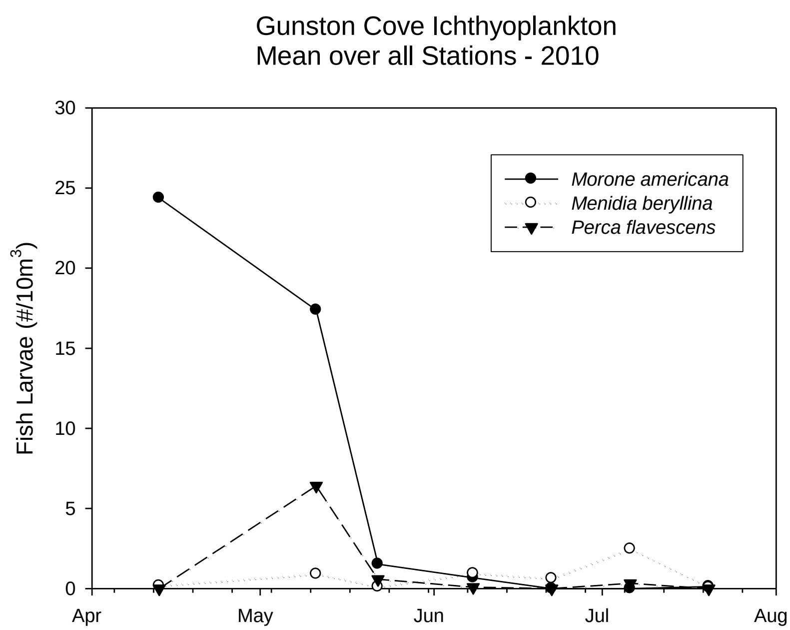
Taxon	Common Name	Number caught Sta 7	Sta 9	Total	% of Total
Alosa sp.	American shad, alewife, hickory shad, or blueback herring	259	1073	1332	17.0
Dorosoma sp.	gizzard shad or threadfin shad	1566	4280	5846	74.4
Morone spp.	white perch or striped bass	183	321	504	6.4
Perca flavescens	yellow perch	34	52	86	1.1
Menidia beryllina	inland silverside	18	69	87	1.1
Lepomis sp.	sunfish	1	0	1	<0.1
Total		2061	5795	7856	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 in early spring attaining a maximum in early May (Figure 56). White perch larval density was highest in mid April (Figure 57). Yellow perch (*Perca flavescens*) peaked in early May while inland silverside (*Menidia beryllina*) were captured in highest numbers in mid July.



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 (submersed 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 – 2010

Trawls

Trawl sampling was conducted between 9 April and 20 September at three fixed stations (7, 9, and 10) that have been sampled continuously since the inception of the survey. A total of 5916 fishes comprising 25 species were collected (Table 4). The majority (92%, numerically) of the fish collected were represented by 2 species: white perch (64.5%), and Alosa sp. (27.5%). Other numerically abundant species (annual total >20) included: blue catfish (3.2%), spottail shiner (1.5%), bay anchovy (1.3%), and gizzard shad (0.5%). Other species were observed sporadically and at low abundances (Table 4, 5A, & 5B).

Seasonal patterns in catches exhibited a unimodal pattern peaking the months of June, July and August that were driven by reproduction and successful recruitment of the dominant species. The dominant anadromous species, white perch, was ubiquitous occurring at all stations on nearly every sampling date (Tables 5B and 6). In the spring adult white perch were primarily caught in the nets while later in the summer juveniles dominated. Typical of previous years, bay anchovy only appeared in the catches at the end of the sampling season, (Tables 5A and 5B). Bay anchovy spawn in polyhaline areas and the offspring exhibit up-estuary dispersal into freshwater during late summer and fall. For other species, catches were low and sporadic, making it difficult to characterize temporal patterns.

In total numbers and species richness of fish, station 7 dominated the other stations with 5540 individuals from 19 species. Stations 9 and 10 had 347 individuals from 7 species and 29 individuals from 9 species, respectively (Table 6). Low catches at station 10 were due in part to excessive SAV biomass that interfered with trawling.

Table 4

Adult and Juvenile Fish Collected by Trawling
Gunston Cove Study - 2010

Anguillidae	*Anguilla rostrata*	American eel	0
Clupeidae	*Alosa aestivalis*	blueback herring	3
	Alosa mediocris	hickory shad	1
	Alosa pseudoharengus	alewife	97
	Alosa sapidissima	American shad	7
	Alosa sp.	herring or shad	1520
	Dorosoma cepedianum	gizzard shad	32
	Brevoortia tyrannus	Atlantic menhanden	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	77
Cyprinidae	*Carassius auratus*	goldfish	1
	Cyprinus carpio	common carp	2
	Hybognathus regius	eastern silvery minnow	16
	Notemigonius crysoleucas	golden shiner	0
	Notropis hudsonius	spottail shiner	89
Catostomidae	*Carpiodes cyprinus*	quillback	0
	Catostomus commersoni	white sucker	0
	Erimyzon oblongatus	creek chubsucker	0
Ictaluridae	*Ameiurus catus*	white catfish	0
	Ameiurus nebulosus	brown bullhead	6
	Ictalurus furcatus	blue catfish	191
	Ictalurus punctatus	channel catfish	0
Belonidae	*Strongylura marina*	Atlantic needlefish	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	5
	Fundulus heteroclitus	mummichog	0
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0
Atherinidae	*Menidia beryllina*	inland silverside	5
Gobiidae	*Gobiosoma bosc*	naked goby	0
Percichthyidae	*Morone americana*	white perch	3813
	Morone saxatilis	striped bass	5
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	0
	Lepomis auritus	redbreast sunfish	0
	Lepomis gibbosus	pumpkinseed	19
	Lepomis macrochirus	bluegill	4
	Lepomis microlophus	redear sunfish	0
	Lepomis sp.	sunfish	1
	Micropterus dolomieu	smallmouth bass	0
	Micropterus salmoides	largemouth bass	6
	Pomoxis nigromaculatus	white crappie	2
Percidae	*Etheostoma olmstedi*	tessellated darter	13
	Perca flavescens	yellow perch	0
Soleidae	*Trinectes maculatus*	hogchoker	1
TOTAL			5916

Table 5A

Adult and Juvenile Fish Collected by Trawling
Gunston Cove Study - 2010

			9-Apr	21-May	21-May	4-Jun	18-Jun	8-Jul	23-Jul
Anguillidae	*Anguilla rostrata*	American eel	0	0	0	0	0	0	0
Clupeidae	*Alosa aestivalis*	blueback herring	0	0	0	0	3	0	0
	Alosa mediocris	hickory shad	0	0	0	0	0	0	0
	Alosa pseudoharengus	alewife	0	0	0	0	5	92	0
	Alosa sapidissima	American shad	0	0	0	0	1	0	1
	Alosa sp.	herring or shad	0	0	0	1520	0	0	1
	Dorosoma cepedianum	gizzard shad	1	0	0	1	30	1	0
	Brevoortia tyrannus	Atlantic menhaden	0	0	0	0	0	0	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	0	0	0	0	0
Cyprinidae	*Carassius auratus*	goldfish	0	0	0	0	1	0	0
	Cyprinus carpio	common carp	0	0	0	1	1	0	0
	Hybognathus regius	eastern silvery minnow	1	0	0	0	0	15	0
	Notemigonius crysoleucas	golden shiner	0	0	0	0	0	0	0
	Notropis hudsonius	spottail shiner	4	0	2	12	6	54	0
Catostomidae	*Carpiodes cyprinus*	quillback	0	0	0	0	0	0	0
	Catostomus commersoni	white sucker	0	0	0	0	0	0	0
	Erimyzon oblongatus	creek chubsucker	0	0	0	0	0	0	0
Ictaluridae	*Ameiurus catus*	white catfish	0	0	0	0	0	0	0
	Ameiurus nebulosus	brown bullhead	0	0	3	1	2	0	0
	Ictalurus furcatus	blue catfish	0	0	9	3	13	1	6
	Ictalurus punctatus	channel catfish	0	0	0	0	0	0	0
Belonidae	*Strongylura marina*	Atlantic needlefish	0	0	0	0	0	0	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	0	0	0	3	0	2	0
	Fundulus heteroclitus	mummichog	0	0	0	0	0	0	0
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0	0	0	0	0	0	0
Atherinidae	*Menidia beryllina*	inland silverside	0	0	0	1	0	2	0
Gobiidae	*Gobiosoma bosc*	naked goby	0	0	0	0	0	0	0
Percichthyidae	*Morone americana*	white perch	4	0	19	669	121	2786	0
	Morone saxatilis	striped bass	0	0	0	2	2	1	0
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	0	0	0	0	0	0	0
	Lepomis auritus	redbreast sunfish	0	0	0	0	0	0	0
	Lepomis gibbosus	pumpkinseed	0	0	1	8	3	1	0
	Lepomis macrochirus	bluegill	1	0	0	1	0	0	0
	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	0	0	0	0	0	0	0
	Micropterus salmoides	largemouth bass	1	0	0	0	1	3	0
	Pomoxis nigromaculatus	white crappie	0	0	0	1	0	1	0
Percidae	*Etheostoma olmstedi*	tessellated darter	6	0	0	2	0	4	1
	Perca flavescens	yellow perch	0	0	0	0	0	0	0
Soleidae	*Trinectes maculatus*	hogchoker	0	0	0	0	0	0	0
TOTAL			17	0	34	2225	189	2964	7

Table 5B

Adult and Juvenile Fish Collected by Trawling
Gunston Cove Study - 2010

			20-Aug	27-Aug	20-Sep
Anguillidae	*Anguilla rostrata*	American eel	0	0	0
Clupeidae	*Alosa aestivalis*	blueback herring	0	0	0
	Alosa mediocris	hickory shad	0	1	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	0
	Brevoortia tyrannus	Atlantic menhaden	0	0	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	1	71	5
Cyprinidae	*Carassius auratus*	goldfish	0	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	6	0	5
Catostomidae	*Carpiodes cyprinus*	quillback	0	0	0
	Catostomus commersoni	white sucker	0	0	0
	Erimyzon oblongatus	creek chubsucker	0	0	0
Ictaluridae	*Ameiurus catus*	white catfish	0	0	0
	Ameiurus nebulosus	brown bullhead	0	0	0
	Ictalurus furcatus	blue catfish	22	40	97
	Ictalurus punctatus	channel catfish	0	0	0
Belonidae	*Strongylura marina*	Atlantic needlefish	0	0	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	0	0	0
	Fundulus heteroclitus	mummichog	0	0	0
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0	0	0
Atherinidae	*Menidia beryllina*	inland silverside	2	0	0
Gobiidae	*Gobiosoma bosc*	naked goby	0	0	0
Percichthyidae	*Morone americana*	white perch	186	8	20
	Morone saxatilis	striped bass	0	0	0
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	0	0	0
	Lepomis auritus	redbreast sunfish	0	0	0
	Lepomis gibbosus	pumpkinseed	6	0	0
	Lepomis macrochirus	bluegill	2	0	0
	Lepomis microlophus	redear sunfish	0	0	0
	Lepomis sp.	sunfish	0	0	0
	Micropterus dolomieu	smallmouth bass	0	0	0
	Micropterus salmoides	largemouth bass	1	0	0
	Pomoxis nigromaculatus	white crappie	0	0	0
Percidae	*Etheostoma olmstedi*	tessellated darter	0	0	0
	Perca flavescens	yellow perch	0	0	0
Soleidae	*Trinectes maculatus*	hogchoker	0	0	1
TOTAL			232	120	128

Table 6

Adult and Juvenile Fish Collected by Trawling
Gunston Cove Study - 2010

		Station	7	9	10
Anguillidae	*Anguilla rostrata*	American eel	0	0	0
Clupeidae	*Alosa aestivalis*	blueback herring	3	0	0
	Alosa mediocris	hickory shad	0	1	0
	Alosa pseudoharengus	alewife	97	0	0
	Alosa sapidissima	American shad	7	0	0
	Alosa sp.	herring or shad	1520	0	0
	Dorosoma cepedianum	gizzard shad	32	0	0
	Brevoortia tyrannus	Atlantic menhaden	0	0	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	6	71	0
Cyprinidae	*Carassius auratus*	goldfish	0	0	1
	Cyprinus carpio	common carp	1	1	0
	Hybognathus regius	eastern silvery minnow	16	0	0
	Notemigonius crysoleucas	golden shiner	0	0	0
	Notropis hudsonius	spottail shiner	88	0	1
Catostomidae	*Carpiodes cyprinus*	quillback	0	0	0
	Catostomus commersoni	white sucker	0	0	0
	Erimyzon oblongatus	creek chubsucker	0	0	0
Ictaluridae	*Ameiurus catus*	white catfish	0	0	0
	Ameiurus nebulosus	brown bullhead	2	1	3
	Ictalurus furcatus	blue catfish	15	176	0
	Ictalurus punctatus	channel catfish	0	0	0
Belonidae	*Strongylura marina*	Atlantic needlefish	0	0	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	4	0	1
	Fundulus heteroclitus	mummichog	0	0	0
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0	0	0
Atherinidae	*Menidia beryllina*	inland silverside	5	0	0
Gobiidae	*Gobiosoma bosc*	naked gobi	0	0	0
Percichthyidae	*Morone americana*	white perch	3709	98	8
	Morone saxatilis	striped bass	5	0	0
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	0	0	0
	Lepomis auritus	redbreast sunfish	0	0	0
	Lepomis gibbosus	pumpkinseed	15	0	4
	Lepomis macrochirus	bluegill	3	0	1
	Lepomis microlophus	redear sunfish	0	0	0
	Lepomis sp.	sunfish	0	0	1
	Micropterus dolomieu	smallmouth bass	0	0	0
	Micropterus salmoides	largemouth bass	4	0	2
	Pomoxis nigromaculatus	white crappie	2	0	0
Percidae	*Etheostoma olmstedi*	tessellated darter	6	0	7
	Perca flavescens	yellow perch	0	0	0
Soleidae	*Trinectes maculatus*	hogchoker	0	1	0
TOTAL			5540	347	29

Note: Station 10 could not be sampled on last four dates due to excessive SAV.

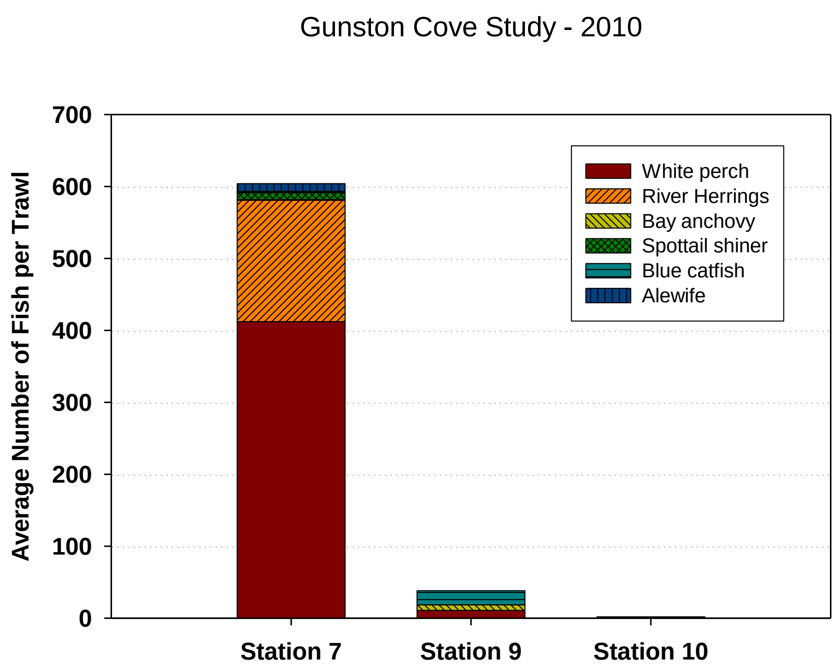


Figure 58. Adult and Juvenile Fishes Collected by Trawling. Dominant Species by Station.

The six most abundant species varied in representation across stations with a single large catch of alewife dominating the pattern at station 7 (Figure 58). Blue catfish were almost exclusively observed at station 9 in relatively high abundance. Blue catfish are primarily a mainstem species and have not featured prominently at stations within the cove. At stations 7 and 9, white perch and juvenile Alosa sp. made up a significant proportion of the total catch. Station 7 was by far the most productive site, eclipsing the other stations in fish abundance by one to two orders of magnitude.

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.

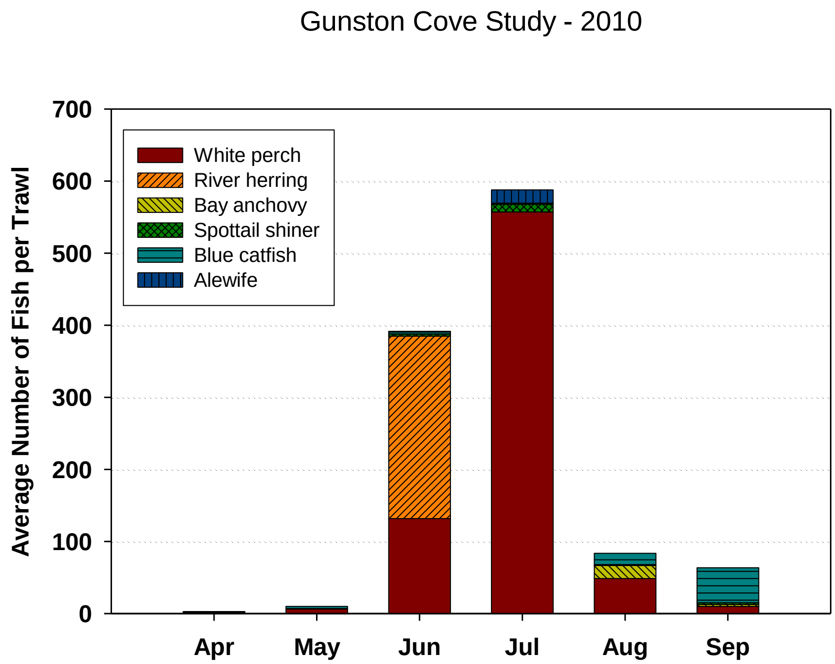


Figure 59. Adult and Juvenile Fishes Collected by Trawling. Dominant Species by Month.

Disregarding large single catches of *Alosa* sp. (in June), white perch and blue catfish were the most common species (Figure 59). Whereas white perch were present throughout the season, blue catfish (primarily juveniles) were mainly captured at the end of the season. Other common species were bay anchovy and spottail shiner. In 2010, the most productive months were June, July, and August, which were dominated by cohorts of juvenile fishes.

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

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

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

Seines

Seine sampling was conducted approximately semi-monthly at 4 stations between 9 April and 20 September. Three of these stations (4, 6, 11) have been sampled continuously since 1985 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 2010, regardless of SAV density, station 4A was sampled concurrently with station 4 so that catch composition could be compared. Due to a mechanical problem on the boat, only one round of sampling was conducted in May and station 4A was sampled on a different day than the other stations.

A total of 36 seine samples were conducted, comprising 8554 fishes and 30 species (Table 7). The most abundant species in seine catches were banded killifish (69.9%), followed by *Alosa* sp. (9%), and white perch (6.7%). Several other species occurred at moderate abundances (>20 total) including: common carp, eastern silvery minnow, golden shiner, spottail shiner, mummichog, eastern mosquitofish, inland silverside, striped bass, pumpkinseed, bluegill, largemouth bass, and tessellated darter (Table 7). Other species occurred sporadically at low abundances. Unlike the previous 4 years, we did not identify any American shad in our catches. All of the Alosa spp. category individuals were small river herring that were not identified to species due to difficulties of distinguishing between small juvenile blueback and alewife. Continuing a recent trend were moderate catches of (primarily juvenile) largemouth bass, which reflects relatively high recruitment success in 2007, 2008, 2009, and 2010.

Seasonal catch patterns were variable with June representing the most productive period. Peaks in abundance tended to be short represented by one or two sampling trips, and for most species these pulses represented cohorts of young-of-the-year. Other peaks in catch constituted pulses of juveniles that recently recruited to shallow habitats accessible by the seine (e.g., gizzard shad, Atlantic menhaden, white perch, and striped bass). For the numerically dominant banded killifish, catches averaged 665 per sampling round.

The productivity of catches at each site varied approximately from n=1878 fish at station 4A to n=2461 at station 11 (Table 9). These stations were similar to each other in species richness with values ranging between 17 and 22 species during 2010. Of these species, 7 were common to all four seine stations. A few high abundance species dominated this pattern (i.e., made up >20% of the total), but particular dominants varied by site. At sites 4A, 4 and 6, banded killifish were the dominant species. At site 11, dominance was shared by Alosa spp., banded killifish, and white perch.

Table 7

Adult and Juvenile Fish Collected by Seining
Gunston Cove Study – 2010

Lepisosteidae	*Lepisosteus osseus*	longnose gar	1
Clupeidae	*Alosa aestivalis*	blueback herring	1
	Alosa mediocris	hickory shad	2
	Alosa pseudoharengus	alewife	0
	Alosa sapidissima	American shad	0
	Alosa spp.	river herring	770
	Dorosoma cepedianum	gizzard shad	2
	Brevoortia tyrannus	Atlantic menhaden	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	0
Cyprinidae	*Carassius auratus*	goldfish	0
	Cyprinella analostana	satinfin shiner	18
	Cyprinus carpio	common carp	48
	Hybognathus regius	eastern silvery minnow	201
	Notemigonus crysoleucas	golden shiner	54
	Notropis hudsonius	spottail shiner	56
	Pimephales promelas	fathead minnow	1
Catastomidae	*Carpiodes cyprinus*	quillback	18
	Catostomus commersoni	white sucker	0
	Erimyzon oblongatus	creek chubsucker	1
	Moxostoma macrolepidotum	shorthead redhorse	0
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	13
Belonidae	*Strongylura marina*	Atlantic needlefish	1
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	5982
	Fundulus heteroclitus	mummichog	100
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	28
Atherinidae	*Menidia beryllina*	inland silverside	48
Percichthyidae	*Morone americana*	white perch	569
	Morone saxatilis	striped bass	72
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	14
	Lepomis auritus	redbreast sunfish	14
	Lepomis gibbosus	pumpkinseed	118
	Lepomis macrochirus	bluegill	62
	Lepomis microlophus	redear sunfish	14
	Lepomis sp.	sunfish	2
	Micropterus dolomieu	smallmouth bass	0
	Micropterus salmoides	largemouth bass	214
	Pomoxis nigromaculatus	crappie	0
Percidae	*Etheostoma olmstedi*	tessellated darter	125
	Perca flavescens	yellow perch	4
Soleidae	*Trinectes maculatus*	hogchoker	1
TOTAL			8554

Table 8A

Adult and Juvenile Fish Collected by Seining

Gunston Cove Study – 2010

			9-Apr	7-May	21-May	4-Jun	18-Jun	8-Jul
Lepisosteidae	*Lepisosteus osseus*	longnose gar	0	0	0	0	0	1
Clupeidae	*Alosa aestivalis*	blueback herring	0	0	0	0	0	0
	Alosa mediocris	hickory shad	0	0	0	2	0	0
	Alosa pseudoharengus	alewife	0	0	0	0	0	0
	Alosa spp.	river herrings	0	0	100	0	609	0
	Dorosoma cepedianum	gizzard shad	0	0	0	0	0	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	0	0	0	0
Cyprinidae	*Carassius auratus*	goldfish	0	0	0	0	0	0
	Cyprinella analostana	satinfin shiner	5	0	11	2	0	0
	Cyprinus carpio	common carp	0	0	0	0	47	0
	Hybognathus regius	eastern silvery minnow	4	0	0	0	24	1
	Notemigonus crysoleucas	golden shiner	40	0	0	13	0	1
	Notropis hudsonius	spottail shiner	12	0	0	0	8	10
	Pimephales promelas	fathead minnow	0	0	0	1	0	0
Catastomidae	*Carpiodes cyprinus*	quillback	0	0	0	9	8	1
	Catostomus commersoni	white sucker	0	0	0	0	0	0
	Erimyzon oblongatus	creek chubsucker	1	0	0	0	0	0
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	0	0	0	9	2	2
Belonidae	*Strongylura marina*	Atlantic needlefish	0	0	0	0	0	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	714	34	1335	534	2039	381
	Fundulus heteroclitus	mummichog	8	0	12	10	12	38
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0	0	0	0	0	1
Atherinidae	*Menidia beryllina*	inland silverside	17	0	4	3	6	4
Percichthyidae	*Morone americana*	white perch	6	0	0	6	83	132
	Morone saxatilis	striped bass	0	0	0	6	23	27
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	4	0	8	1	0	0
	Lepomis auritus	redbreast sunfish	1	0	0	0	3	0
	Lepomis gibbosus	pumpkinseed	8	0	38	1	2	35
	Lepomis macrochirus	bluegill	7	0	12	3	0	1
	Lepomis microlophus	redear sunfish	0	0	0	0	0	0
	Lepomis sp.	sunfish	0	0	0	0	0	0
	Micropterus salmoides	largemouth bass	1	0	0	0	129	54
Percidae	*Etheostoma olmstedi*	tessellated darter	47	5	15	13	1	17
	Perca flavescens	yellow perch	1	0	0	1	0	0
Soleidae	*Trinectes maculatus*	hogchoker	0	0	0	0	0	0
TOTAL			876	39	1535	614	2996	706

Note: 7-May data for Station 4B only; 21-May data for Stations 4, 6, and 11 only

Table 8B

Adult and Juvenile Fish Collected by Seining
Gunston Cove Study - 2010

			23-Jul	20-Aug	27-Aug	20-Sept
Lepisosteidae	*Lepisosteus osseus*	longnose gar	0	0	0	0
Clupeidae	*Alosa aestivalis*	blueback herring	0	1	0	0
	Alosa mediocris	hickory shad	0	0	0	0
	Alosa pseudoharengus	alewife	0	0	0	0
	Alosa spp.	river herrings	0	0	0	61
	Dorosoma cepedianum	gizzard shad	0	0	0	2
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	0	0
Cyprinidae	*Carassius auratus*	goldfish	0	0	0	0
	Cyprinella analostana	satinfin shiner	0	0	0	0
	Cyprinus carpio	common carp	0	0	1	0
	Hybognathus regius	eastern silvery minnow	39	32	7	94
	Notemigonus crysoleucas	golden shiner	0	0	0	0
	Notropis hudsonius	spottail shiner	13	0	1	12
	Pimephales promelas	fathead minnow	0	0	0	0
Catastomidae	*Carpiodes cyprinus*	quillback	0	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	0	0	1
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	197	166	364	218
	Fundulus heteroclitus	mummichog	16	0	3	1
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0	0	0	26
Atherinidae	*Menidia beryllina*	inland silverside	1	0	0	13
Percichthyidae	*Morone americana*	white perch	63	129	5	145
	Morone saxatilis	striped bass	8	7	0	1
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	0	1	0	0
	Lepomis auritus	redbreast sunfish	0	0	10	0
	Lepomis gibbosus	pumpkinseed	1	11	8	14
	Lepomis macrochirus	bluegill	2	17	14	6
	Lepomis microlophus	redear sunfish	4	5	1	4
	Lepomis sp.	sunfish	0	1	1	0
	Micropterus salmoides	largemouth bass	18	4	7	1
Percidae	*Etheostoma olmstedi*	tessellated darter	3	13	2	9
	Perca flavescens	yellow perch	0	0	0	2
Soleidae	*Trinectes maculatus*	hogchoker	0	1	0	0
TOTAL			365	389	424	610

Table 9

Adult and Juvenile Fish Collected by Seining
Gunston Cove Study - 2010

		Station--->	4	6	11	4A
Lepisosteidae	*Lepisosteus osseus*	longnose gar	0	1	0	0
Clupeidae	*Alosa aestivalis*	blueback herring	0	0	1	0
	Alosa mediocris	hickory shad	0	0	2	0
	Alosa pseudoharengus	alewife	0	0	0	0
	Alosa spp.	river herrings	0	0	770	0
	Dorosoma cepedianum	gizzard shad	0	0	2	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	0	0
Cyprinidae	*Carassius auratus*	goldfish	0	0	0	0
	Cyprinella analostana	satinfin shiner	3	14	0	1
	Cyprinus carpio	common carp	0	1	47	0
	Hybognathus regius	eastern silvery minnow	7	3	191	0
	Notemigonus crysoleucas	golden shiner	35	17	0	2
	Notropis hudsonius	spottail shiner	5	8	35	8
	Pimephales promelas	fathead minnow	0	1	0	0
Catastomidae	*Carpiodes cyprinus*	quillback	0	0	9	9
	Catostomus commersoni	white sucker	0	0	0	0
	Erimyzon oblongatus	creek chubsucker	1	0	0	0
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	9	2	0	2
Belonidae	*Strongylura marina*	Atlantic needlefish	0	1	0	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	1948	1685	772	1577
	Fundulus heteroclitus	mummichog	45	54	0	1
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	2	2	0	24
Atherinidae	*Menidia beryllina*	inland silverside	0	4	25	19
Percichthyidae	*Morone americana*	white perch	5	60	446	58
	Morone saxatilis	striped bass	0	0	51	21
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	5	9	0	0
	Lepomis auritus	redbreast sunfish	0	4	0	10
	Lepomis gibbosus	pumpkinseed	25	41	8	44
	Lepomis macrochirus	bluegill	15	30	3	14
	Lepomis microlophus	redear sunfish	1	11	0	2
	Lepomis sp.	sunfish	2	0	0	0
	Micropterus salmoides	largemouth bass	26	44	92	52
Percidae	*Etheostoma olmstedi*	tessellated darter	29	56	6	34
	Perca flavescens	yellow perch	3	1	0	0
Soleidae	*Trinectes maculatus*	hogchoker	0	0	1	0
TOTAL			2166	2049	2461	1878

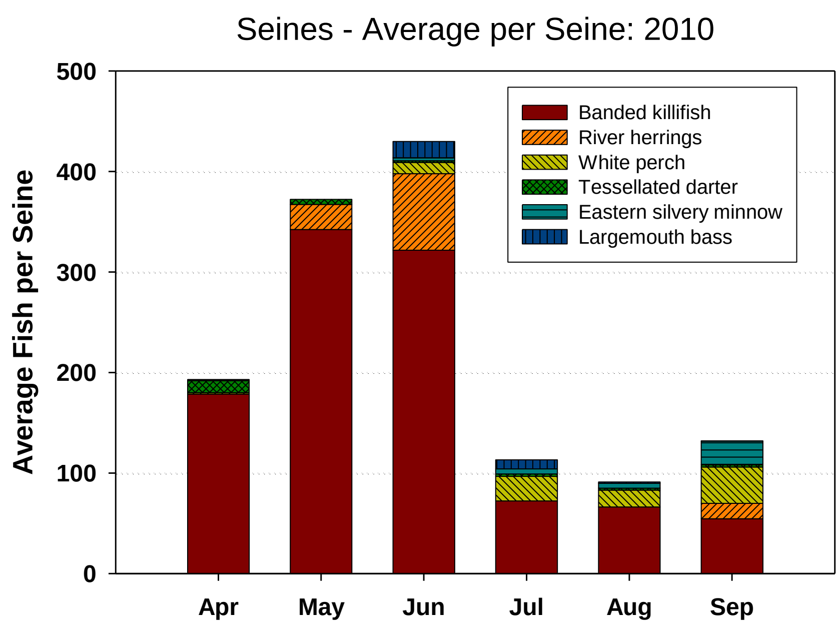


Figure 60. Adult and Juvenile Fish Collected by Seining. Dominant Species by Station.

Typical of shallow littoral zone habitats in Gunston Cove during the past decade, the most productive period for seine sampling occurred in the months of May, and June (Figure 60). Banded killifish occurred in every month peaking in June, while other species peaked at different times: river herring pulses were present in May and June and again in September, white perch and eastern silvery minnow occurred primarily in July, August and September. Largemouth bass (mostly young-of-the-year) occurred in June and July, which is consistent with known pattern of spawning in May.

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.

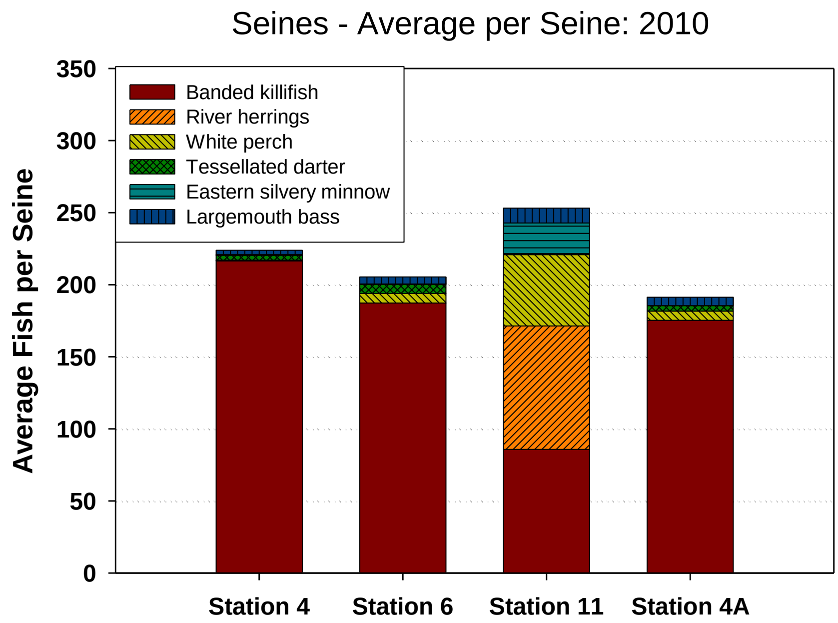


Figure 61. Adult and Juvenile Fish Collected by Seining. Dominant Species by Month.

The 6 dominant species ranked by catch rate included banded killifish and white perch, which were present at every station (Figure 61). Other dominant species in 2010 included river herrings, tessellated darter, eastern silvery minnow, and largemouth bass. Whereas banded killifish and tessellated darter were ever present in seine catches, white perch occurred mainly at station 11, which continues a long-term trend for this species to be less abundant in the cove than near the mainstem of the Potomac. River herring, eastern silvery minnow, and largemouth bass were similarly centered spatially at station 11. In addition, station 11 had a higher total catch of all fishes than other stations.

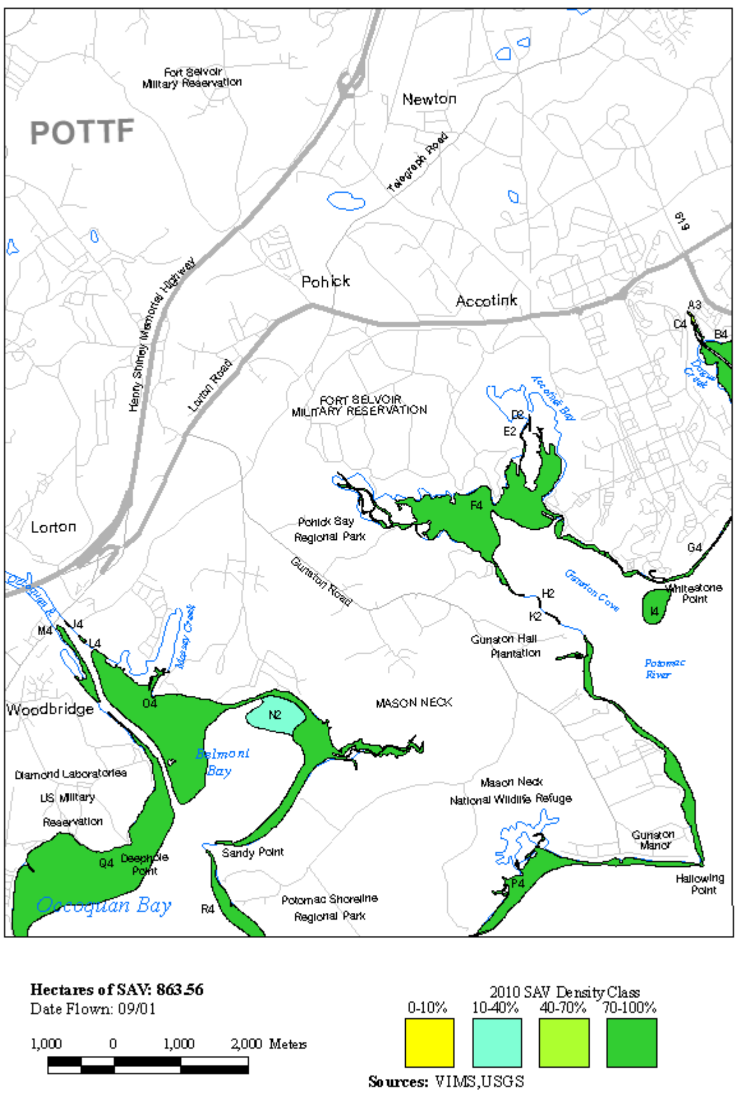
Spottail shiner (*Notropis hudsonius*), a member of the minnow family, is moderately abundant in the open water and along the shore. Spawning occurs throughout the warmer months. It reaches sexual maturily at about 5.5 cm and may attain a length of 10 cm. They feed primarily on benthic invertebrates 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.

F. Submersed Aquatic Vegetation – 2010

The distribution of submersed aquatic vegetation (SAV) in the Gunston Cove area in fall 2010 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 into the inner portions of Gunston Cove. Total coverage was about 160 hectares, down from the peak of over 200 hectares in 2005, but similar to the last several years. The fringing beds continued to be found along much of the shoreline and the bed of SAV continues along the sill at the mouth of the cove. Species data for 2010 was not available for Gunston Cove from the VIMS website, but field observations indicate that *Hydrilla* tends to dominate in the shallows with *Vallisneria*, *Myriophyllum*, and *Ceratophyllum* common in deeper areas.



Valisneria americana
Water celery

Hydrilla verticillata
Hydrilla

Figure 64. Distribution and Density of Submersed Aquatic Vegetation in the Gunston Cove area. 2010. VIMS (http://www.vims.edu/bio/sav/index.html).

H. Benthic Macroinvertebrates - 2010

Macroinvertebrate sampling was restarted in 2010 after several years. Triplicate petite ponar samples were collected at the cove (Station 7) and river (Station 9) sites on four dates (May 25, June 22, July 20, and August 17).

Oligochaetes were the most common invertebrates collected in these samples and were found at about twice the density at Station 9 than at Station 7 (Figure 65). In the cove diptera (chironomid/midge) larvae made up the bulk of the remaining organisms with a handful of amphipods turning up in some of the samples. In the river, several groups were found in moderate numbers: amphipods (crustaceans commonly known as scuds), and *Corbicula* (Asiatic clam). Diptera were rare in the river and *Corbicula* were absent in the cove.

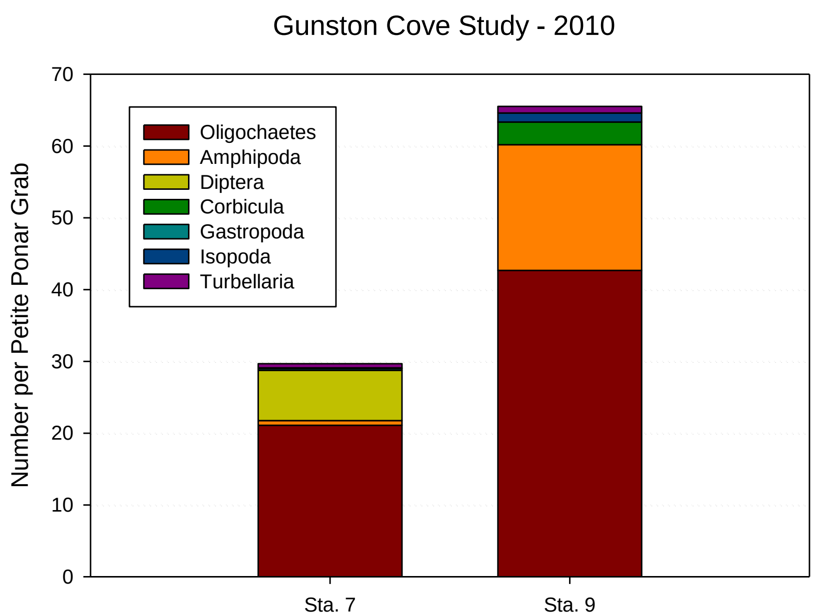


Figure 65. Average abundance of various benthic macroinvertebrate taxa in petite ponar samples collected on four dates in 2010.

These results are consistent with previous collections although the higher density of oligochaetes in the channel is unusual. The composition of the benthic macroinvertebrate community at these two sites seems to mainly reflect the texture of bottom substrates. In the cove at Station 7, the bottom sediments are fine and organic with anoxia just below the surface. These conditions favor chironomids and oligochaetes and are not supportive of the other taxa found in the river. In the river sediments are coarser and are comprised of a mixture of bivalve shells (mainly *Corbicula*) and sand/silt. This type of substrate is supportive of a wider array of species.

DISCUSSION

A. 2010 Data

The year 2010 was characterized by above normal temperatures for most of the year. July was the warmest month and June had the greatest departure from normal. There were 62 days with high temperatures above 90°F (32.2°C) which was twice the number in any other recent year. Potomac River flows were about average in spring, but dropped steadily to below normal values in June where they remained for most of the summer. Local tributary flows were somewhat below normal for most of the year, but dropped to almost nothing in September. A late September rain event lifted flows back into the normal range.

Specific conductance was relatively constant through August, increasing slightly in September as inflow to the river receded. Chloride showed a gradual increase through the year which quickened in September. Total alkalinity also showed a gradual increase through the year at both sites. All of these parameters reflected a gradual increase in ionic concentration as freshwater flow declined during summer and fall.

Dissolved oxygen was generally higher in the cove than in the river. Values were relatively high in April, dropped off a bit in May and then were above saturation again in the summer. pH exhibited similar spatial and temporal patterns. Total alkalinity was somewhat higher in the river than in the cove and in spring.

Water clarity was slightly higher in the river than in the cove in spring. However, in summer and fall, the cove generally had higher water clarity. Water in the cove has become clearer in recent years, but this was the first time that cove Secchi was higher than river readings for most of the summer. .

Ammonia nitrogen was very low at both sites during most of the year, but increased rather dramatically in the river in May and June. Nitrate was steady at about 1 mg/L in spring, but declined strongly in June to very low values (<0.1 mg/L) for the remainder of the year. Nitrite nitrogen was also consistently higher in the river with a peak in early June coinciding with the ammonia nitrogen peak. Organic nitrogen was generally higher in the cove and reached a peak in late June. Total phosphorus exhibited a seasonal increase at both sites with maximum values in July. Soluble reactive phosphorus was consistently higher in the river and did not show any clear seasonal patterns. N to P ratio was similar at the two sites and declined seasonally, approaching values indicating a shift to N limitation. BOD and VSS, reflecting organic matter in water column, were similar at the two sites as was TSS.

Chlorophyll concentrations were low (10-20 μg/L) and very similar in both cove and river sites in the spring. In June chlorophyll increased markedly in the river reaching over 50 μg/L in July and remaining high through August. Surprisingly, cove values increased only gradually reaching a peak of about 35 μg/L in July and August. This is the first year that summer chlorophyll was higher in the river than the cove. Phytoplankton density and biovolume showed similar evidence that river values were equal to or greater than cove values. Phytoplankton density peaked first in the cove, but was higher later in the summer in the river. Phytoplankton biovolume was higher all summer in the river. Cyanobacteria were dominant in terms of cell density in the cove and river. Cove and river had similar abundance of cells which is unusual; cove is generally higher. Of the cyanobacteria, *Oscillatoria* and *Aphanocapsa* were more abundant in the cove and *Microcystis* was more abundant in the river. The diatom *Melosira* was the most abundant eukaryotic alga in both areas. In terms of biovolume, diatoms were dominant on most dates at both stations. *Oscillatoria* and *Anabaena* were the most important cyanobacteria, but *Melosira* was the most dominant taxon overall.

Rotifers were numerous in the cove from May through July. *Filinia* and *Keratella* were dominant in May followed by *Brachionus* in June and a mix of all three in July. In the river a large surge of *Keratella* in early May led to the highest rotifer densities of the year. On other dates river rotifer densities were much lower than those in the cove. The small cladoceran *Bosmina* was found in moderate numbers in May and early June at both sites with higher abundance in the cove. The larger cladoceran *Diaphanosoma* was quite high in early June at both sites with a second peak in the river in early July. Following its high abundance in early May, *Daphnia* was uncommon in the cove, but maintained moderate values in May and early June in the river. *Moina*, normally a relatively rare cladoceran, reached high densities in late May and early June in the river, but was much less common in the cove. *Leptodora* was quite abundant in May and early June in the cove and river. Copepod nauplii were present at moderate values in the cove and river over the entire year with a peak in May in the cove and July in the river. *Eurytemora* was very abundant in some samples in April and May and was rarer in the late summer and fall. *Diaptomus* was relatively rare in 2010, peaking in the spring with a secondary peak in late July in the river. Cyclopoid copepods were relatively rare in the cove, but showed a strong late summer peak in the river.

In 2010 ichthyoplankton was dominated by *Dorosoma* sp. (gizzard shad) and, to a lesser extent, alosids (herring and shad). Members of the genus *Morone* (white perch or striped bass) were significant, but comprised a lesser percentage of the catch than normal. Yellow perch and inland silversides were found at numbers somewhat greater than normal.

In trawls, the overwhelming majority of the fish collected were represented by 2 taxa: white perch and *Alosa* sp. (shad/herring). Other numerically abundant species included: blue catfish, spottail shiner, bay anchovy, and gizzard shad. As usual, white perch was found throughout the year and at all stations. *Alosa* sp. were sporadic through time and found mainly in the mid cove area. Blue catfish was found more frequently in late summer and fall and mainly in the river. Spottail shiner were found throughout the year, but mainly at cove sites. Adults tended to be captured in spring and juveniles in the late summer. The most abundant species collected in seines was banded killifish followed by *Alosa* sp. and white perch. Banded killifish and white perch were collected at all stations and throughout the year.

Submersed aquatic vegetation (SAV) continued to be present at high densities in both Pohick and Accotink Bays and to penetrate the inner portions of Gunston Cove in 2010. A fringe of

SAV was observed all along the Gunston Cove shoreline and a band of lower density SAV was found across the cove mouth. Coverage reported by aerial surveys in 2010 was similar to the last few years and much elevated over pre-2005 levels, but less extensive than the peak year of 2005.

In benthic samples, oligochaetes were the most common invertebrates collected and were found at about twice the density at Station 9 than at Station 7. In the cove diptera (chironomid/midge) larvae made up the bulk of the remaining organisms with a handful of amphipods turning up in some of the samples. In the river, several groups were found in moderate numbers: amphipods (crustaceans commonly known as scuds), and *Corbicula* (Asiatic clam). Diptera were rare in the river and *Corbicula* were absent in the cove. These results were similar to those observed in previous years.

B. Water Quality Trends: 1983-2010

To assess long-term trends in water quality, data from 1983 to 2010 were pooled into two data files: one for Mason data and one for Noman Cole laboratory data. Then, subgroups were selected based on season and station. For water quality parameters, we focused on summer (June-September) data as this period is the most stable and often presents the greatest water quality challenges and the highest biological activity and abundances. We examined the cove and river separately with the cove represented by Station 7 and the river by Station 9. We tried several methods for tracking long-term trends, settling on a scatterplot with LOWESS trend line. Each observation in a particular year is plotted as an open circle on the scatterplot. The LOWESS (locally weighted sum of squares) line is drawn by a series of linear regressions moving through the years. We also calculated the Pearson correlation coefficient and performed linear regressions to test for statistical significance of a linear relationship over the entire period of record (Tables 10 and 11). This was similar to the analysis performed in previous report.

Table 10
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1984-2010
GMU Water Quality Data
June-September

Parameter	Station 7 Corr. Coeff.	Station 7 Reg. Coeff.	Station 7 Signif.	Station 9 Corr. Coeff.	Station 9 Reg. Coeff.	Station 9 Signif.
Temperature	0.193	0.072	0.002	0.101	----	NS
Conductivity, standardized to 25°C	0.176	2.94	0.006	0.021	----	NS
Dissolved oxygen, mg/L	0.024	----	NS	0.185	0.032	0.007
Dissolved oxygen, percent saturation	0.094	----	NS	0.201	0.435	0.004
Secchi disk depth	0.686	1.62	<0.001	0.344	0.658	<0.001
Light extinction coefficient	0.610	0.113	<0.001	0.116	----	NS
pH, Field	-0.085	----	NS	0.113	----	NS
Chlorophyll, depth-integrated	-0.498	-4.14	<0.001	-0.185	-0.658	0.008
Chlorophyll, surface	-0.504	-4.41	<0.001	-0.182	-0.768	0.008

For Station 7, n=241-260 except pH, Field where n=194 and Light extinction coefficient where n=180.
For Station 9, n=200-214 except pH, Field where n=162 and Light extinction coefficient where n=149.

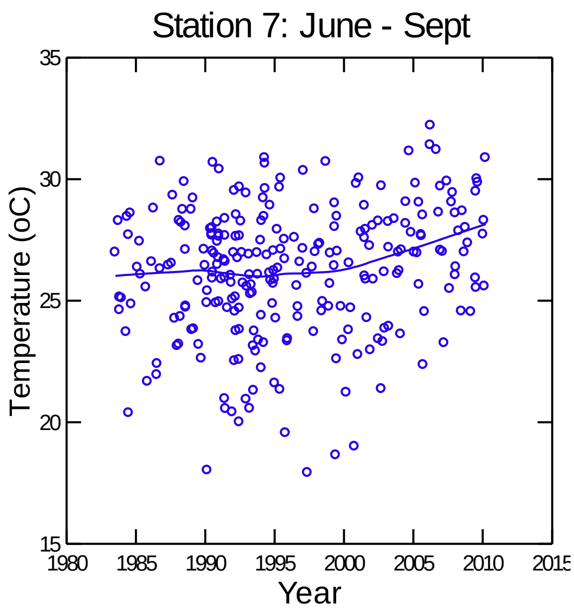
Significance column indicates the probability that a correlation coefficient this large could be due to chance alone. If this probability is greater than 0.05, then NS (not significant) is indicated.

Table 11
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1983-2010
Fairfax County Environmental Laboratory Data
June-September

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Chloride	+0.036	----	NS	+0.039	----	NS
Lab pH	-0.333	-0.027	<0.001	-0.273	-0.017	<0.001
Alkalinity	-0.009	----	NS	+0.117	0.190	0.022
BOD	-0.602	-0.193	<0.001	-0.473	-0.064	<0.001
Total Suspended Solids	-0.282	-1.000	<0.001	-0.101	----	NS
Volatile Suspended Solids	-0.375	-0.780	<0.001	-0.396	-0.179	<0.001
Total Phosphorus	-0.485	-0.004	<0.001	-0.226	-0.001	<0.001
Soluble Reactive Phosphorus	+0.003	----	NS	0.204	0.0004	<0.001
Ammonia Nitrogen	-0.234	-0.017	<0.001	-0.236	-0.003	<0.001
Un-ionized Ammonia Nitrogen	-0.266	-0.005	<0.001	-0.310	-0.0004	<0.001
Nitrite Nitrogen	-0.336	-0.003	<0.001	-0.220	-0.002	<0.001
Nitrate Nitrogen	-0.480	-0.035	<0.001	-0.586	-0.040	<0.001
Organic Nitrogen	-0.504	-0.053	<0.001	-0.334	-0.014	<0.001
N to P Ratio	-0.223	-0.315	<0.001	-0.532	-0.717	<0.001
Chlorophyll a, surface	-0.312	-3.27	<0.001	-0.175	-1.01	0.040

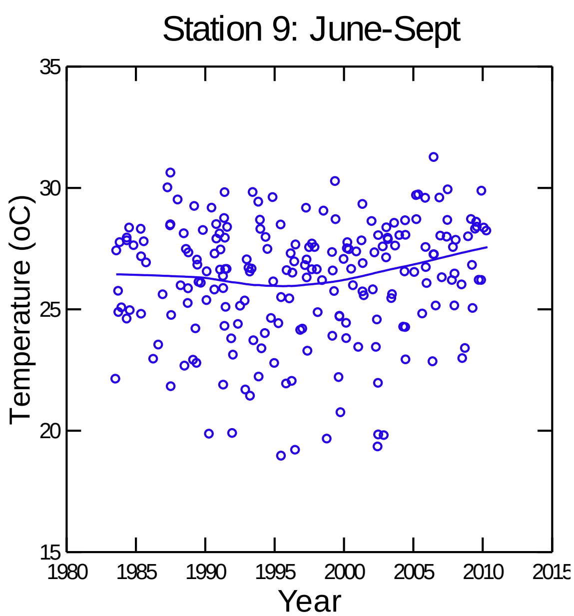
For Station 7, n=348-389 except Nitrite Nitrogen where n=311 and Chlorophyll a where n=138.
For Station 9, n=348-397 except Nitrite Nitrogen where n=310 and Chlorophyll a where n=138.

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



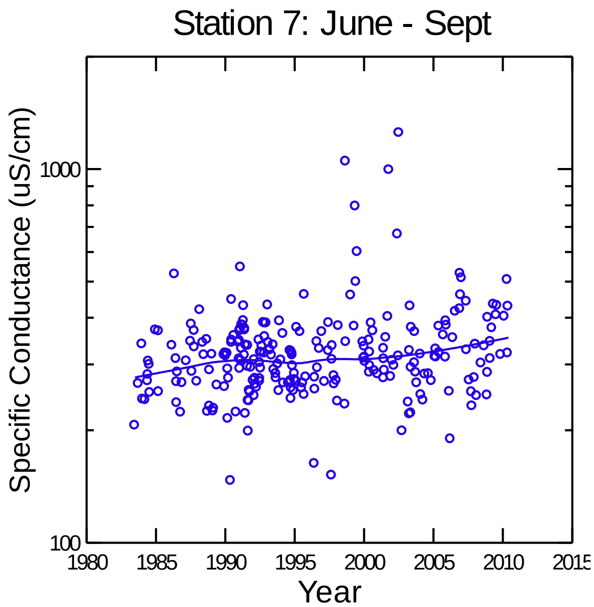
Water temperatures during the summer months generally varied between 20 and 30°C over the study period (Figure 69). The LOWESS curve indicated an average of about 26°C during the period 1984-2000 with a distinct upward trend in the last few years approaching 28ºC. Linear regression analysis indicated a significant linear trend in water temperature in the cove when the entire period of record is considered (Table 10). The slope of this relationship is 0.07°C/year.

Figure 69. Long term trend in Water Temperature (GMU Field Data). Station 7. Gunston Cove.



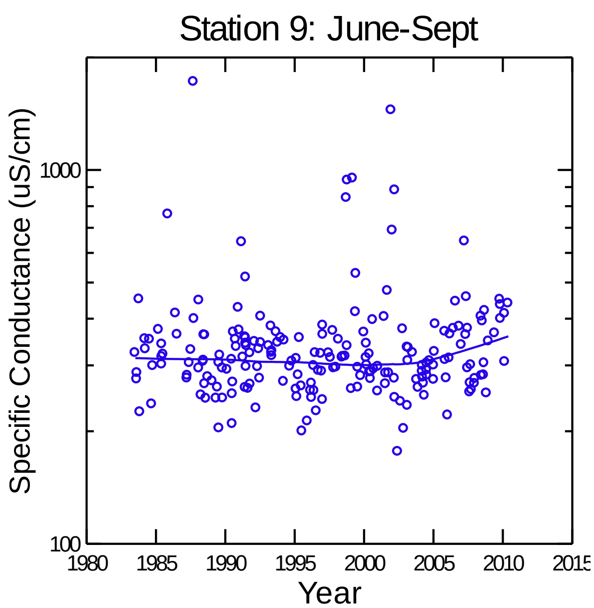
In the river summer temperatures have been slightly cooler than in the cove (Figure 70). The trend line again started out at about 26°C, but has increased less strongly. There appear to be somewhat fewer readings above 30° C in the river Linear regression over the study period was not significant (Table 10).

Figure 70. Long term trend in Water Temperature (GMU Field Data). Station 9. Gunston Cove.



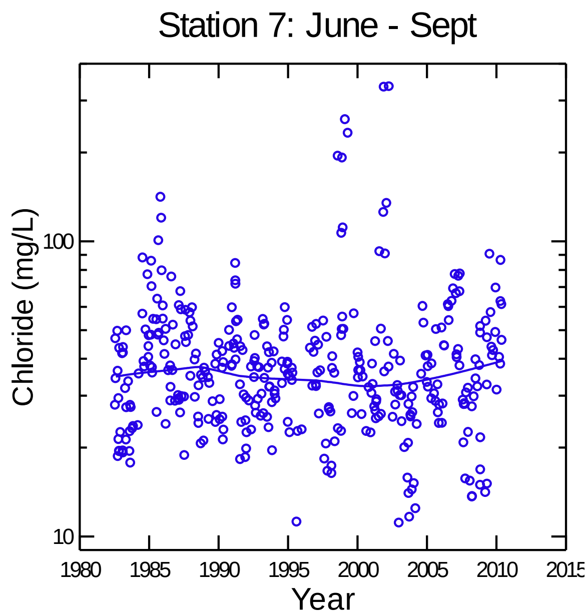
Specific conductance was generally in the range 200-400 uS/cm over the study period (Figure 71). Some significantly higher readings have been observed sporadically. A slight increase in specific conductance was suggested by the LOWESS line over the study period. This was confirmed by linear regression analysis which found a significant linear increase of 2.9 uS/cm per year over the long term study period (Table 10). The results for 2010 were centered around the trend line.

Figure 71. Long term trend in Specific Conductance (GMU Field Data). Station 7. Gunston Cove.



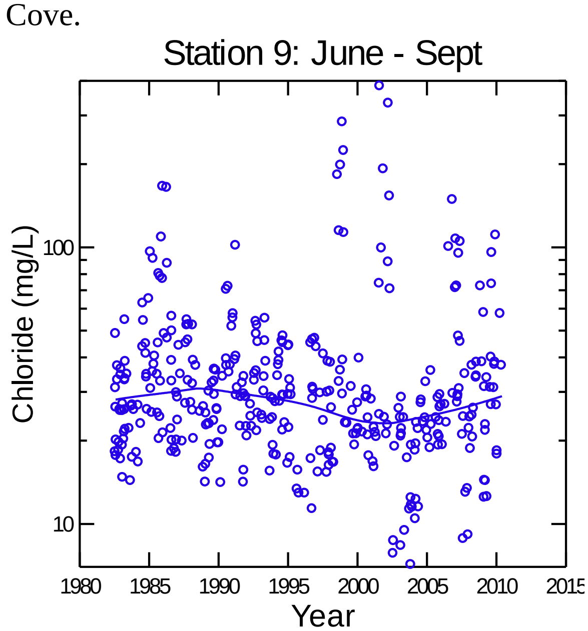
Conductivity values in the river were in the same general range as in the cove (Figure 72). Most values were between 200 and 400 uS/cm with a few much higher values. These higher values are probably attributable to intrusions of brackish water from downstream during years of low river flow. Linear regression did not reveal a significant trend in river conductivity (Table 10). The 2010 results were generally above the long term trend line.

Figure 72. Long term trend in Specific Conductance (GMU Field Data). Station 9. River mainstem.



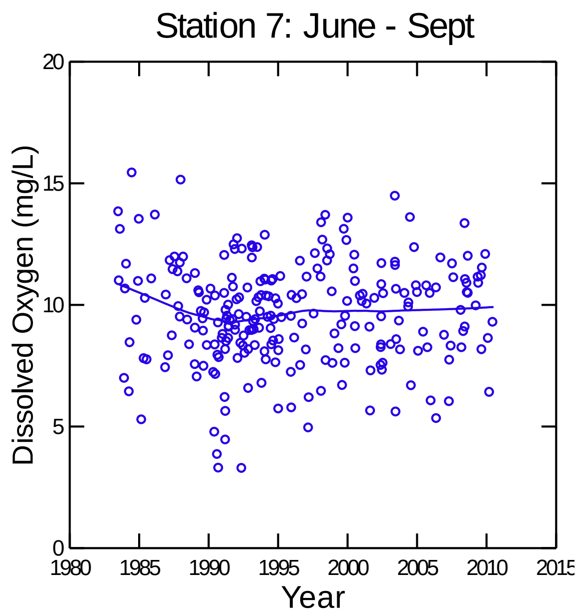
Chloride levels were clustered in a relatively narrow range of 20-60 mg/L for the entire study period (Figure 73). Higher values observed in some years were probably due to the estuarine water intrusions that occur in dry years. The trend is nearly flat and a linear regression was not statistically significant (Table 11). 2010 levels were above the trend line.

Figure 73. Long term trend in Chloride (Fairfax County Lab Data). Station 7. Gunston Cove.



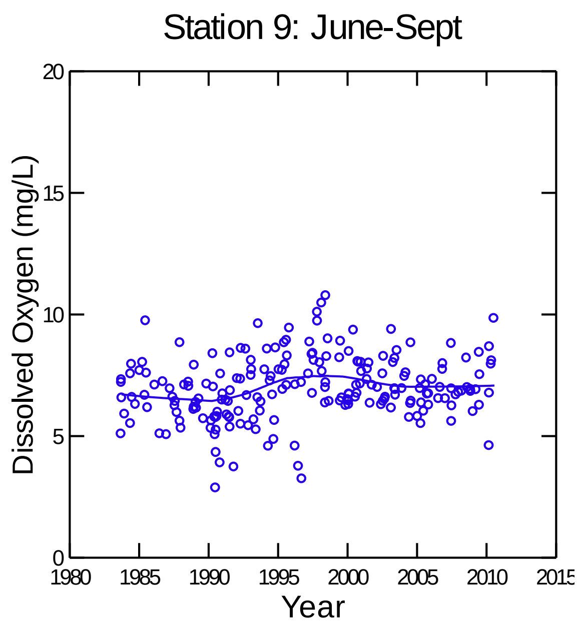
Chloride in the river has been slightly more variable than that in the cove, but in the same general range (Figure 74). The higher readings are again due to brackish water intrusions in dry years. A slight trend of increasing values in the 1980's followed by decreases in the 1990's and leveling in the 2000's was suggested by the LOWESS trend line. However, regression analysis was not statistically significant (Table 11). The 2010 values clustered around the trend line with a few higher readings.

Figure 74. Long term trend in Chloride (Fairfax County Lab Data). Station 9. River mainstem.



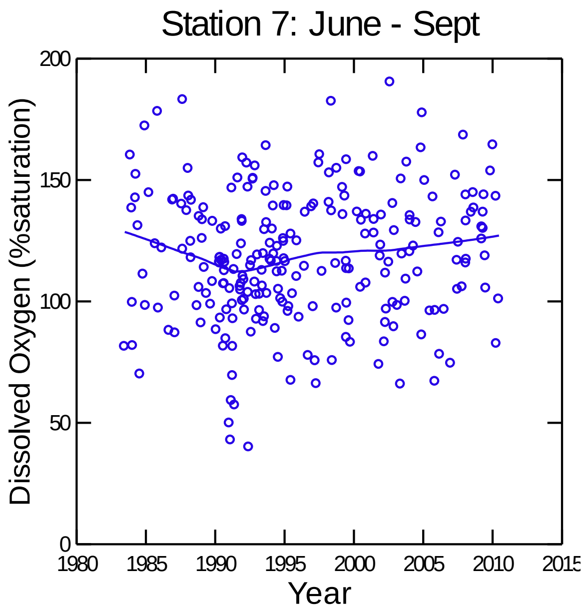
Dissolved oxygen in the cove has generally been in the range 7-12 mg/L during the summer months (Figure 75). A slight downward trend was observed through 1990, but since then the trend line has flattened, suggesting little consistent change and a mean of about 10 mg/L. In the cove dissolved oxygen (mg/L) did not exhibit a significant linear trend over the long term study period (Table 10).

Figure 75. Long term trend in Dissolved Oxygen, mg/L (GMU Data). Station 7. Gunston Cove.



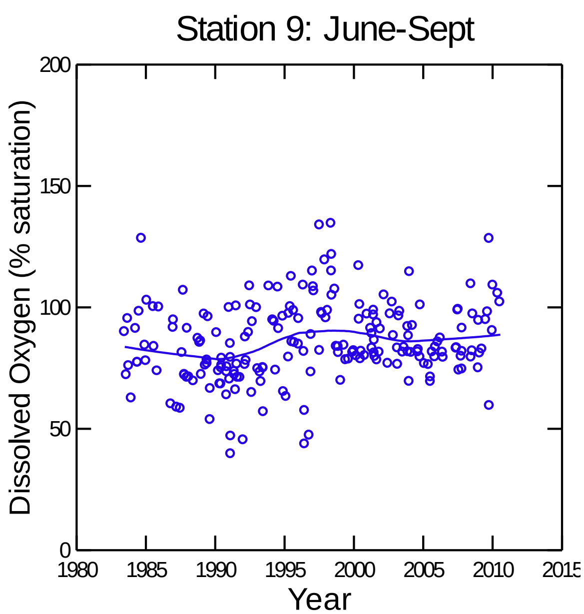
In the river dissolved oxygen values generally were in the range 5-9 mg/L over the long term study period (Figure 76). The LOWESS trend line suggested a decline in the 1980's, an increase in the early to mid 1990's and a decline in the 2000's. The linear regression analysis over the entire period indicated a significant positive trend with slope of 0.032 mg/L per year (Table 10). This implies an increase of 0.86 mg/L over the study period. 2010 readings were above the long term trend line.

Figure 76. Long term trend in Dissolved Oxygen, mg/L (GMU Data). Station 9. River mainstem.



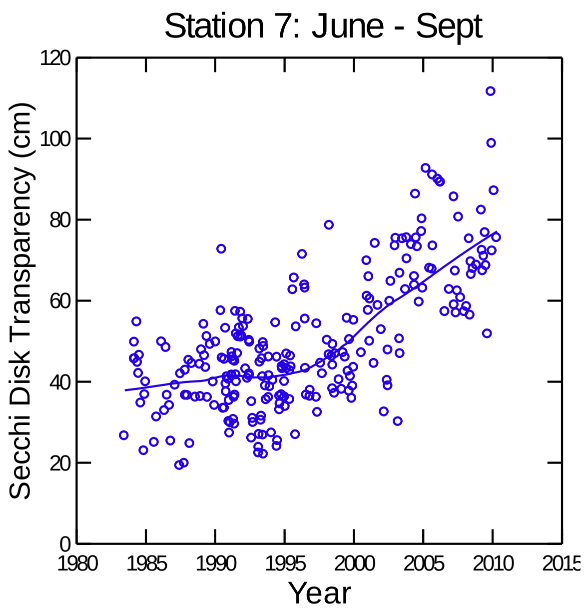
Dissolved oxygen was generally in the range 100-150% saturation in the cove over the long term study period indicating the importance of photosynthesis in the cove (Figure 77). A decline was indicated by the trend line through 1990 followed by a slight recovery in subsequent years. Percent saturation DO did not exhibit a significant linear trend over the long term study period (Table 10).

Figure 77. Long term trend in Dissolved Oxygen, % saturation (GMU Data). Station 7. Gunston Cove.



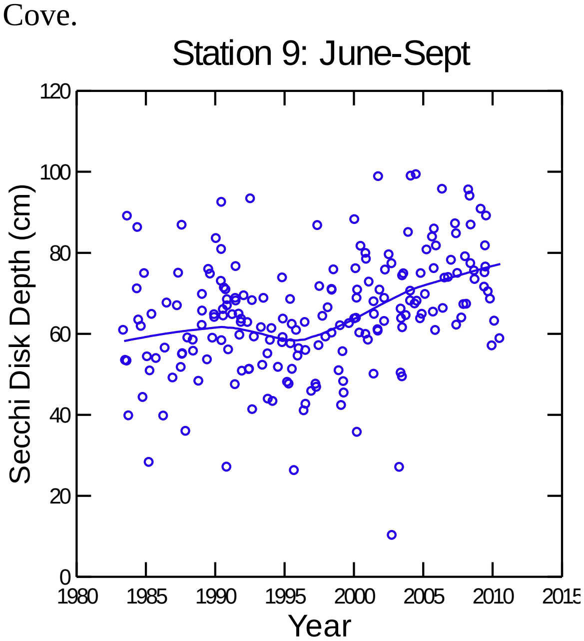
In the river dissolved oxygen was generally less than 100% indicating that photosynthesis was much less important in the river than in the cove (Figure 78). The temporal pattern showed a slight decline in the 1980's, an increase in the 1990's, and a subsequent slight decline in the 2000's. In the river a significant linear increase was indicated by regression analysis with a slope of 0.43% per year yielding about 12% increase over the study period (Table 10). 2010 readings were clearly above the long term trend line

Figure 78. Long term trend in Dissolved Oxygen, % saturation (GMU Data). Station 9. Gunston Cove.



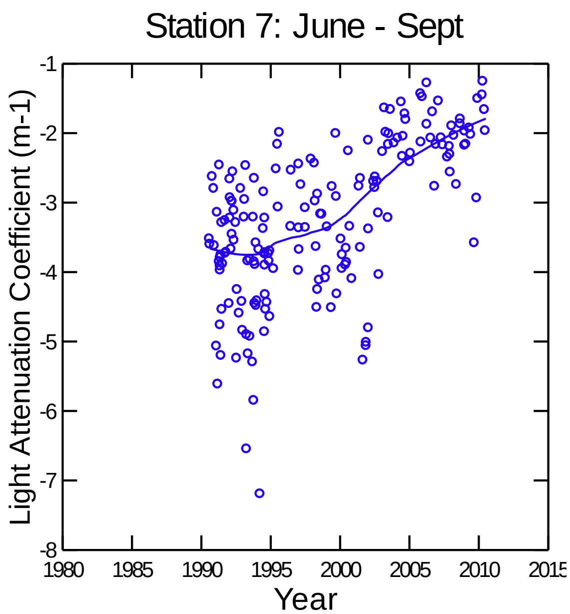
Secchi disk transparency is a measure of water clarity. Secchi disk was fairly constant from 1984 through 1995 with the trend line at about 40 cm (Figure 79). Since 1995 there has been a steady increase in the trend line from 40 cm to nearly 80 cm in 2010. Linear regression was highly significant with a predicted increase of 1.6 cm per year or a total of 43 cm over the study period (Table 10). Most 2010 readings were above the trend line and some exceeded 100 cm for the first time in the study.

Figure 79. Long term trend in Secchi Disk Transparency (GMU Data). Station 7. Gunston Cove.



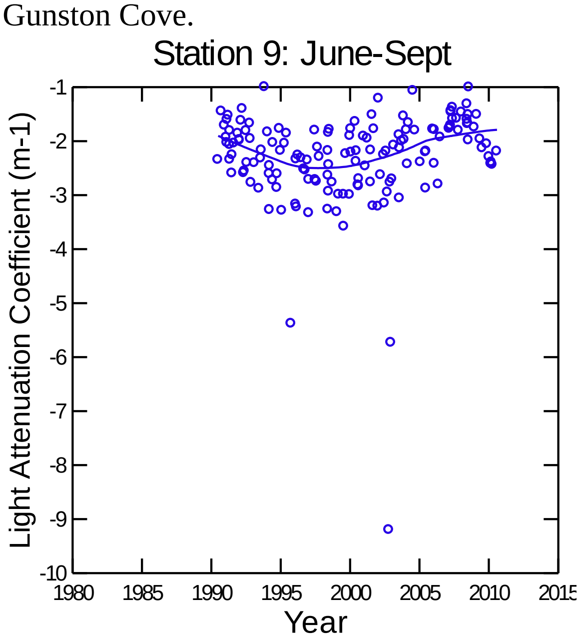
In the river Secchi depth was somewhat greater than in the cove initially (Figure 80). The trend line rose from 55 cm in 1984 to 62 cm in 1991. This was followed by a decline to about 58 cm in 1996 and then a steady increase to the 2010 level of about 80 cm. Linear regression revealed a significant increase of 0.66 cm per year with total increase of 18 cm predicted over of the study period (Table 10).

Figure 80. Long term trend in Secchi Disk Transparency (GMU Data). Station 9. River mainstem.



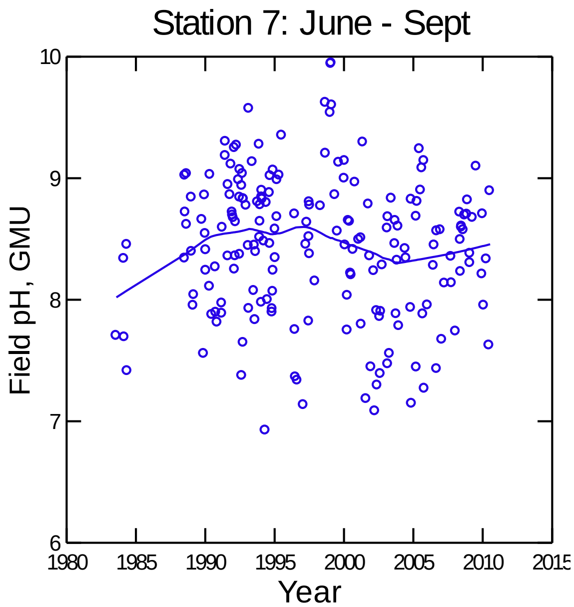
Light attenuation coefficient, another measure of water clarity, reinforces the conclusion that water clarity has been improving in the cove since 1995 (Figure 81). Trend line for the coefficient rose from about -4 to less than -2 m^{-1} during this time. Consistent with this was the regression analysis which revealed a significant linear increase in light attenuation coefficient over the period 1991-2010 with a slope of 0.11 per year yielding a prediction that light attenuation improved by about 3 units over this period (Table 10).

Figure 81. Long term trend in Light Attenuation Coefficient (GMU Data). Station 7. Gunston Cove.



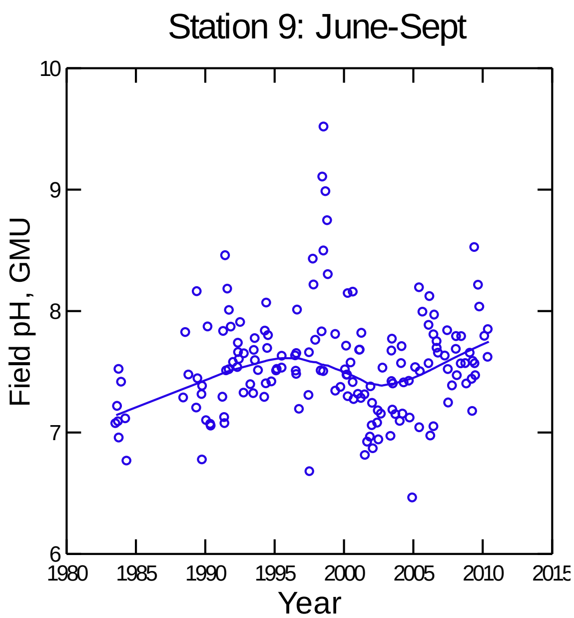
In the river light attenuation coefficient suggested a decline in light transparency between 1991 and 1997 followed by an increase since that time (Figure 82). Regression did not reveal a significant linear trend over the entire period (Table 10).

Figure 82. Long term trend in Light Attenuation Coefficient (GMU Data). Station 9. River mainstem.



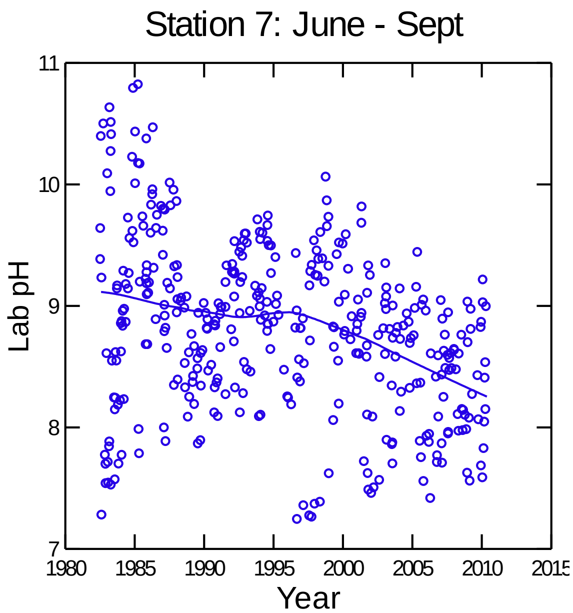
Field pH has not been measured as consistently over the entire study period as other parameters. There is little evidence for a consistent trend over the measurement period (Figure 83). Linear regression analysis did not provide evidence of a linear trend when the entire study period was (Table 10).

Figure 83. Long term trend in Field pH (GMU Data). Station 7. Gunston Cove.



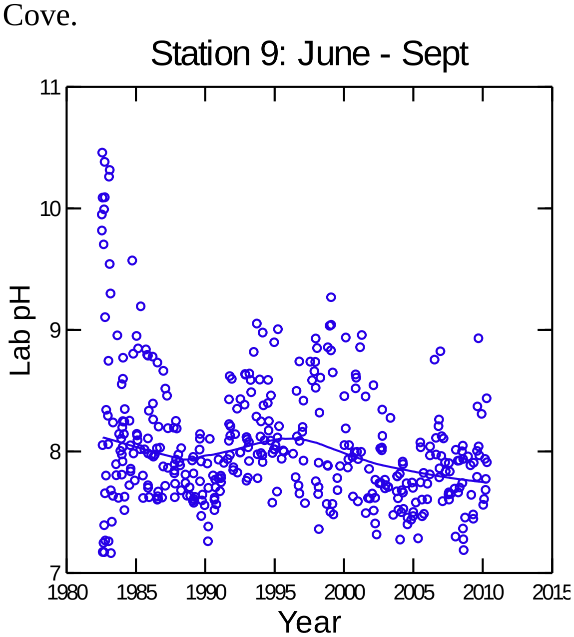
In the river a similar pattern has been observed over this period (Figure 84). pH in the river has been consistently lower by about 1 pH unit than in the cove. A gradual increase from 7.2 in 1989 to 7.7 in 1998 was followed by a decline to about 7.4. In recent years pH has again increased somewhat. When all years were considered, no linear trend was found (Table 10).

Figure 84. Long term trend in Field pH (GMU Data). Station 9. River mainstem.



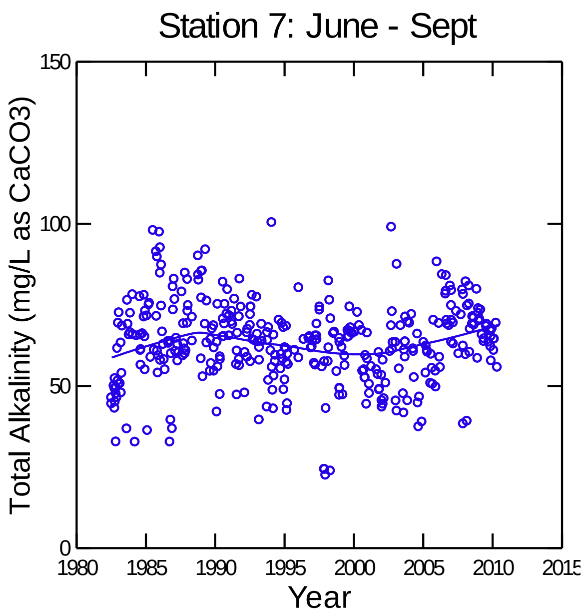
Lab pH as measured by Fairfax County personnel were generally in the range 7.5 to 9.5 over the long term study period (Figure 85). Since about 1998 a decline is very evident with the trend line decreasing from about 9 to about 8.2. Linear regression indicated a significant decline in lab pH over the study period at a rate of about 0.027 pH units per year or a total of 0.76 units over the study period (Table 11).

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



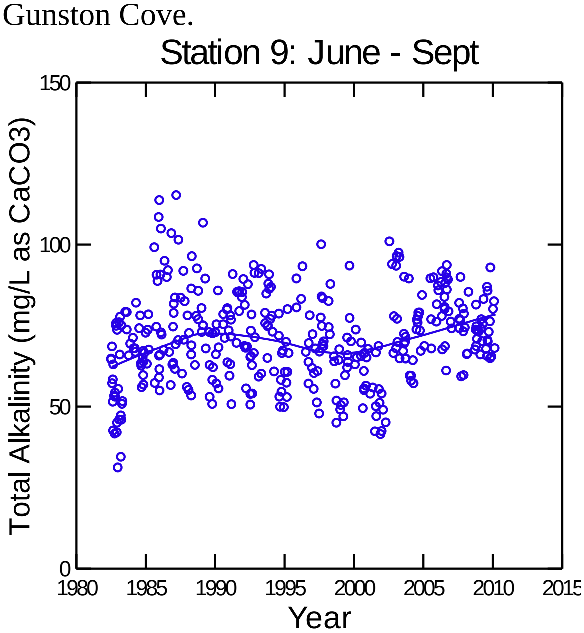
In the river, long term pH trends as measured by Fairfax County lab personnel indicate that most values fell between 7 and 9 (Figure 86). The trend line has increased and decreased slightly over the years with data since 1998 showing a slight decline. pH in the river showed a significant linear decline with a rate of 0.017 per year yielding a total decline of 0.48 units over the long term study period (Table 11).

Figure 86. Long term trend in Lab pH (Fairfax County Lab Data). Station 9. Potomac mainstem.



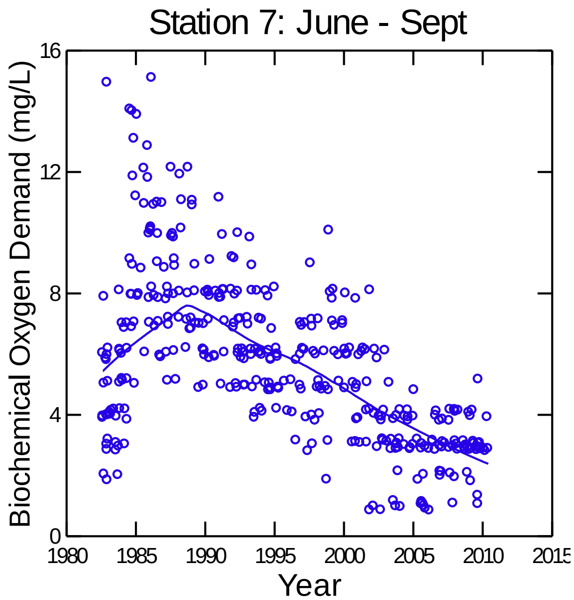
Total alkalinity as measured by Fairfax County personnel exhibited a rise from 1983 to 1990, a slow decline during the 1990's and a slow increase in the 2000's (Figure 87). The trend line at 2010 was slightly higher than it was in 1983. Overall, there has not been a statistically significant linear trend in total alkalinity in the cove over this period (Table 11).

Figure 87. Long term trend in Total Alkalinity (Fairfax County Lab Data). Station 7. Gunston Cove.



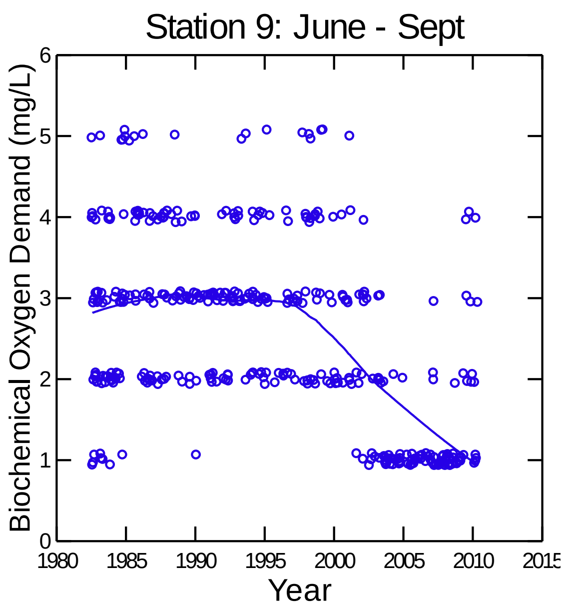
In the river a similar pattern has been observed over the three decadal intervals (Figure 88). However, there is a slightly significant linear trend over the period with a slope of 0.19 mg/L suggesting a modest increase of about 5 mg/L (Table 11).

Figure 88. Long term trend in Total Alkalinity (Fairfax County Lab Data). Station 9. Potomac mainstem.



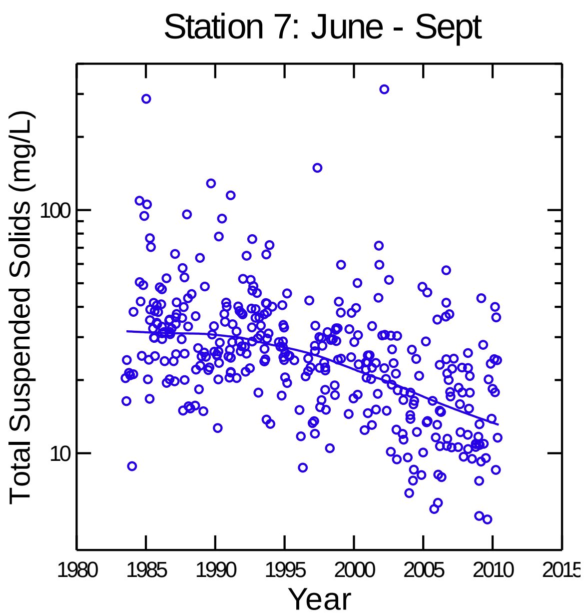
Biochemical oxygen demand has shown a distinct pattern over the long term study period in Gunston Cove (Figure 89). In the 1980's the trend line rose from about 5 mg/L to 8 mg/L by 1987. Since then there has been a steady decline such that the trend line has dropped back to about 2 mg/L. BOD has shown a significant linear decline over the entire study period at a rate of 0.19 mg/L per year yielding a net decline of 4.6 mg/L over the entire period of record (Table 11).

Figure 89. Long term trend in Biochemical Oxygen Demand (Fairfax County Lab Data). Station 7. Gunston Cove.



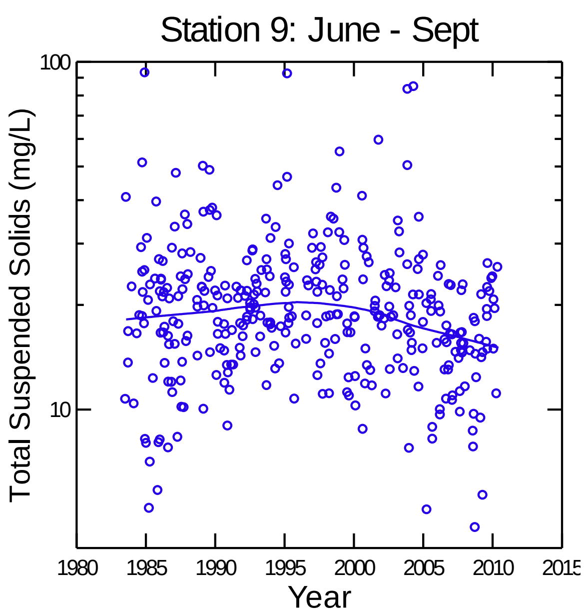
In the river biochemical oxygen demand exhibited a less distinct pattern through the mid 1990's (Figure 90). However, since that time it has decreased steadily to a median value of 1 mg/L. BOD in the river has exhibited a significant linear decrease at a rate of 0.06 units when the entire period of record was considered (Table 11). Recently, there have been a recurrence of BOD of 2 or greater.

Figure 90. Long term trend in Biochemical Oxygen Demand (Fairfax County Lab Data). Station 9. Potomac mainstem.



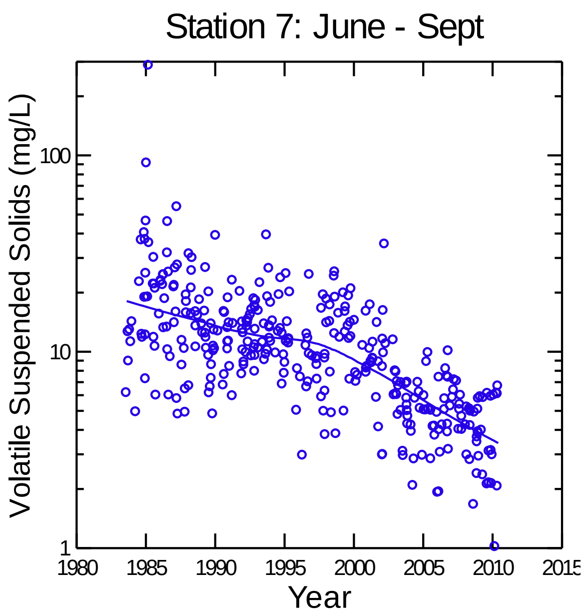
Total suspended solids (TSS) has shown a great deal of variability over the long term study period. Nonetheless, a decreasing trend has been detected in TSS in the cove with the trend line decreasing from about 30 mg/L in 1983 to about 12 mg/L in 2010 (Figure 91). Linear regression was significant indicating a decline of 1.0 mg/L per year yielding a total decline of 27 mg/L since 1984 (Table 11).

Figure 91. Long term trend in Total Suspended Solids (Fairfax County Lab Data). Station 7. Gunston Cove.



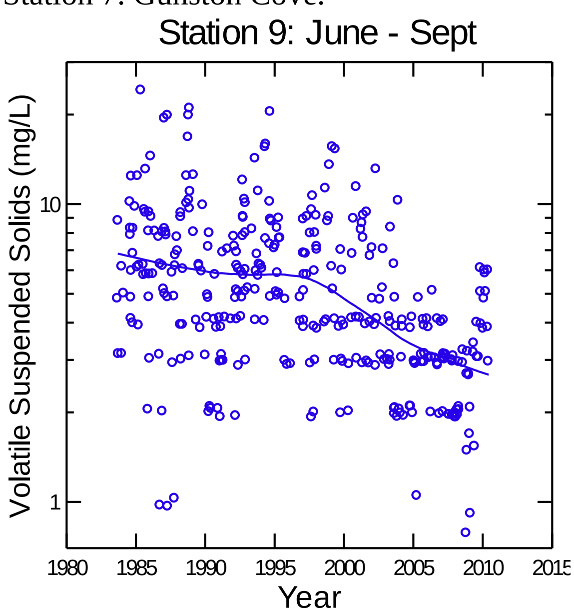
In the river TSS trends have not been as apparent (Figure 92). While much higher values have been observed sporadically, the LOWESS line remained steady at about 20 mg/L through 2000. Since then a slight decline is suggested. In the river TSS did not exhibit a significant linear trend over the period of record (Table 11). Most readings in 2010 were above the trend line.

Figure 92. Long term trend in Total Suspended Solids (Fairfax County Lab Data). Station 9. Potomac mainstem.



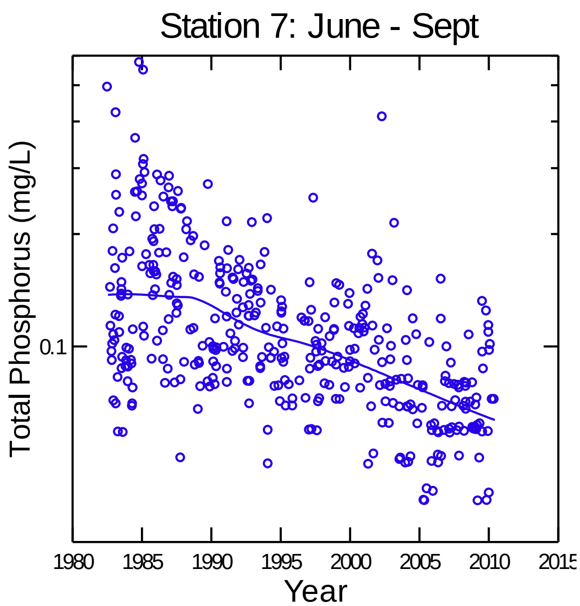
Volatile suspended solids have consistently declined over the study period and this decline seems to have accelerated in recent years (Figure 93). The LOWESS trend line has declined from 20 mg/L in 1984 to 3.5 mg/L in 2010. VSS has demonstrated a significant linear decline at a rate of 0.78 mg/L per year or a total of 21 mg/L over the study period (Table 11).

Figure 93. Long term trend in Volatile Suspended Solids (Fairfax County Lab Data). Station 7. Gunston Cove.



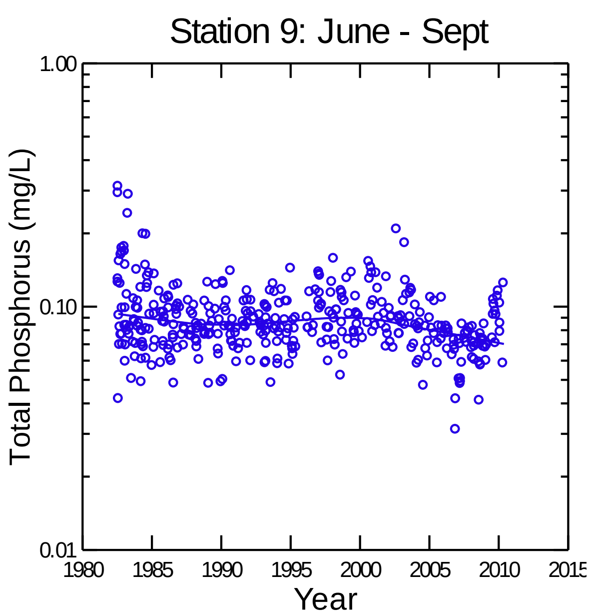
In the river the trend line for volatile suspended solids (VSS) was steady from 1984 through the mid 1990's, but has decreased consistently since then. Trend line values of about 7 mg/L in 1984 have dropped to about 3 mg/L in 2009 (Figure 94). VSS in the river demonstrated a significant linear decline at a rate of 0.18 mg/L per year or 4.7 mg/L since 1984 (Table 11). Note that all VSS readings in 2010 were above the trend line.

Figure 94. Long term trend in Volatile Suspended Solids (Fairfax County Lab Data). Station 9. Potomac mainstem.



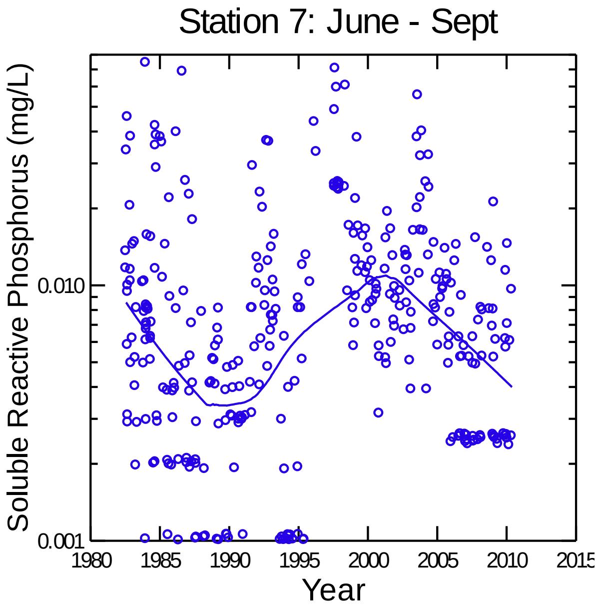
In the cove, total phosphorus (TP) has undergone a consistent steady decline since the late 1980's in the cove (Figure 95). By 2010 the trend line had dropped below 0.07 mg/L. Linear regression over the entire period of record indicated a significant linear decline of 0.004 mg/L per year or 0.1 mg/L over the entire study period (Table 11).

Figure 95. Long term trend in Total Phosphorus (Fairfax County Lab Data). Station 7. Gunston Cove.



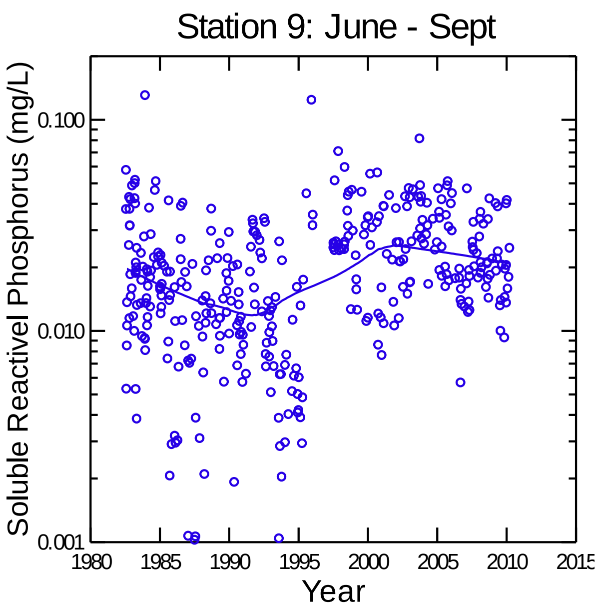
Total phosphorus (TP) values in the river have shown less of a trend over time (Figure 96). Values were steady through about 2000, but have recently shown a decline. TP exhibited a slight, but significant linear decrease in the river over the long term study period with a very modest slope of 0.001 mg/L per year (Table 11). Values in 2010 were above the trend line.

Figure 96. Long term trend in Total Phosphorus (Fairfax County Lab Data). Station 9. Potomac mainstem.



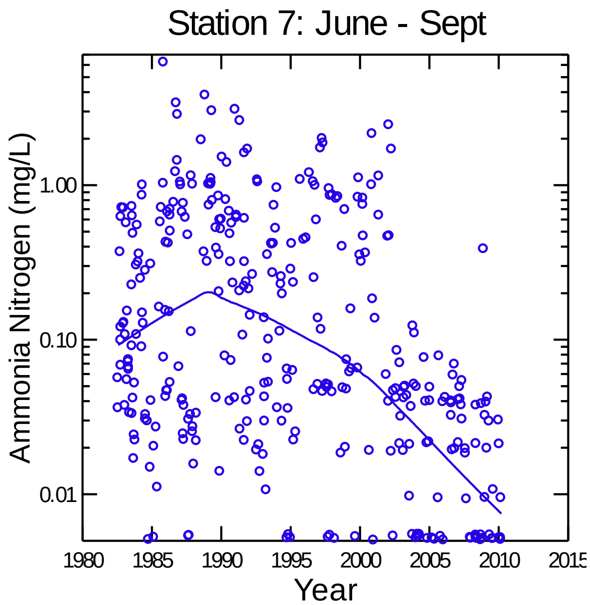
Soluble reactive phosphorus (SRP) declined in the cove during the first few years of the long term data set, but demonstrated an increase to near its initial level by 2000 (Figure 97). Since then a decline has ensued. The pattern through 2000 was consistent with the concept that SRP is negatively correlated with phytoplankton abundance; when phytoplankton are abundant, they draw down SRP. The decline in phytoplankton since about 1990 has allowed SRP to increase. The recent decline is harder to explain and has resulted in removing any statistically significant trends existing earlier (Table 11). One possibility is that less SRP is entering the cove water; another is that increased SAV is taking more up.

Figure 97. Long term trend in Soluble Reactive Phosphorus (Fairfax County Lab Data). Station 7. Gunston Cove.



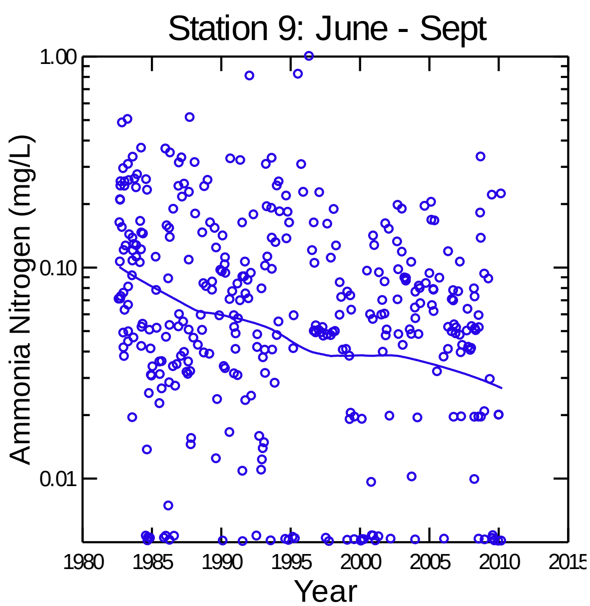
Soluble reactive phosphorus (SRP) in the river has generally been present at higher levels than in the cove, but has undergone a similar decline and resurgence (Figure 98). By 2010 the trend line in the river was at 0.02 mg/L compared to less than 0.01 mg/L in the cove. Again, this may reflect less demand for P in the river; algae in the river may be more light-limited. Values in the river in 2010 were slightly higher than in the 1980's. In the river SRP showed a positive linear trend over the study period (Table 11).

Figure 98. Long term trend in Soluble Reactive Phosphorus (Fairfax County Lab Data). Station 9. Potomac mainstem.



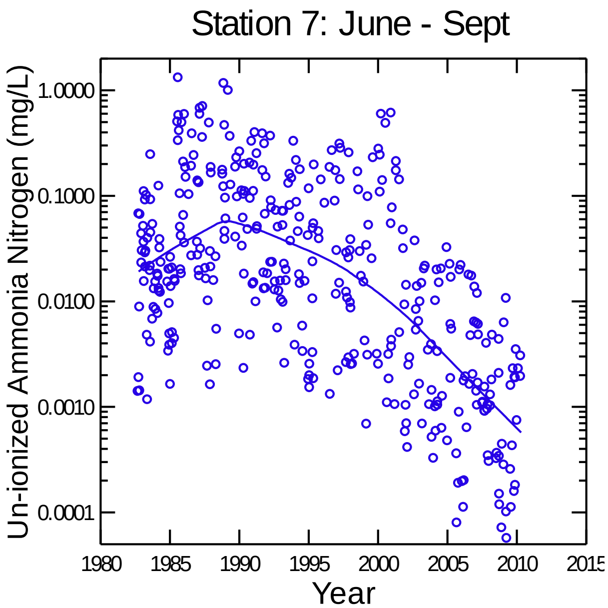
Ammonia nitrogen levels were very variable over the long term study period in the cove, but a trend of decreasing values is evident from the LOWESS trend line (Figure 99). Since 1989 the trend line has decreased from about 0.2 mg/L to less 0.01 mg/L. Linear regression has revealed a significant decline over the entire period of record with a rate of 0.017 mg/L per year yielding a total decline of 0.48 mg/L (Table 11).

Figure 99. Long term trend in Ammonia Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



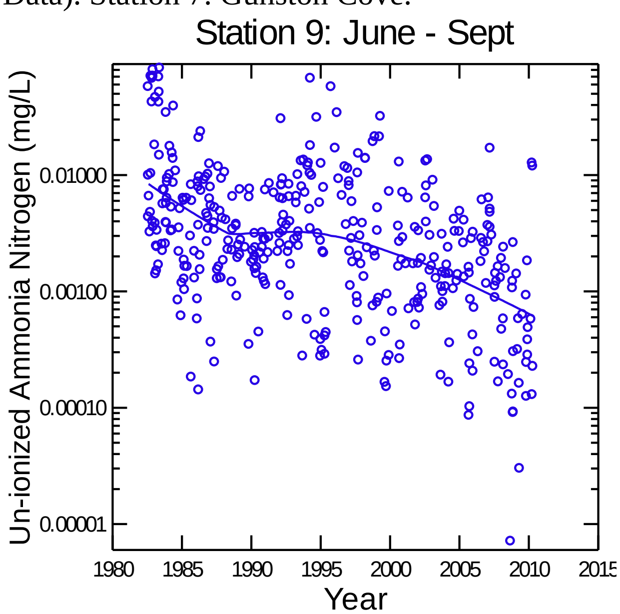
In the river a decreasing trend in ammonia nitrogen has also been observed over most of the study period (Figure 100). Between 1983 and 1999 the trend line dropped from 0.1 mg/L to 0.04 mg/L. Since 1999 it has continued to decline. Overall, in the river ammonia nitrogen has demonstrated a significant decline over the study period at a rate of 0.003 mg/L per year or a total of 0.08 over the study period (Table 11).

Figure 100. Long term trend in Ammonia Nitrogen (Fairfax County Lab Data). Station 9. Potomac mainstem.



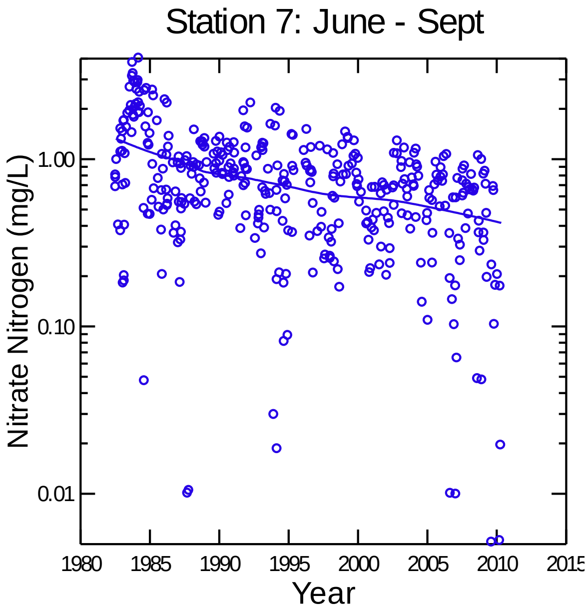
Un-ionized ammonia nitrogen in the cove demonstrated a clear increase in the 1980's with a continuous decline since that time (Figure 101). The LOWESS trend peaked at about 0.07 mg/L and is now less than 0.001 mg/L. When considered over the entire time period, there was a significant decline at a rate of 0.005 mg/L per year or a total of 0.14 mg/L over the 28 years (Table 11).

Figure 101. Long term trend in Un-ionized Ammonia Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



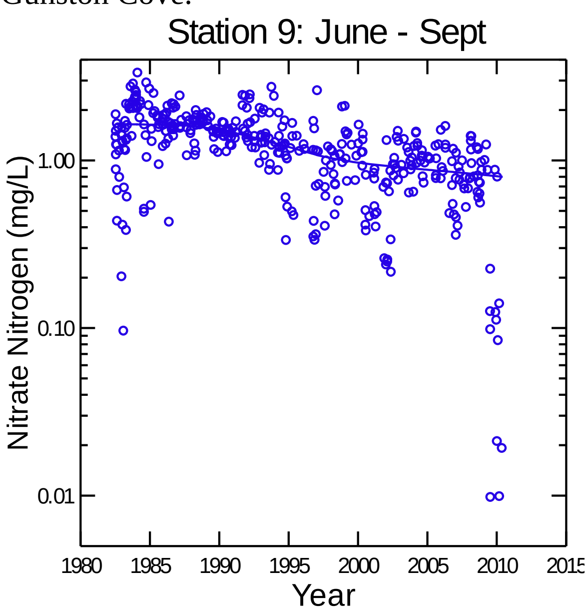
Un-ionized nitrogen in the river declined during the 1980's, was stable in the early 1990's and has declined since (Figure 102). LOWESS values have dropped from about 0.009 mg/L to less than 0.001 mg/L. Linear regression analysis over the entire period of record suggested a significant decline at a rate of 0.0004 units per year (Table 11).

Figure 102. Long term trend in Un-ionized Ammonia Nitrogen (Fairfax County Lab Data). Station 9. Potomac mainstem.



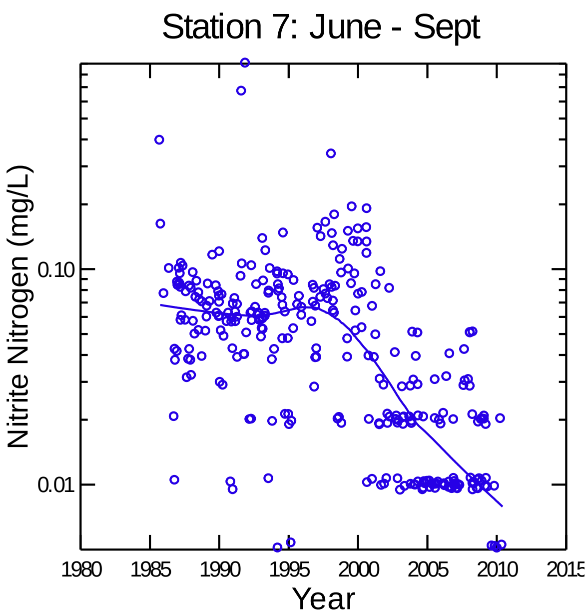
Nitrate nitrogen has demonstrated a steady decline in the cove over the entire period of record (Figure 103). The trend line was at 1.3 mg/L in 1983 and by 2010 was at 0.4 mg/L. Linear regression suggested a decline rate of 0.035 mg/L per year yielding a total decline of 1.0 mg/L over the long term study period (Table 11).

Figure 103. Long term trend in Nitrate Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



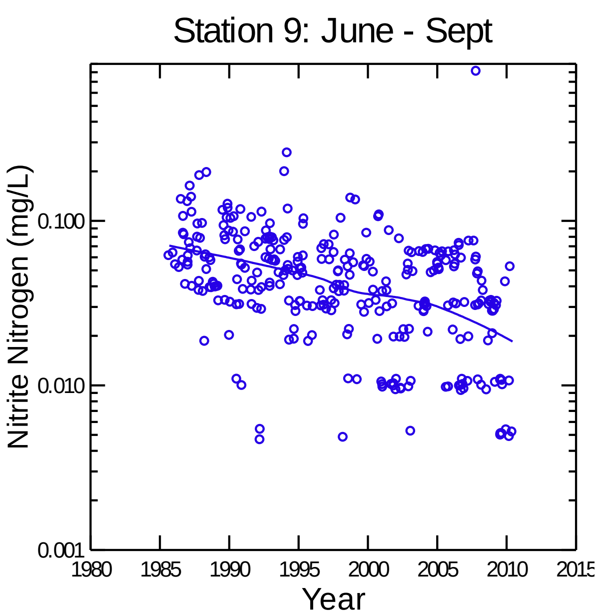
In the river nitrate nitrogen declined steadily through 2001 and has remained steady or declined more slowly since (Figure 104). The trend line dropped from 1.5 mg/L in the mid 1980's to 0.85 mg/L in 2010. Linear regression indicated a rate of decline which would have yielded a 1.1 mg/L decrease in nitrate nitrogen over the study period (Table 11). 2010 values were well below the trend line.

Figure 104. Long term trend in Nitrate Nitrogen (Fairfax County Lab Data). Station 9. River mainstem.



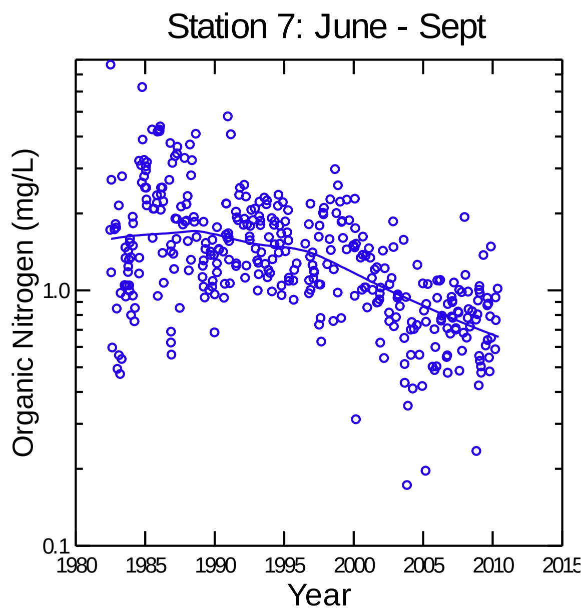
The trend line for nitrite nitrogen indicated steady values at about 0.06-0.07 mg/L through 1999 (Figure 105). Since then there is clear evidence for a decline with the LOWESS line reaching below 0.01 in 2010. Linear regression revealed a significant decline when the entire period of record was considered (Table 10).

Figure 105. Long term trend in Nitrite Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



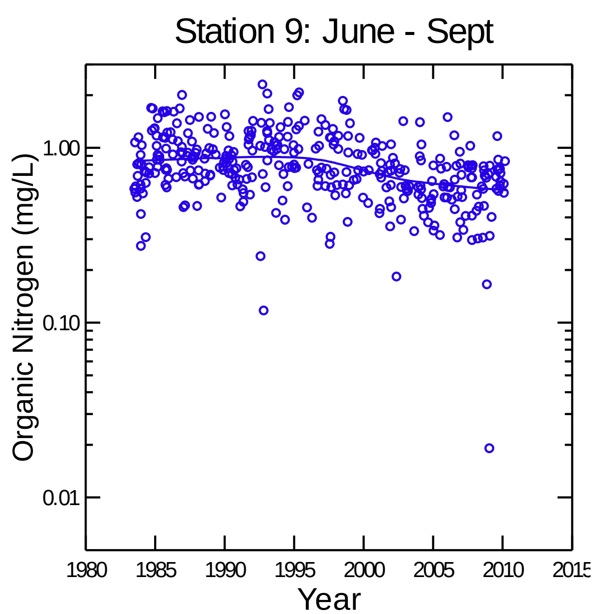
Nitrite nitrogen in the river demonstrated a pattern of decrease during the long term study period (Figure 106). The LOWESS line dropped from 0.07 mg/L in 1986 to 0.03 mg/L in 2009. Linear regression indicated a significant linear decline at a rate of 0.002 mg/L per year or 0.05 mg/L over the study period (Table 11).

Figure 106. Long term trend in Nitrite Nitrogen (Fairfax County Lab Data). Station 9. Potomac mainstem.



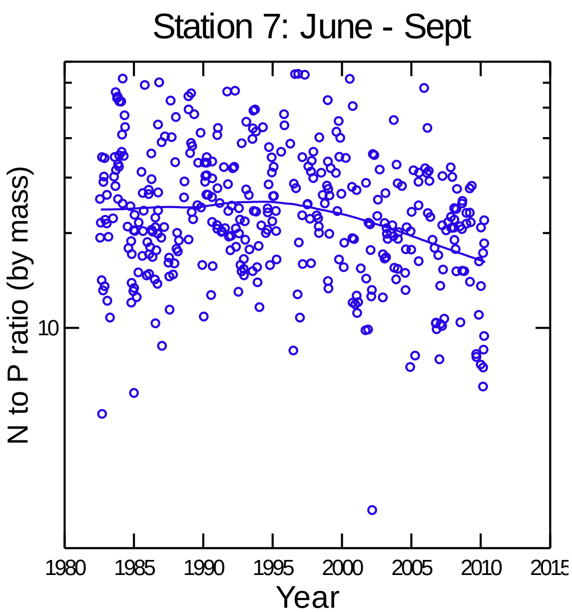
Organic nitrogen in the cove was fairly high in the 1980's and has since undergone a consistent decline through 2010 (Figure 107). In 1983 the trend line was at 1.5 mg/L and dropped to 0.6 mg/L in 2009. Regression analysis indicated a significant decline over the study period at a rate of about 0.053 mg/L per year or a total of 1.5 mg/L over the whole study period (Table 11).

Figure 107. Long term trend in Organic Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



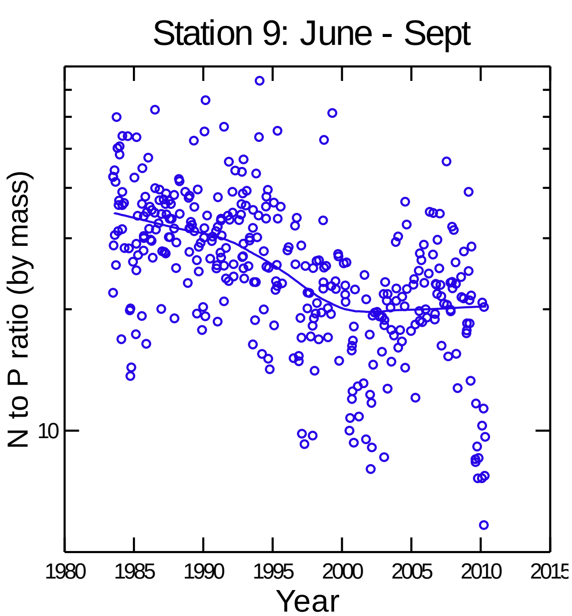
In the river organic nitrogen was steady from 1984 through 1995 and since then has consistently declined (Figure 108). The LOWESS line peaked at about 0.9 mg/L and has dropped to about 0.6 mg/L. Regression analysis indicated a significant linear decline at a rate of 0.014 mg/L when the entire period of record was considered for a total decline of 0.4 (Table 11).

Figure 108. Long term trend in Organic Nitrogen (Fairfax County Lab Data). Station 9. River mainstem.



Nitrogen to phosphorus ratio (N/P ratio) in the cove exhibited large variability, but the trend line was flat until about 1998. Since then, there has been a clear decline with the LOWESS line approaching 15 by 2009 (Figure 109). Regression analysis over the period of record indicates a statistically significant decline at a rate of 0.31 per year or about 8.7 units over the entire period (Table 11).

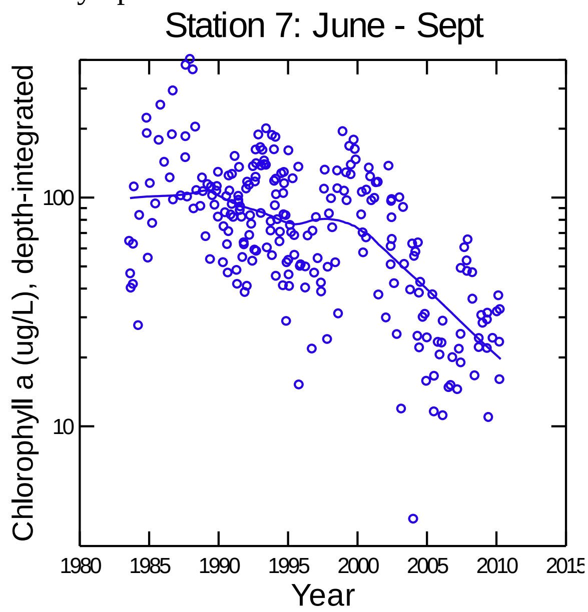
Figure 109. Long term trend in N to P Ratio (Fairfax County Lab Data). Station 7. Gunston Cove.



Nitrogen to phosphorus (N/P) ratio in the river exhibited a strong continuous decline through about 2000 (Figure 110). The LOWESS trend line declined from about 35 in 1984 to 20 in 2000. Since then a gradual increase is suggested. Linear regression analysis confirmed this decline and suggested a rate of 0.72 units per year or a total of 20 units over the long term study period (Table 11). 2010 data were substantially below the trend line falling to values indicative of N limitation.

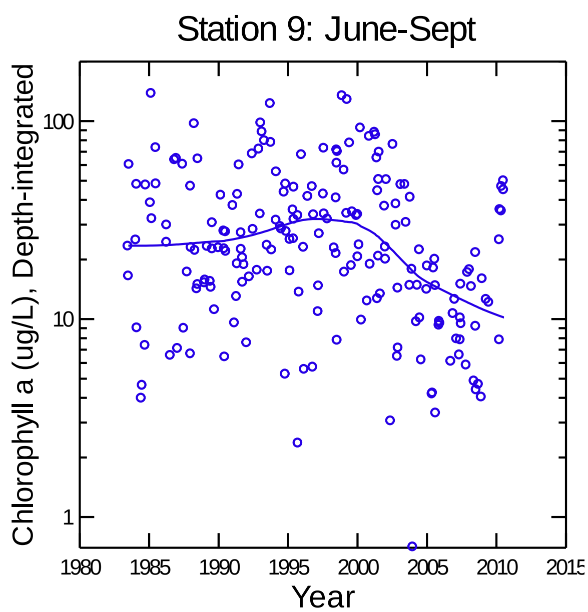
Figure 110. Long term trend in N to P Ratio (Fairfax County Lab Data). Station 9. River mainstem.

C. Phytoplankton Trends: 1984-2010



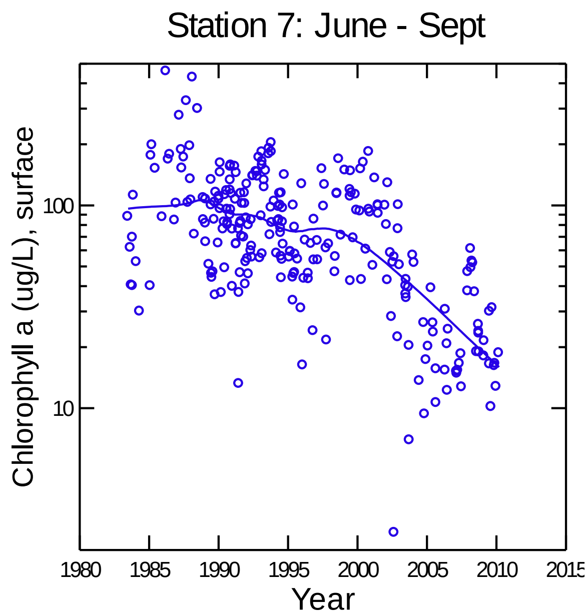
Depth-integrated chlorophyll *a* in the cove demonstrated a gradual decline from 1988 to 2000 and a much stronger decrease since then (Figure 111). The LOWESS line has declined from about 100 ug/L to a level of about 20 ug/L in 2010. The observed decrease has resulted in chlorophyll values within the range of water clarity impairment-based criteria which are 43 ug/L and 11 ug/L to allow SAV growth to 0.5 m and 1.0 m, respectively (CBP 2006). Regression analysis has revealed a clear linear trend of decreasing values at the rate of 4.1 ug/L per year or about 110 ug/L over the 27 year long term data set (Table 10).

Figure 111. Long term trend in Depth-integrated Chlorophyll *a* (GMU Lab Data). Station 7. Gunston Cove.



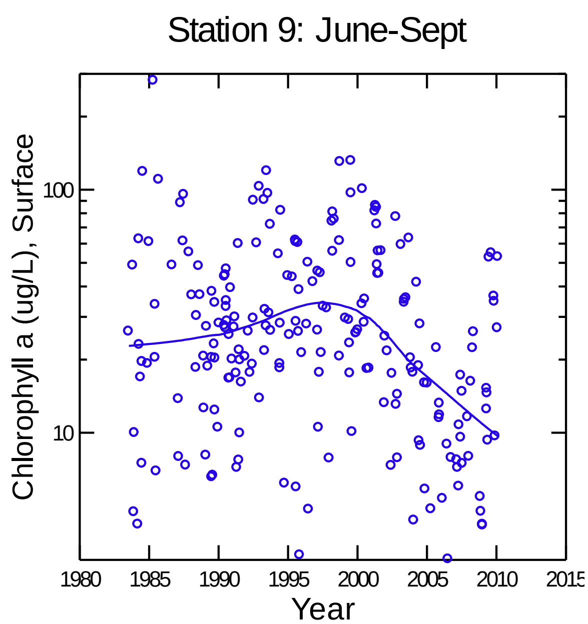
In the river depth-integrated chlorophyll *a* was fairly consistent through 2000 with the trend line varying between 20 and 30 ug/L (Figure 112). However, in recent years a strong decline has been observed with trend line values now at about 10 ug/L. Note that in 2010 river chlorophylls were well above this trend line. Regression analysis revealed a significant linear decline at a rate of 0.66 ug/L/yr when the entire period is considered (Table 10).

Figure 112. Long term trend in Depth-integrated Chlorophyll *a* (GMU Lab Data). Station 9. River mainstem.



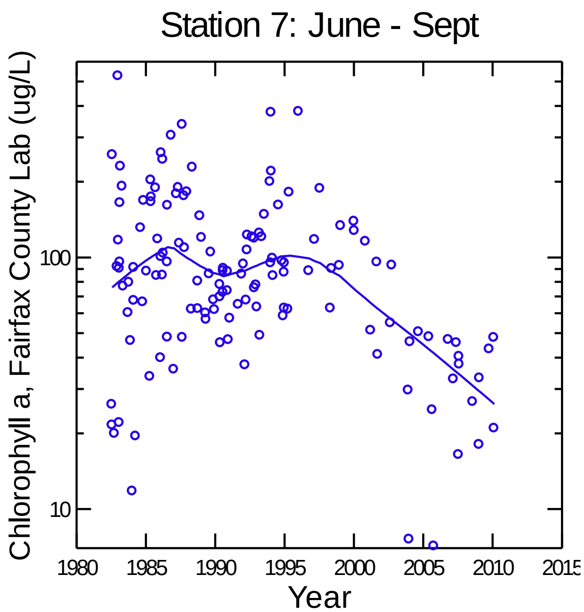
Surface chlorophyll *a* in the cove exhibited a clear decline over the long term study period, especially since 2000 (Figure 113). Trend line values of just over 100 ug/L in 1988 dropped to about 15 ug/L in 2010. The observed decrease has brought chlorophyll values into the range of water clarity impairment-based criteria which are 43 ug/L and 11 ug/L to allow SAV growth to 0.5 m and 1.0 m, respectively. Linear regression confirmed the linear decline and suggested a rate of 4.4 ug/L per year or 119 ug/L over the entire study (Table 10).

Figure 113. Long term trend in Surface Chlorophyll *a* (GMU Data). Station 7. Gunston Cove.



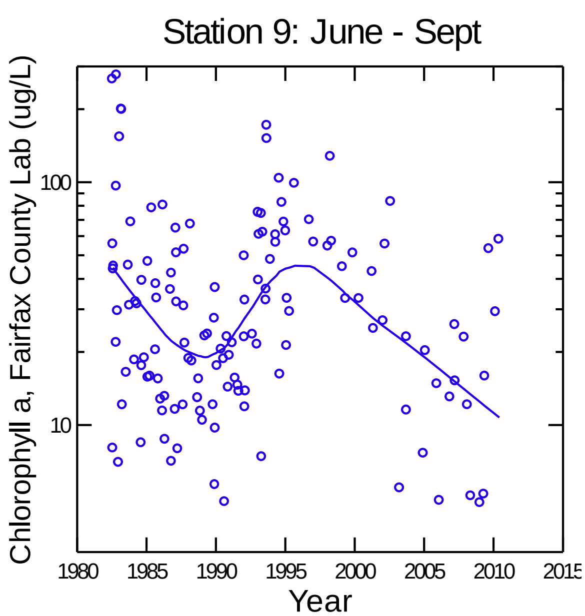
In the river the LOWESS line for surface chlorophyll *a* increased slowly from 1983 to 2000 and then declined markedly (Figure 114). Linear regression revealed a significant decline in surface chlorophyll across this period with a rate of 0.8 ug/L/yr or about 21 ug/L over the whole period (Table 10)

Figure 114. Long term trend in Surface Chlorophyll *a* (GMU Data). Station 9. River mainstem.



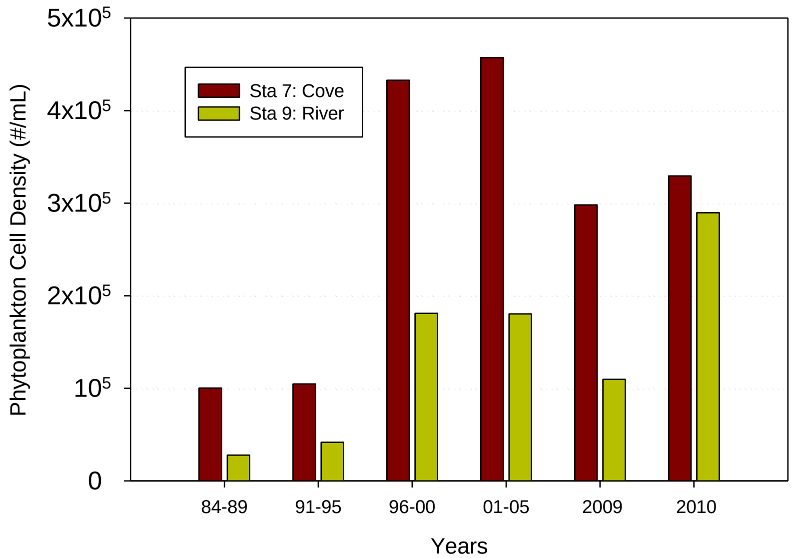
Surface chlorophyll *a* in the cove measured by the Fairfax County Lab exhibited a clear decline over the long term study period, especially since 1998 (Figure 115). Trend line values of just over 100 ug/L in 1988 dropped to about 25 ug/L in 2010. Regression analysis indicated a significant linear decline at a rate of 3.3 ug/L bringing the total decline to about 92 ug/L (Table 11). The observed decrease has brought chlorophyll values into the range of water clarity impairment-based criteria which are 43 ug/L and 11 ug/L to allow SAV growth to 0.5 m and 1.0 m, respectively.

Figure 115. Long term trend in Surface Chlorophyll *a* (Fairfax County Data). Station 7. Gunston Cove.



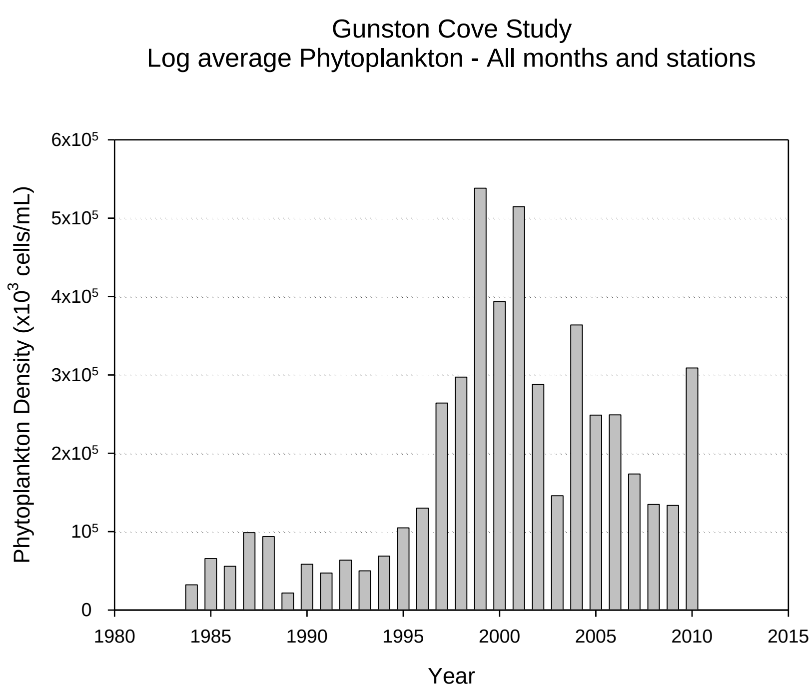
In the river surface chlorophyll *a* exhibited changing trends over the study period (Figure 116). The trend line decreased from about 45 ug/L in 1983 to 20 ug/L by 1990, then increased to about 50 ug/L by 1995. Since that time a steady decline has been observed bringing the trend line to about 10 ug/L. Regression analysis over the period of record was significant despite the variable trend (Table 11).

Figure 116. Long term trend in Surface Chlorophyll *a* (Fairfax County Data Data). Station 9. River mainstem.



Phytoplankton cell density in the cove in 2010 was similar to 2009 and markedly lower than the averages for 1996-2000 and 2001-2005 (Figure 117). In the river phytoplankton cell density was substantially higher than observed in 2009 and clearly higher than any other period on the graph. Most of the cells are relatively small so the relatively high number of cells does not necessarily mean an increase in phytoplankton biomass

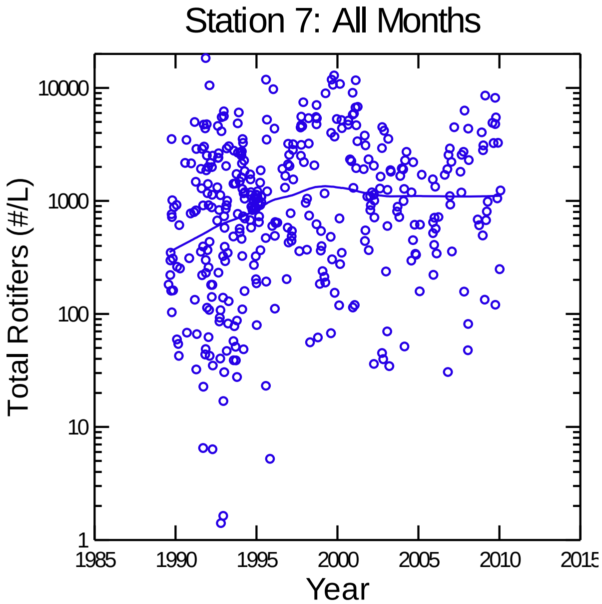
Figure 117. Interannual Comparison of Phytoplankton Density by Region.



By looking at individual years (Figure 118), we see that phytoplankton densities in the 2010 were lower than the peak years of 1999-2001, but higher than most years since then. This was due to moderately high averages at both stations

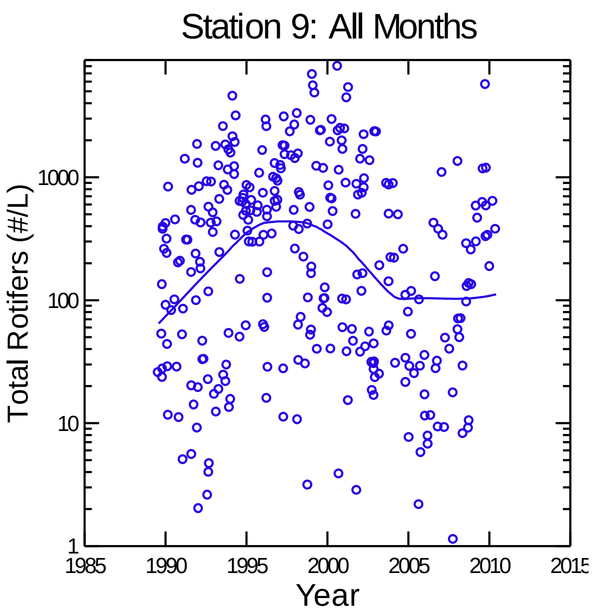
Figure 118. Interannual Trend in Average Phytoplankton Density. Units are thousands of cells per mL.

D. Zooplankton Trends: 1990-2010



In the Cove total rotifers continued to show a leveling off after an initial period of steady increase (Figure 119). The LOWESS fit line indicated about 1000/L in 2010, up from about 400/L in 1990. Linear regression analysis continued to indicate a statistically significant linear increase in total rotifers over the period since 1990 (Table 12).

Figure 119. Long term trend in Total Rotifers. Station 7. Gunston Cove.



In the Potomac mainstem, rotifers have exhibited an intitial increase, but then a marked decline in abundance which has leveled off. In the last two years values have been well above the trend line (Figure 120). The LOWESS line has dropped to about 100/L whereas it had been at about 500/L in 1996-1999 period. When the entire 1990-2003 period was considered, total rotifers did not exhibit a significant linear trend in the river (Table 12).

Figure 120. Long term trend in Total Rotifers. Station 9. River mainstem.

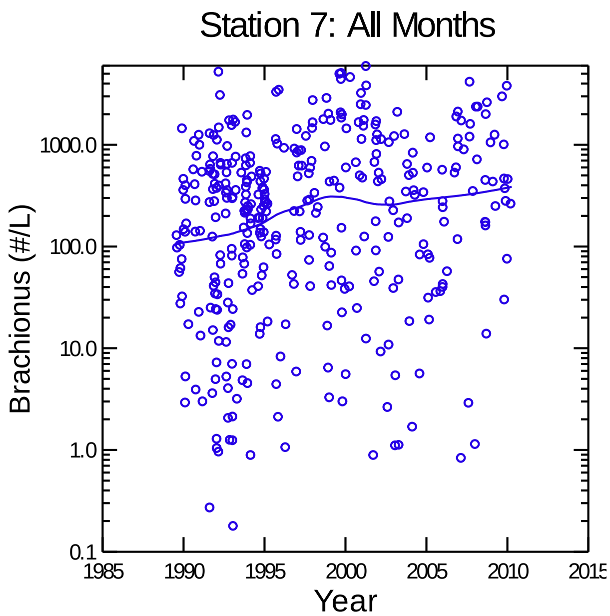
Table 12
Correlation and Linear Regression Coefficients
Zooplankton Parameters vs. Year for 1990-2010
All Nonzero Values Used, All Values Logged to Base 10

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Brachionus (m)	0.169 (364)	0.027	0.001	0.033 (288)	---	NS
Conochilidae (m)	0.201 (326)	0.024	<0.001	0.081 (244)	---	NS
Filinia (m)	0.238 (310)	0.037	<0.001	0.084 (198)	---	NS
Keratella (m)	0.300 (373)	0.041	<0.001	0.027 (298)	---	NS
Polyarthra (m)	0.228 (360)	0.030	<0.001	0.025 (280)	---	NS
Total Rotifers (m)	0.198 (390)	0.024	<0.001	0.069 (310)	---	NS
Bosmina (m)	0.091 (211)	---	NS	0.141 (246)	---	NS
Diaphanosoma (M)	0.008 (302)	---	NS	0.049 (204)	---	NS
Daphnia (M)	0.164 (251)	0.031	0.009	0.114 (157)	---	NS
Chydorid cladocera (M)	0.254 (209)	0.038	<0.001	0.395 (127)	0.051	<0.001
Leptodora (M)	0.052 (155)	---	NS	0.076 (108)	---	NS
Copepod nauplii (m)	0.415 (369)	0.044	<0.001	0.242 (306)	---	<0.001
Adult and copepodid copepods (M)	0.095 (486)	0.015	0.036	0.085 (351)	---	NS

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

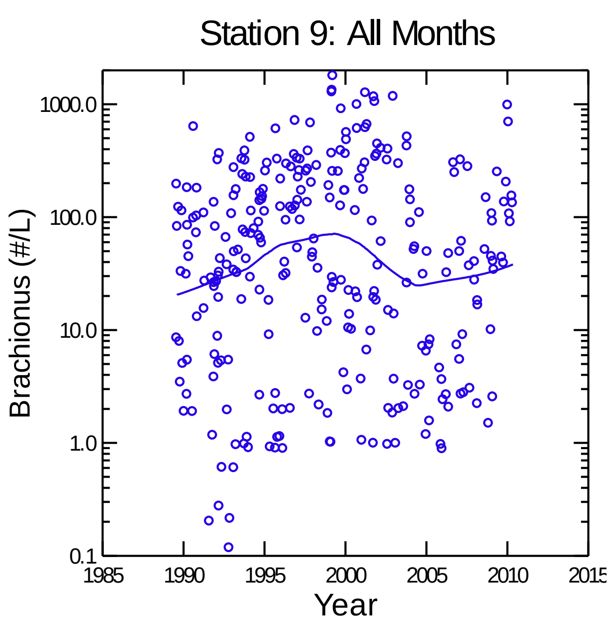
Significance column indicates the probability that a correlation coefficient this large could be due to chance alone. If this probability is greater than 0.05, then NS (not significant) is indicated.

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



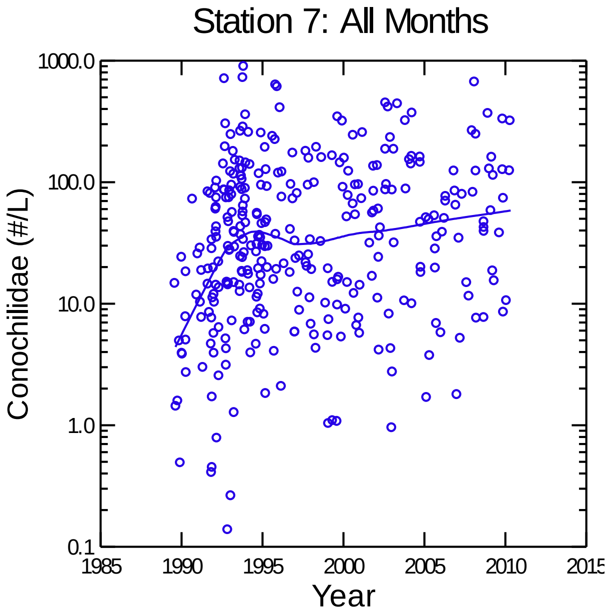
Brachionus is the dominant rotifer in Gunston Cove and the trends in total rotifers are generally mirrored in those in *Brachionus* (Figure 121). The LOWESS line for *Brachionus* suggested about 4000/L in 2010, greater than the 100/L found in 1990. A statistically significant linear increase was found over the study period (Table 12). Densities for the last 2-3 years have fallen above the trend line.

Figure 121. Long term trend in *Brachionus*. Station 7. Gunston Cove.



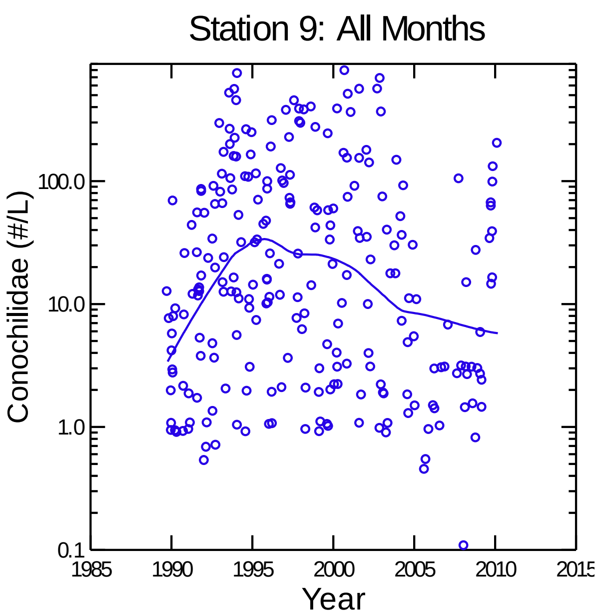
In the river the LOWESS line for *Brachionus* increased through 2000, but dropped markedly from 2000-2005.Since 2005 an increase has been noted, particularly in the last 3 years. The LOWESS value in 2010 was about 40/L, well below the peak of 80/L in 1999 (Figure 122). No linear trend was indicated when the entire study period was considered (Table 12).

Figure 122. Long term trend in *Brachionus*. Station 9. River mainstem.



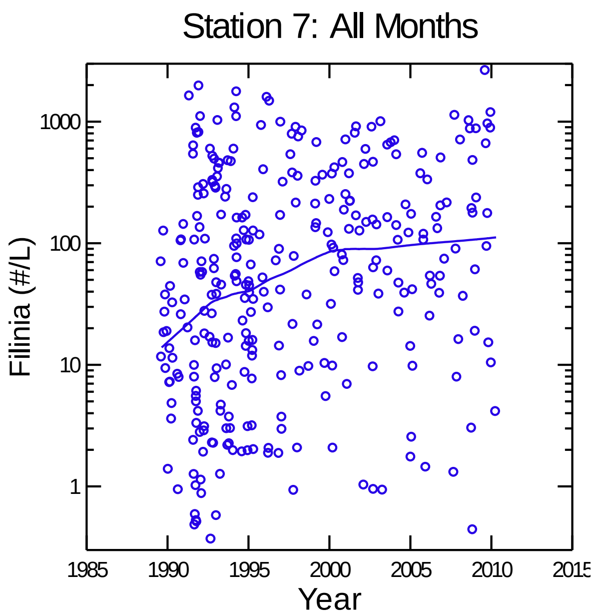
Conochilidae increased strongly from 1990-1995, leveled off, and is now showing a gradual increase. In 2010 the LOWESS trend line stood at about 60/L (Figure 123). This was well above levels of about 5/L in 1990. Over the entire period of record, a significant linear increase was found (Table 12).

Figure 123. Long term trend in Conochilidae. Station 7. Gunston Cove.



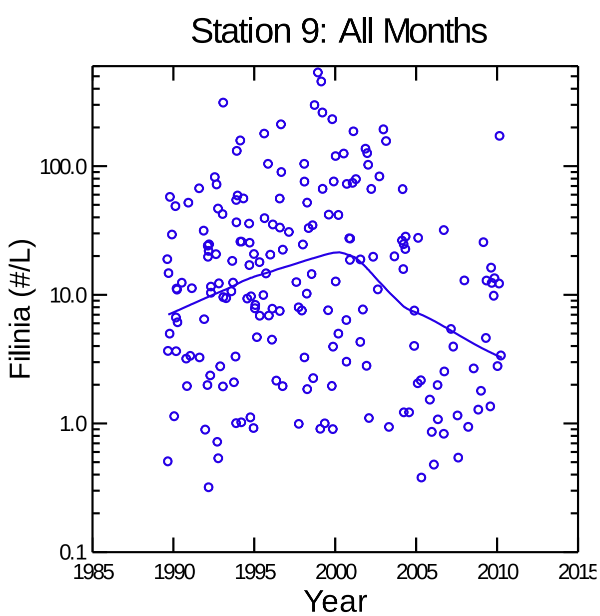
In the river, Conochilidae exhibited a strong increase in the early 1990's similar to that observed in the cove (Figure 124). However, since that time densities have declined steadily in the river. The trend line has gone from 3/L in 1990 to 35/L in 1995 to 6/L in 2010. Most values in the last 2 years were above the trend line. When the entire period of record was examined, there was not a significant linear trend (Table 12).

Figure 124. Long term trend in Conochilidae. Station 9. Gunston Cove.



In the cove *Filinia* exhibited a steady increase from 1990 through 2000 rising from about 15/L to nearly 100/L (Figure 125). It has now leveled off at about 110/L. When the entire period of record was considered, there is strong evidence for a linear increase in the cove (Table 12).

Figure 125. Long term trend in *Filinia*. Station 7. Gunston Cove.



In the river *Filinia* demonstrated an increase through about 2001, but has declined strongly since. The trend line indicates about 3/L in 2010, below both the 7/L in 1990 and well as the peak of 20/L (Figure 126). When the entire period of record was examined, there was not a significant linear trend (Table 12).

Figure 126. Long term trend in *Filinia*. Station 9. River mainstem.

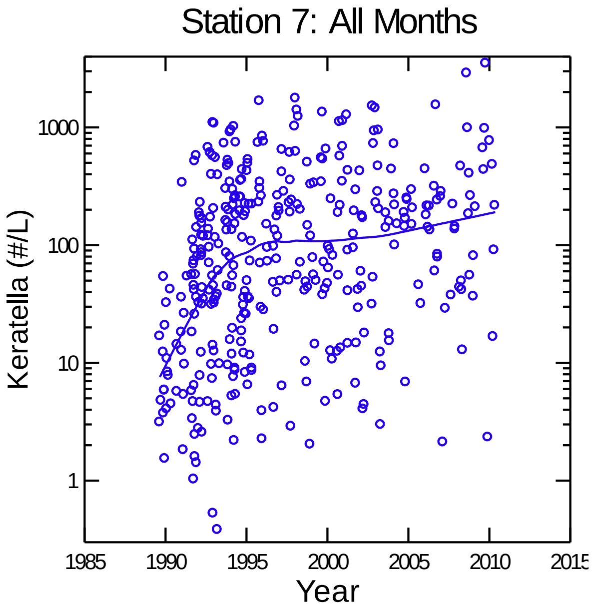


Figure 127. Long term trend in *Keratella*. Station 7. Gunston Cove.

Keratella increased strongly from 1990 to 1995 and has shown only a mild increase since then with the trend line reaching about 200/L (Figure 127). When the entire period of record was examined, there was a significant linear increase (Table 12).

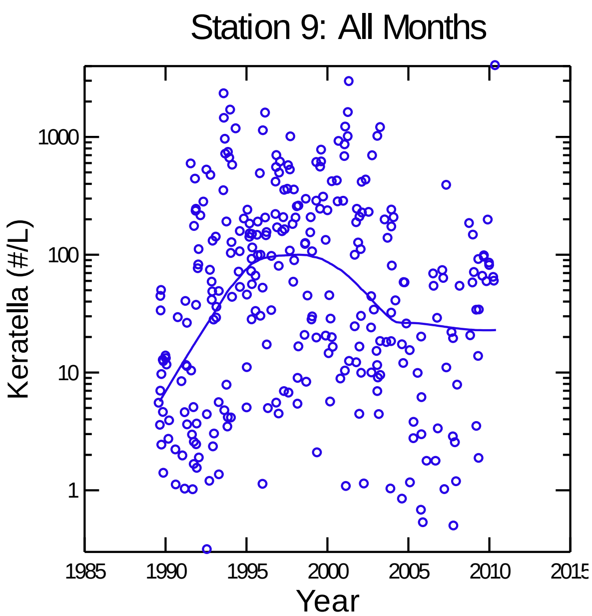
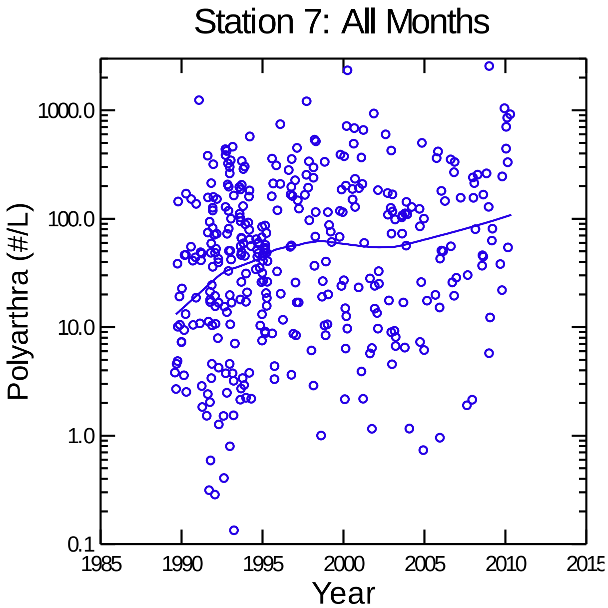


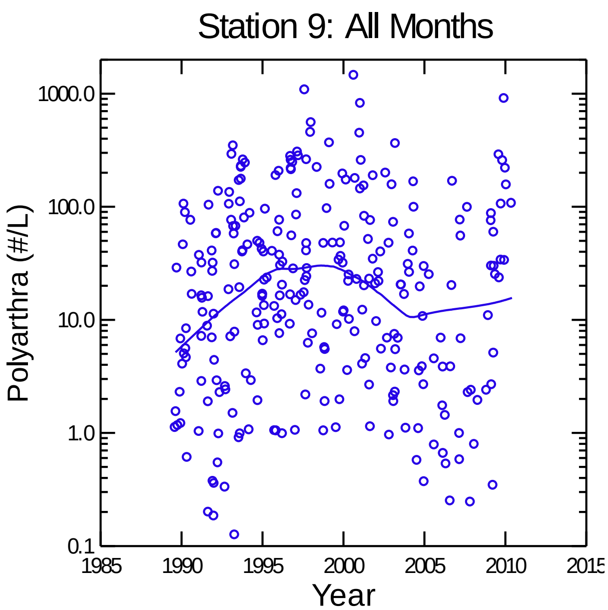
Figure 128. Long term trend in *Keratella*. Station 9. Gunston Cove.

In the river *Keratella* increased from less than 10/L in 1990 to peak values of about 100/L in the mid to late 1990's (Figure 128).. The trend line then declined to about 25/L where it has remained. Values for the last couple of years are consistently above the trend line. Linear regression showed no significant trend when the entire study period was considered (Table 12).



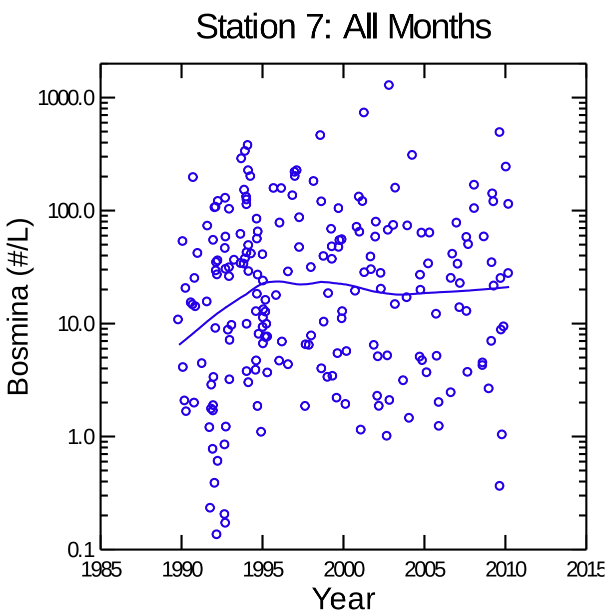
The trend line for *Polyarthra* in the cove increased steadily from 1990 to about 2000 rising from 15/L to about 60/L (Figure 129). Since 2000 densities have increased more slowly with the trend line reaching about 100/L. Regression analysis indicated a significant linear increase when the entire period of record was examined (Table 12).

Figure 129. Long term trend in *Polyarthra*. Station 7. Gunston Cove.



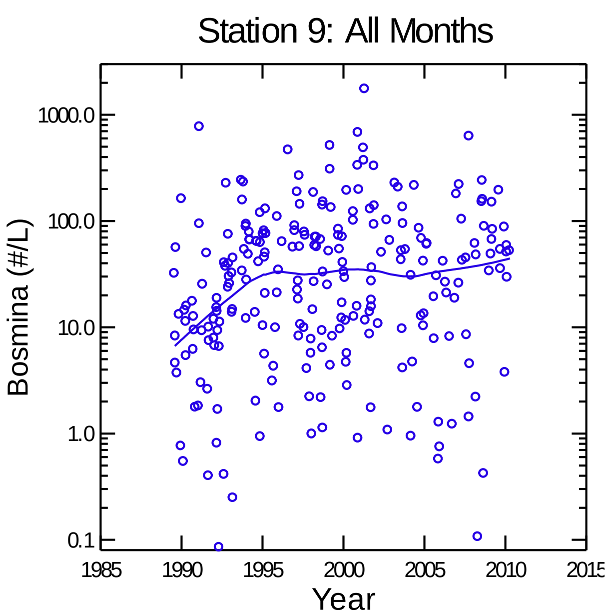
In the river *Polyarthra* showed a marked increase from 1990 to 2000 and then a decline to 2005. Recently values have increased somewhat (Figure 130). Linear regression analysis did not indicate a significant trend over the period of record (Table 12).

Figure 130. Long term trend in *Polyarthra*. Station 9. River mainstem.



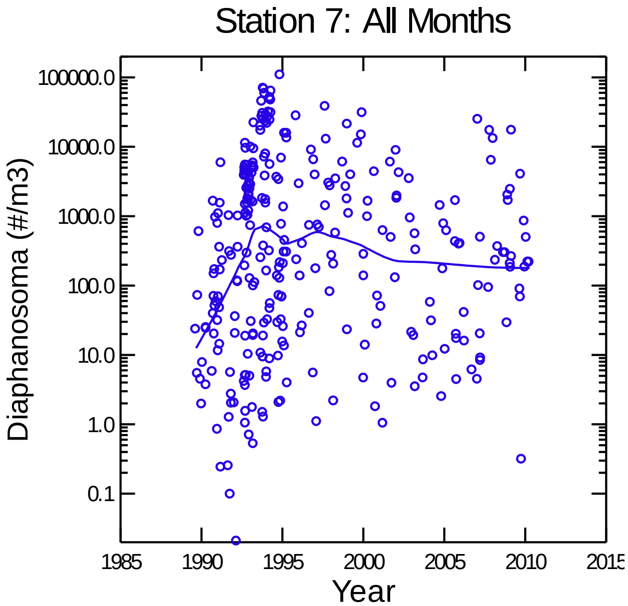
The trend line for *Bosmina* in the cove showed an increase from 7/L in 1990 to about 25/L in 2000 (Figure 131). Since 2000 a very modest decline has occurred reaching 20/L in 2010. Linear regression did not indicate a significant trend in the cove over the entire period of record (Table 12).

Figure 131. Long term trend in *Bosmina*. Station 7. Gunston Cove.



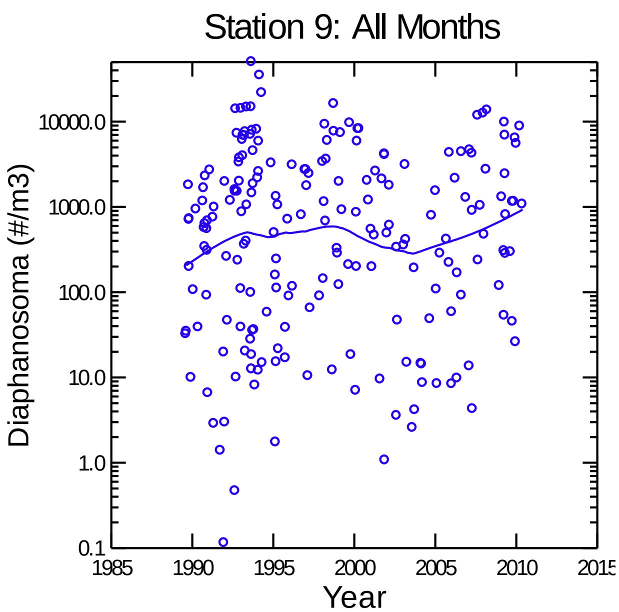
In the river mainstem the LOWESS curve for *Bosmina* increased from 1990 to 1995, and has remained rather constant since (Figure 132). The current trend line value of 40/L remains higher than the 6/L found for 1990. Regression analysis did not indicate a significant linear increase over the entire period of record (Table 12).

Figure 132. Long term trend in *Bosmina*. Station 9. River mainstem.



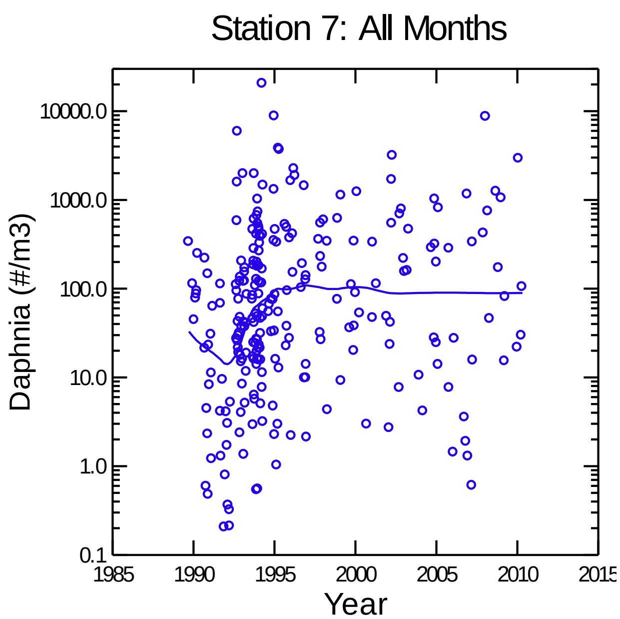
Diaphanosoma increased in 2008-20110 and the trend line appears to be stabilizing at about 200/m^3 (Figure 133). This followed a strong increase in the early 1990’s. This is lower than the value of 500/m^3 in the mid 1990’s, but well above . the 20/m^3 observed in 1990. Linear regression analysis of the entire period of record indicated a no significant linear trend (Table 12).

Figure 133. Long term trend in *Diaphanosoma*. Station 7. Gunston Cove.



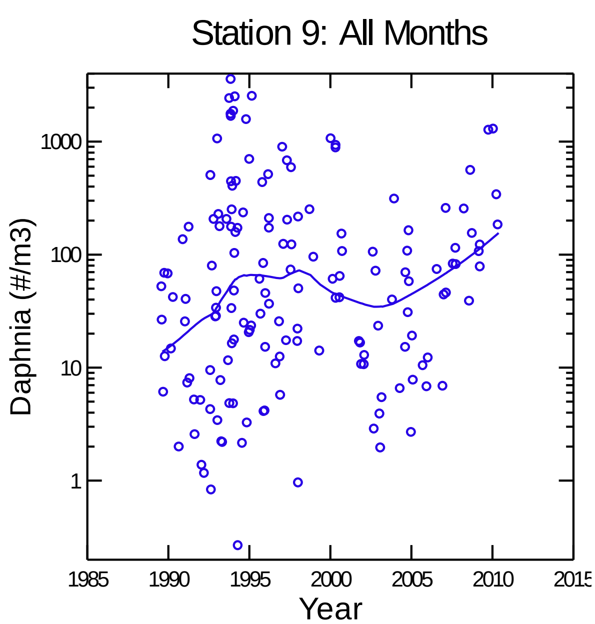
In the river the LOWESS line suggested a generally stable trend in *Diaphanosoma* (Figure 134). The trend line value of 1000/m^3 found in 2010 compared with values as high as 800/m^3 in 1999 and 1993 and as low as the 200/m^3 in 1990. Regression analysis indicated no significant linear trend over the period of record (Table 12).

Figure 134. Long term trend in *Diaphanosoma*. Station 9. River mainstem.



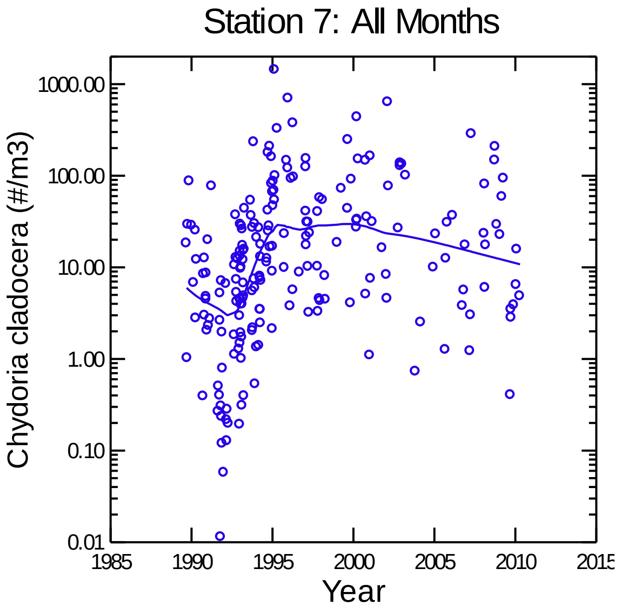
Daphnia in the cove stabilized in 2009, reaching about 90/m^3 similar to about 100/m^3 in 1995 (Figure 135). This is up from the low of about 10/m^3 in 1992 and the value of 40/m^3 in 1990. Regression analysis examining the entire period of record gave some support for a linear increase (Table 12).

Figure 135. Long term trend in *Daphnia*. Station 7. Gunston Cove.



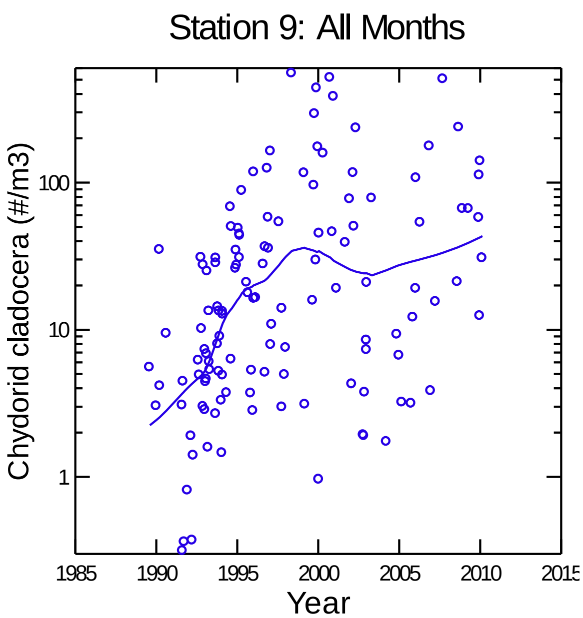
Daphnia in the river has shown a lot of variability over time, but little consistent trend (Figure 136). The trend line in 2010 reached 150/m^3, substantially higher than the level observed at the beginning of the record in 1990. Regression analysis indicated no significant linear trend over the study period (Table 12).

Figure 136. Long term trend in *Daphnia*. Station 9. River mainstem.



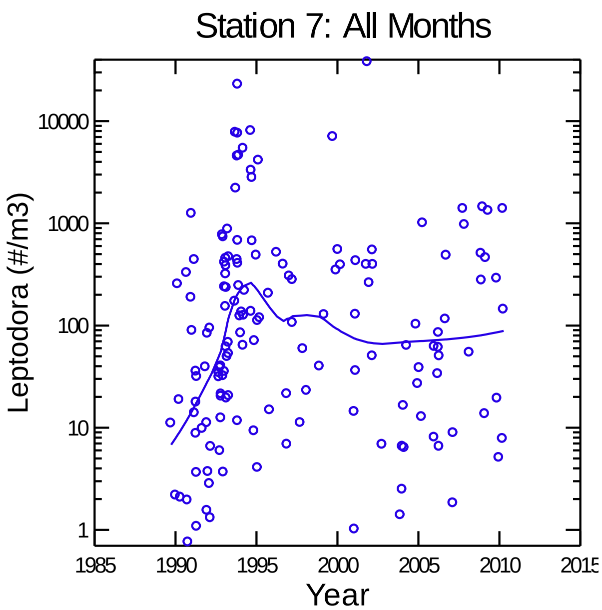
Chydorid cladocera in the cove continued a slow decline observed in recent years to about 10/m^3, substantially higher than the low of 3/m^3 in 1992 and the initial value of 8/m^3 in 1990, but below trend line values of 30/m^3 observed between 1995 and 2000 (Figure 137). Regression analysis gave evidence for a linear increase over the study period (Table 12).

Figure 137. Long term trend in Chydorid Cladocera. Station 7. Gunston Cove.



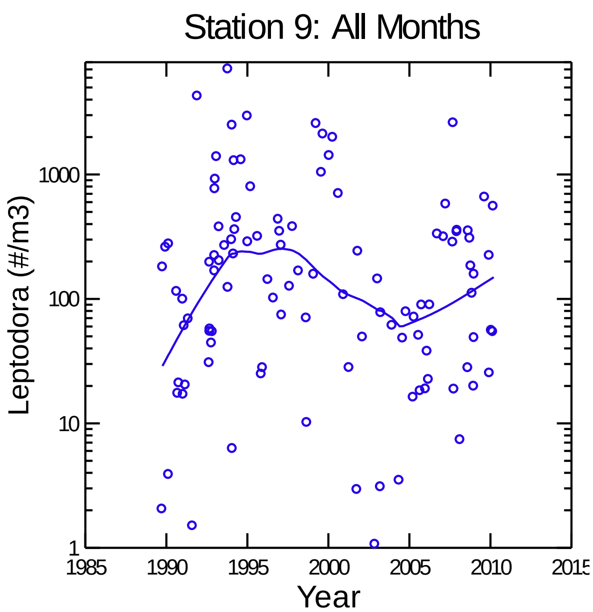
In the river chydorids continued a gradual increase to about 40/m^3, well above the low of about 4/m^3 in the early 1990's (Figure 138). There was evidence for a linear increase in chydorids over the entire study period as indicated by linear regression analysis (Table 12).

Figure 138. Long term trend in Chydorid Cladocera. Station 9. River mainstem.



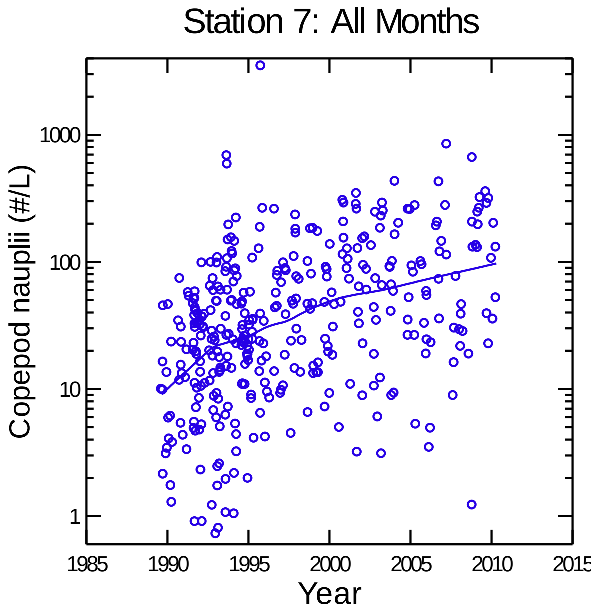
In the cove the trend line for *Leptodora*, the large predaceous cladoceran, has stabilized at about 100/m^3, down from its high of about 200/m^3 in 1994, but above the 1990 value of 10/m^3 (Figure 139). There was not evidence for a significant linear change in *Leptodora* over the entire study period (Table 12).

Figure 139. Long term trend in *Leptodora*. Station 7. Gunston Cove.



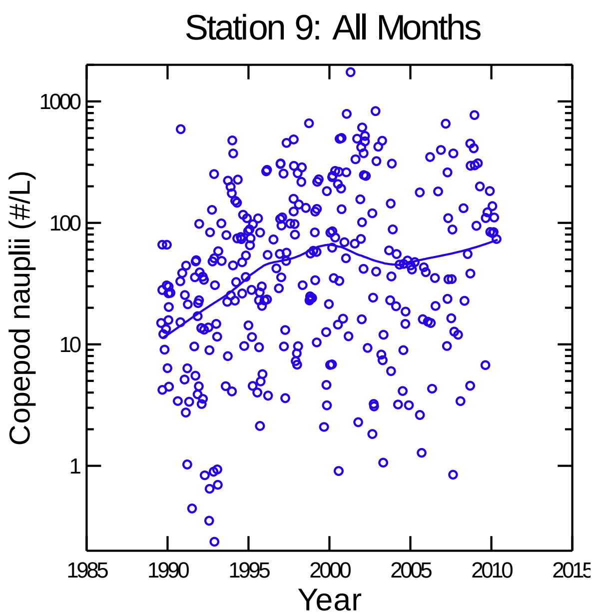
In the river, *Leptodora* densities continued to increase following a decline which began in 1995 resulting in trend line values of about 150/m^3 for 2010 (Figure 140). These values are well above those observed in 1990, but are substantially lower than the peak of 300/m^3 in 1994. Linear regression analysis did not detect a significant linear trend when the whole study period was considered (Table 12).

Figure 140. Long term trend in *Leptodora*. Station 9. River mainstem.



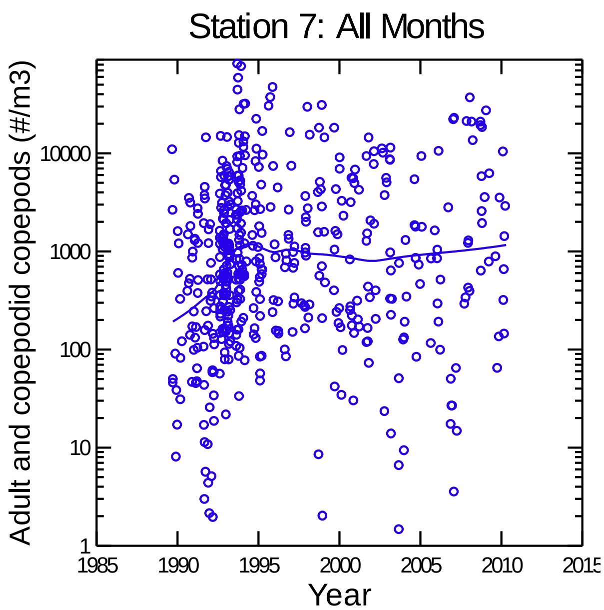
Copepod nauplii, the immature stages of copepods, continued their upward trend in 2010 (Figure 141). Trend line values reached 100/L in 2010 well above the initial level of 10/L observed in 1990. A strong linear increase was observed over the study period (Table 12).

Figure 141. Long term trend in Copepod Nauplii. Station 7. Gunston Cove.



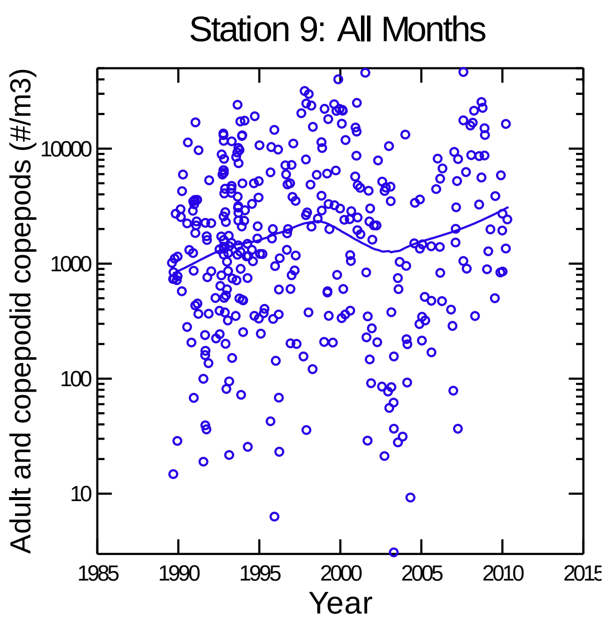
In the river, copepod nauplii showed a gradual increase following a decline begun in 2000 (Figure 142). The 2010 LOWESS trend line value was 80/L, up from an initial value of 10/L in 1990, just overtaking the previous peak of about 70/L. And recent values have been above the trend line. A significant linear increase was found for nauplii over the study period (Table 12).

Figure 142. Long term trend in Copepod Nauplii. Station 9. River mainstem.



Adult and copepodid copepods increased strongly in the early 1990's and since have remained fairly constant (Figure 143). Levels in 2010 were higher resulting in a trend line level of about 1000/m^3, above the initial level of 200/m^3 observed in 1990 and similar to the a peak of 1000/m^3 in 1994. Copepods exhibited a significant linear increase in the cove over the study period (Table 12).

Figure 143. Long term trend in Adult and Copepodid Copepods. Station 7. Gunston Cove.



Adult and copepodid copepods continued to increase following a slight decline begun in 1998 (Figure 144). The trend line in 2009 reached 3000/m^3, similar to the previous maximum of 2500/m^3 in 1998. A significant linear increase was not found when the entire study period was considered (Table 12).

Figure 144. Long term trend in Adult and Copepodid Copepods. Station 9. River mainstem.

E. Ichthyoplankton Trends

Ichthyoplankton monitoring provides a crucial link between nutrients, phytoplankton, zooplankton and juvenile fishes in seines and trawls. The ability of larvae to find food after yolk is consumed may represent a critical period when survival determines the abundance of a year-class. The timing of peak density of feeding stage fish larvae is a complex function of reproductive output as well as the temperature and flow regimes. These peaks may coincide with an abundance or scarcity of zooplankton prey. When the timing of fish larva predators overlaps with their zooplankton prey, the result is often a high abundance of juveniles that can be observed in high density in seines and trawl samples from throughout the cove. In addition, high densities of larvae but low juvenile abundance may indicate that other factors (e.g., lack of significant refuge for settling juveniles) are modifying the abundance of a year-class. For example, there is more variability in the smoothed trend of fish density from seine and trawl catches for species such as river herring, gizzard shad, and white perch, than there is in the larval density trends. This situation has multiple explanations including a change in distribution of larvae during development and significant year-class modifications that occur during late larval and early juvenile stages.

For all of the dominant species of ichthyoplankton, densities have exhibited a slightly declining or relatively flat trend over the course of monitoring on this survey. Clupeid larvae (which are primarily river herring and gizzard shad), *Morone* sp. (mostly white perch), Atherinids (inland silversides), and yellow perch all exhibited a spike in density during the earliest five years of monitoring. In all cases, this pattern was followed by a rapid decline to a relatively flat trend in density during the past decade. For Clupeids, *Morone* sp. and Atherinids, 1996 was an exceptional year with high mean larval densities. Comparing 2009 with the previous year, the largest changes occurred for *Alosa* sp. and *Dorosoma* sp. with an approximate 15- and 3.4-fold increase in total number captured, respectively for these groups (Table 13).

The peaks in abundance over the season reflect characteristic spawning times of each species. The earliest are yellow perch (Figure 152) and white perch (Figure 148), followed by gizzard shad and river herring (Figure 146), and inland silversides (Figure 150). Yellow perch tend to have a narrower spawning period – thus the larval density peaks at the beginning of the sampling season and tapers rapidly. By comparison, white perch begin spawning early but have a more protracted spawning period. Consequently, white perch larvae are found throughout most of the sampling season. Gizzard shad and river herring show a more pronounced peak in mean larval density that is centered around the last weeks of May. More detailed analysis of periodicity and inter-annual variability of larval fish data could be combined effectively with regional temperature, river flow patterns, and zooplankton data, but this is beyond the scope of this report.

Table 13. The larval fishes collected in Gunston Cove and the Potomac River in 2004-10

Table 13
Larval Fishes Collected, by Taxon
Gunston Cove Study – 2004-10

Taxon	Common Name	Number caught 2005	2006	2007	2008	2009	2010	Total (%)
Clupeidae	herring and shad family	650	0	6	0	0	0	656 (3.9)
Alosa sp.	American shad, alewife, hickory shad, or blueback herring	569	63	103	15	224	1332	2306 (13.7)
Dorosoma sp.	gizzard shad or threadfin shad	2110	254	992	510	1768	5846	11480 (68.2)
Brevortia tyranus	menhanden	0	0	0	2	0	0	2 (<0.1)
Morone sp.	white perch or striped bass	242	52	233	427	414	504	1872 (11.1)
Perca flavescens	yellow perch	0	136	70	6	2	86	300 (1.8)
Menidia beryllina	inland silverside	26	54	31	8	10	87	216 (1.3)
Erimyzon oblongus	creek chubsucker	1	0	0	0	0	0	1 (<0.1)
Strongylura marina	Atlantic needlefish	0	0	0	1	1	0	2 (<0.1)
Lepomis sp.	sunfish	0	0	0	0	0	1	1(<0.1)
Unidentified		0	0	5	0	0	0	5 (<0.1)
Total		3598	559	1440	969	2419	7856	16841

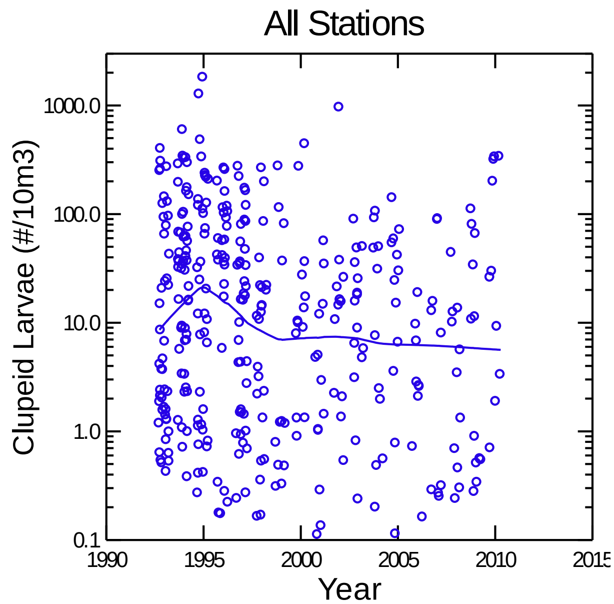


Figure 145. Long term trend in Clupeid Larvae.

A graph of clupeid fish larvae averaged over all stations from 1993 through 2003 is shown in Figure 145. Because of the difficulty of distinguishing post yolk sack gizzard shad from the alewife and blueback herring, this graph groups all three species. The trend line remains steady at about 7 larvae per 10 m^3 where it has been since about 1999. It remains lower than values of about 25 per 10 m^3 in the mid 1990's.

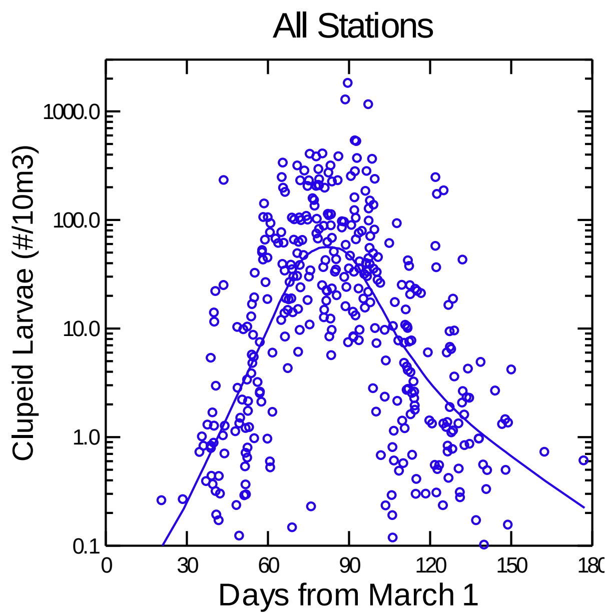


Figure 146. Seasonal pattern in Clupeid Larvae.

The seasonal pattern in clupeid larvae for 1993-2007 (Figure 146) shows that a peak in density occurs about 80-85 days after March 1, or in the last two weeks of May. A first explanation of the timing and breadth of the peak most certainly lies in the interannual variability of the development of warming of the creek and cove water. A second explanation is the sequentially extended spawning period by the three dominant clupeid species. The occurrence of the peak late in the spring may indicate a dominance of gizzard shad larvae in the data.

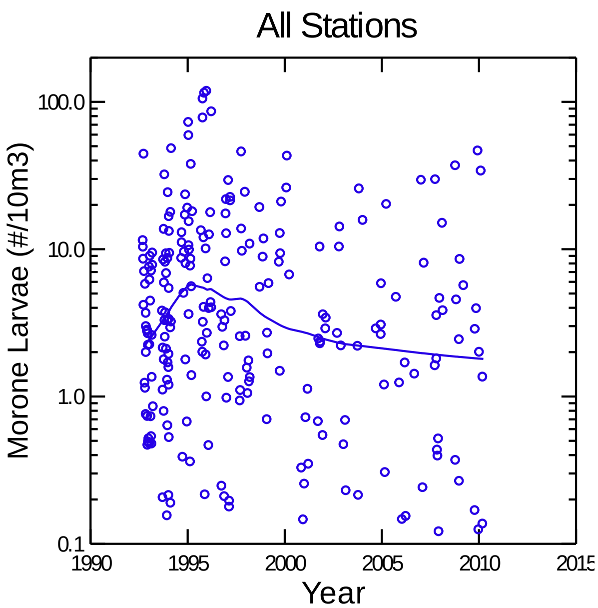


Figure 147. Long term trend in *Morone* Larvae.

The trend in number of white perch larvae per 10 m^3 since 1993 is depicted in the LOWESS graph in Figure 147. A steady decline in catch is shown since 1996, although it appears to be leveling off and the overall range of values is similar over the period.

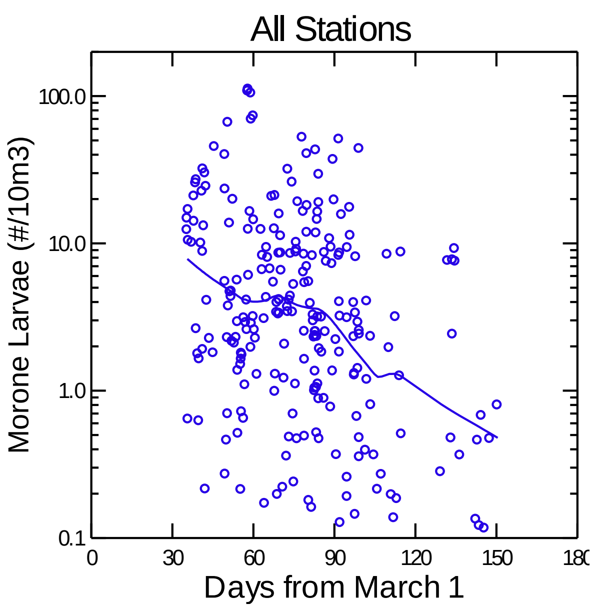


Figure 148. Seasonal pattern in *Morone* Larvae.

The seasonal occurrence of number of white perch larvae per 10 m^3 is shown in Figure 148. The highest density of larvae occurs on the earliest date that larvae appear in the collections and declines thereafter. This peak occurs in early April.

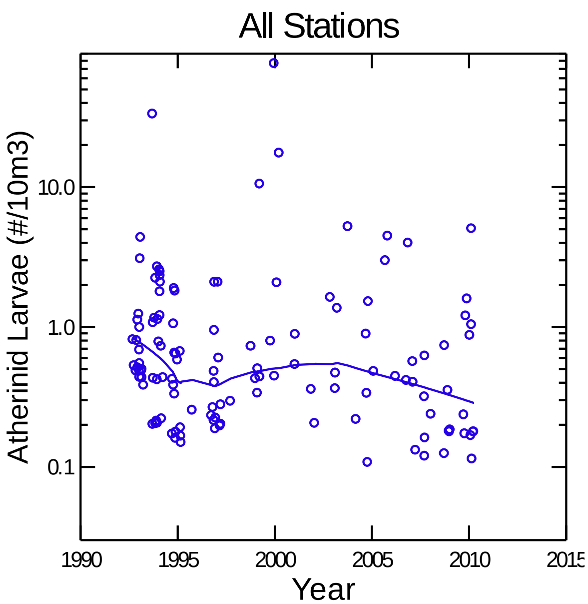


Figure 149. Long term trend in Atherinid Larvae.

The long term trend in density of Atherinid larvae (probably all inland silverside larvae) is presented in a LOWESS graph in Figure 149. The number of atherinid larvae per 10m^3 caught in individual has remained rather low. These open water collections are probably not totally representative of the population of larvae in the cove, since they may remain in the shallows along the shore or in the submerged weed beds where they are spawned.

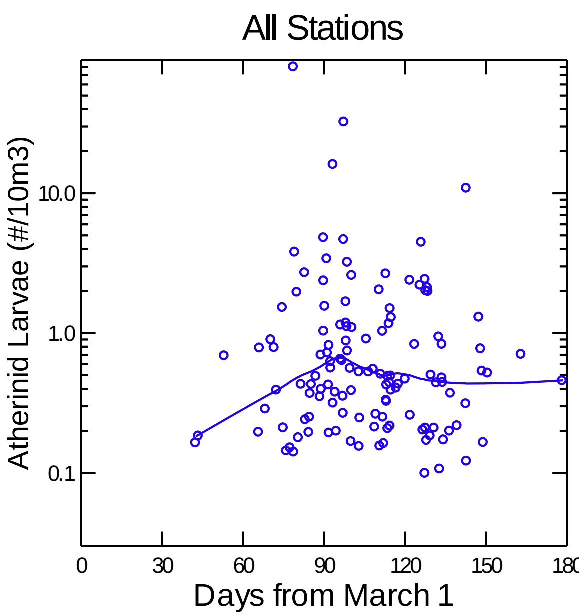


Figure 150. Seasonal pattern in Atherinid Larvae.

The seasonal occurrence of atherinid larvae per 10m^3 is shown in a LOWESS graph in Figure 150. The pattern shows maximum density around 90 days after March 1, or around the first week of June. However, the peak is not pronounced, and the density persists at a slightly lower level into the fall.

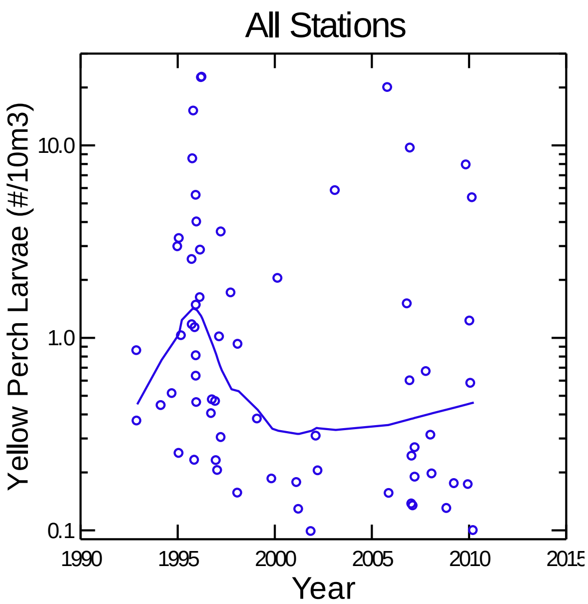


Figure 151. Long term trend in Yellow Perch Larvae.

The LOWESS graph in Figure 151 gathers the trend in density of yellow perch since 1993. Following unusually high densities in 1996, the general has been flat, but with a lot of variability.

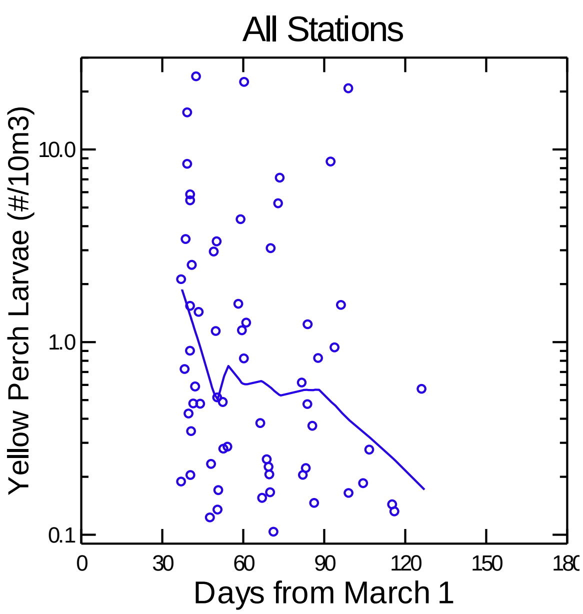


Figure 152. Long term trend in Yellow Perch Larvae.

The long term pattern of seasonal occurrence of yellow perch larval density is presented in a LOWESS graph in Figure 152. The greatest densities occur in early April, but larvae persist as late as early June.

F. Adult and Juvenile Fish Trends: 1984-2010

Trawls

Overall patterns

Annual abundance of juvenile fishes inside Gunston Cove is indexed by mean catch per trawl in the inner cove (stations 7 and 10 combined; Table 14, Figure 153a). Since 1984, this index has fluctuated by over an order of magnitude, and the pattern was predominately due to changes in the catch rate of white perch (Figure 153a). Consequently, the catch rates of white perch and all species combined has exhibited a continuous declining trend across this entire period (Figure 153b). On average, catch rates of fishes within the cove were approximately one-third of what was recorded in the first few years of the survey (Figure 153b). The overall catch rate for the inner cove (stations 7 and 10) in 2010 was above the long-term mean (118.7) for the survey, and ranked in the 96th percentile. Of the most typically captured species only, white perch showed a remarkable increase to the highest level observed on this survey. At station 9 in the main stem of the river, catch rate of all species combined was also below the long-term mean (56.9), and ranked in the 41st percentile. At station 9, juvenile fishes are less common than in shallower nursery habitats represented by stations inside the cove. Therefore, catch rates at station 9 exhibited less variability than in the cove and generally reflected more, older fish in these samples than at the other stations. Annual trends in total catch rate at station 9 were still driven by white perch (Figure 158a). With the exception of 2007 which had the highest catch rate on the survey, white perch catch rates at station 9 have demonstrated a relatively flat trend. The importance of other species in the catches is apparent via the lower proportion of white perch in catches at station 9 since 2000 (Figure 158b,c).

High inter-annual variability in juvenile abundance is a typical life history characteristic of many juvenile anadromous fishes such as white perch and anadromous alosines, and catch rates on this survey reflect this. In addition, some of the variability at stations 7 and 10 coincides with a pronounced increase in SAV since 2000. This increase in SAV not only reduced the efficiency of trawls at station 10, but may represent a significant alternative habitat for white perch. Therefore, a spatial shift in the distribution of juvenile white perch might also have affected catches at station 7 where SAV does not directly impede trawling.

Annual trends in other dominant species captured by the trawl survey are presented below. Note that the smoothed trends were generated by LOWESS algorithm on non-zero catches. For species that were captured in a high proportion of the catches, these trends approach the same pattern as the mean catch per trawl. By comparison, the trend in mean catch per trawl of species that are infrequently captured will be relatively flat.

Table 14
Mean catch of adult and juvenile fishes per trawl for all months at Stations 7 and 10 combined

	All Species	white perch	blueback herring	alewife	gizzard shad	bay anchovy	spottail shiner	brown bullhead	pumpkin-seed
2010*	310.7	206.8	0.2	5.4	1.8	0.3	5.0	0.4	1.2
2009	94.0	19.2	1.1	47.5	0.6	6.5	2.8	0.2	2.8
2008	70.7	16.2	0.0	0.1	4.0	0.3	2.6	0.6	7.0
2007	227.3	141.4	23.6	8.8	0.2	15.8	20.1	0.2	2.6
2006	23.4	8.6	1.4	0.6	0.2	2.0	2.7	0.4	1.6
2005	64.4	19.9	10.6	15.2	0.9	0.0	6.1	0.4	1.4
2004	340.3	19.5	281.3	27.5	0.7	0.5	6.7	0.1	0.4
2003	50.3	9.6	18.8	3.5	0.0	7.4	2.8	1.3	0.5
2002	81.0	15.5	9.9	27.7	0.1	16.2	0.7	0.9	1.7
2001	143.5	47.0	40.5	9.9	0.3	35.1	2.8	3.3	1.4
2000	70.0	54.9	3.6	1.9	2.4	1.7	1.3	2.0	0.6
1999	86.9	63.2	4.2	0.5	1.0	5.4	4.8	2.4	1.8
1998	83.2	63.9	2.2	0.5	0.6	3.7	6.8	1.0	1.7
1997	81.4	61.7	1.9	1.0	5.0	2.6	2.9	1.5	1.2
1996	48.0	35.4	2.5	1.6	0.5	0.2	2.6	0.5	2.1
1995	88.6	69.7	4.1	2.1	0.4	3.0	3.0	1.9	1.8
1994	92.2	66.9	0.8	0.1	0.1	0.5	6.2	3.2	2.7
1993	232.1	203.3	1.3	0.5	1.3	0.6	6.9	4.3	3.2
1992	112.8	81.6	0.2	0.0	0.9	0.8	2.4	11.5	5.1
1991	123.7	90.9	1.0	0.5	8.1	2.6	2.9	12.4	1.7
1990	72.8	33.3	21.9	3.2	0.1	1.1	1.1	10.0	0.5
1989	78.4	14.9	16.1	0.2	42.4	0.2	0.5	3.0	0.6
1988	96.0	45.1	11.2	8.8	12.7	8.3	1.8	5.3	0.9
1987	106.7	54.3	16.0	3.5	5.6	8.8	0.7	15.0	1.4
1986	124.6	65.4	1.9	24.0	4.1	4.2	0.5	18.4	0.6
1985	134.4	43.2	13.5	12.4	2.9	48.1	0.9	9.6	0.0
1984	167.8	99.5	7.5	0.7	13.8	8.1	1.7	33.3	0.2

*2010 data: Sta 10 not sampled late July – Sept. Average shown is mean of avg of Sta 7 and avg of Sta10, not avg of all trawls at Sta 7 and 10 pooled.

Table 15
Mean catch of adult and juvenile fishes per trawl for all months at Station 9

Year	All Species	white perch	American eel	bay anchovy	spottail shiner	brown bullhead	channel cat	tessellated darter	hogchoker
2010	38.6	10.7	0.0	7.9	0.0	0.1	0.0	0.0	0.1
2009	40.4	15.2	0.0	8.6	0.4	0.2	0.7	0.1	0.4
2008	95.0	10.0	0.0	80.0	0.1	0.0	0.0	0.0	0.0
2007	253.8	195.7	0.0	0.7	1.1	0.0	0.0	0.9	0.0
2006	68.1	31.0	0.2	3.0	0.2	8.0	4.6	0.0	0.2
2005	91.1	36.5	0.0	12.1	1.8	2.2	4.7	0.1	0.1
2004	41.9	20.4	0.0	0.0	1.1	2.2	6.6	0.0	0.9
2003	62.5	29.9	0.1	0.0	0.6	2.1	14.1	1.2	6.6
2002	52.9	27.2	0.1	0.5	0.0	2.2	10.2	0.8	1.9
2001	77.1	40.1	0.2	22.2	0.1	0.9	5.5	0.8	1.3
2000	52.4	43.4	0.1	0.0	0.1	2.2	0.9	0.0	2.2
1999	23.1	19.1	0.1	0.2	0.0	0.2	3.2	0.0	0.9
1998	22.1	12.8	0.1	0.4	0.1	0.2	4.5	2.0	0.2
1997	49.6	37.2	0.2	0.0	1.1	0.3	2.3	0.4	0.3
1996	14.0	7.0	0.1	0.0	0.1	0.1	1.7	0.8	0.0
1995	31.9	17.4	0.3	0.2	0.2	4.3	2.0	0.1	0.5
1994	31.9	13.4	3.1	0.1	0.0	2.4	4.2	3.5	2.4
1993	31.2	6.8	1.6	0.0	6.6	1.3	6.8	7.9	1.2
1992	27.5	14.2	2.6	0.0	0.0	1.2	1.7	0.8	6.6
1991	67.9	42.4	0.4	1.9	0.1	1.0	1.9	0.4	6.3
1990	101.5	50.6	1.0	0.0	0.1	5.2	0.8	0.1	4.0
1989	14.3	7.9	0.2	0.4	0.0	1.5	0.3	0.3	0.2
1988	19.2	5.2	0.0	11.5	0.0	0.0	1.6	0.0	0.5

Table 16
Mean catch of adult and juvenile fishes per trawl for all months at Stations 7, 9, and 10 combined

Year	All Species	white perch	blueback herring	alewife	gizzard shad	bay anchovy	spottail shiner	brown bullhead	channel cat
2010*	220.0	141.5	0.1	3.6	1.2	2.9	3.3	0.3	0.0
2009	76.2	17.9	0.9	31.9	0.4	7.2	2.0	0.2	0.4
2008	78.8	14.1	0.0	0.0	2.7	26.8	1.7	0.4	0.0
2007	236.1	159.5	16.6	11.6	0.1	10.7	13.8	0.1	0.0
2006	38.3	16.1	1.0	0.4	0.1	2.4	1.0	2.9	1.5
2005	114.8	26.4	7.5	15.8	0.6	4.3	4.6	1.0	1.8
2004	240.8	19.8	187.6	19.5	0.5	0.3	4.8	0.8	2.2
2003	54.4	16.4	12.6	2.3	0.0	4.9	2.0	1.6	5.3
2002	71.6	19.6	6.6	19.0	0.1	10.6	0.4	1.3	4.6
2001	122.3	45.8	27.6	6.8	0.3	31.0	1.9	2.6	1.8
2000	64.1	51.0	2.4	1.3	1.7	1.1	0.9	2.1	1.4
1999	65.6	48.4	2.8	0.3	0.7	3.7	3.2	1.7	0.8
1998	62.8	46.8	1.4	0.4	0.4	2.6	4.5	0.7	2.1
1997	70.8	53.5	1.3	0.7	3.3	1.7	2.3	1.1	3.1
1996	36.7	25.9	1.6	1.1	0.3	0.1	1.7	0.4	2.0
1995	69.7	52.3	2.7	1.5	0.2	2.1	2.0	2.7	2.9
1994	73.2	50.1	0.5	0.0	0.1	0.4	4.2	2.9	2.2
1993	167.8	140.4	0.9	0.4	0.9	0.4	6.8	3.3	1.8
1992	88.5	62.3	0.2	0.0	0.6	0.6	1.7	8.6	0.5
1991	103.8	73.6	0.6	0.4	5.2	2.4	1.9	8.4	4.7
1990	82.4	39.1	14.6	2.2	0.1	0.8	0.8	8.4	13.3
1989	57.0	12.6	11.0	0.2	28.4	0.3	0.3	2.5	0.7
1988	85.7	39.8	9.7	7.6	11.0	8.7	1.6	4.6	0.3
1987	106.7	54.3	16.0	3.5	5.6	8.8	0.7	15.0	0.0
1986	124.6	65.4	1.9	24.0	4.1	4.2	0.5	18.4	0.0
1985	134.4	43.2	13.5	12.4	2.9	48.1	0.9	9.6	0.0
1984	202.6	133.3	6.6	0.6	13.4	8.0	1.6	35.0	0.1

*2010 data: Sta 10 not sampled late July – Sept. Average shown is mean of avg of Sta 7 and avg of Sta10, not avg of all trawls at Sta 7 and 10 pooled.

Table 17
The number of trawls per station in each month at Stations 7, 9, and 10 in each year

Year		Months											
		J	F	M	A	M	J	J	A	S	O	N	D
2010	Sta 7&9			0	1	2	2	2	2	1	0	0	0
	Sta 10			0	1	2	2	1	0	0	0	0	0
2009				0	1	2	2	2	2	1	0	0	0
2008				0	1	2	2	2	2	1	0	0	0
2007				0	1	2	2	2	2	1	0	0	0
2006				0	1	2	2	2	2	1	0	0	0
2005	Sta 7 & 9			0	1	2	2	2	2	1	1	0	0
	Sta 10			0	1	2	2	2	2	0	0	0	0
2004	Sta 7, 9&10			0	1	1	2	2	2	1	0	0	0
2003				1	2	2	2	2	1	1	1	1	1
2002													
	Sta 7 & 9			1	2	2	2	2	2	2	1	1	1
	Sta 10			0	2	2	2	2	2	2	1	1	1
2001													
	Sta 7			1	2	2	1	2	3	2	1	1	1
	Sta 9			1	2	1	1	2	3	2	1	1	1
	Sta 10			1	2	2	1	2	3	2	1	1	1
2000				1	2	2	2	2	2	2	2	1	1
1999				1	2	2	2	2	2	2	1	1	1
1998				1	2	2	2	2	2	2	1	1	1
1997				1	2	2	2	2	2	2	2	1	1
1996													
	Sta 7			1	2	2	1	2	1	2	1	1	1
	Sta 10			1	2	1	2	2	1	2	1	1	1
	Sta 9			1	2	2	1	2	1	2	1	1	1
1995				1	2	2	2	2	2	2	2	1	
1994				1	1	1	2	2		2	2	1	
1993				1	1	2	2	3	2	2	2	1	1
1992													
	Sta 7 and 10			1	1	1	1	1	1	1	1	1	1
	Sta 9			1	1		1	1	1	1	1	1	1
1991				1	1	1	1	1	1	1	1	1	
1990				1	1	1	1	1	1	1	1		
1989			1	1	1	1	1	1	2	2	1	1	
1988													
	Sta 7 and 10			1	1	1	2	2	2	2	1	1	
	Sta 9									2	1	1	
1987	Sta 7 and 10			1	1	1	1	1	1	1	1	1	
1986	Sta 7 and 10			1	1	1	1	1	1	1	1	1	
1985	Sta 7 and 10				1	1	1		1	1	2	1	
1984	Sta 7 and 10			1	2	3	2	3	2	3	3	2	1

Table 18
Mean catch of adult and juvenile fishes per trawl in all months at each station

Year	Station 10	Station 7	Station 9
2010	5.8*	615.6	38.6
2009	45.2	142.8	40.2
2008	91.3	50.0	95.0
2007	64.4	390.1	253.8
2006	6.2	40.7	68.1
2005	20.2	96.6	91.1
2004	22.4	658.2	41.9
2003	39.4	61.3	62.5
2002	70.9	91.2	52.9
2001	119.1	167.8	77.1
2000	44.8	95.1	52.4
1999	56.6	117.2	23.1
1998	78.1	88.3	22.1
1997	51.4	111.5	49.6
1996	31.5	64.5	14.0
1995	69.6	107.6	31.9
1994	62.1	122.2	31.9
1993	109.2	354.9	31.2
1992	70.2	155.5	27.5
1991	73.6	173.9	67.9
1990	68.4	77.2	101.5
1989	104.2	52.6	14.3
1988	96.2	95.8	19.2
1987	131.9	84.3	
1986	153.4	95.8	
1985	146.1	122.6	
1984	207.7	197.4	

* in 2010, no samples were taken at Sta 10 after mid-July due to interference of SAV.

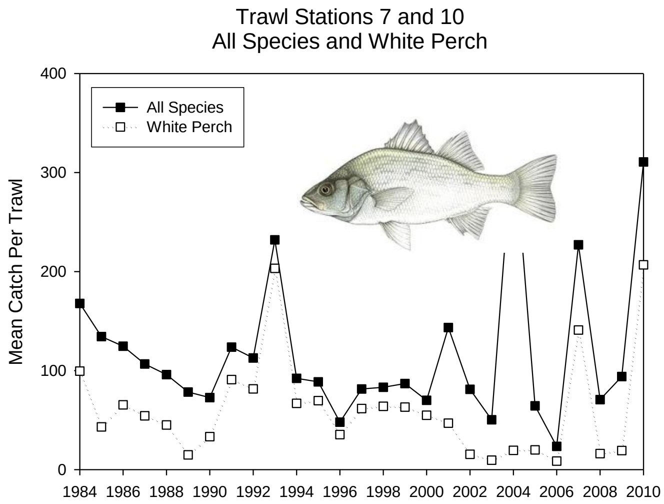


Figure 153a. Trawls. Annual Averages.
All Species and White Perch. Cove Stations 7 and 10.

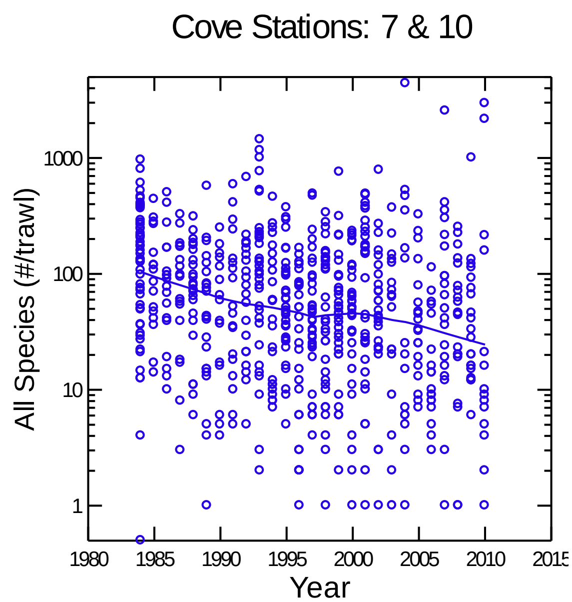


Figure 153b. Trawls. Long Term
Trend in Total Catch

Mean total number of fish per trawl sample exhibited a decline since the study began (Table 14 and Figure 153a, b), and this pattern was primarily a function of catches of white perch. The decline in white perch catch rates was punctuated by strong cohorts in 1993, 2007, and 2010. Excepting the strong year-classes, white perch catch rates appear to have gone through three phases: low to moderate catch rates between 1985 and 1990, high to moderate catch rates between 1991 and 2000, and with exception of two strong year classes, low catch rates between 2001 and 2010. For the remaining component of the catch, a complementary pattern is evident. Species other than white perch made up: a moderate to large proportion of the catch until 1990; a relative small part of the catch between 1991 and 2000; and, excepting 2006, a moderate to large proportion of the catch from 2001 to 2010.

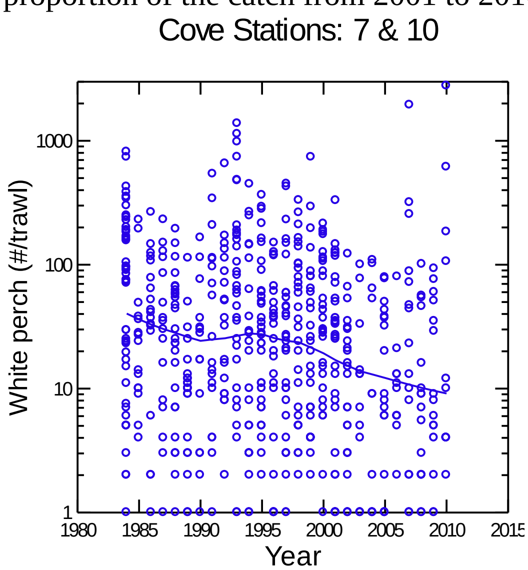


Figure 153c. Trawls. Long Term
Trend in White Perch. Sta 7 & 10.

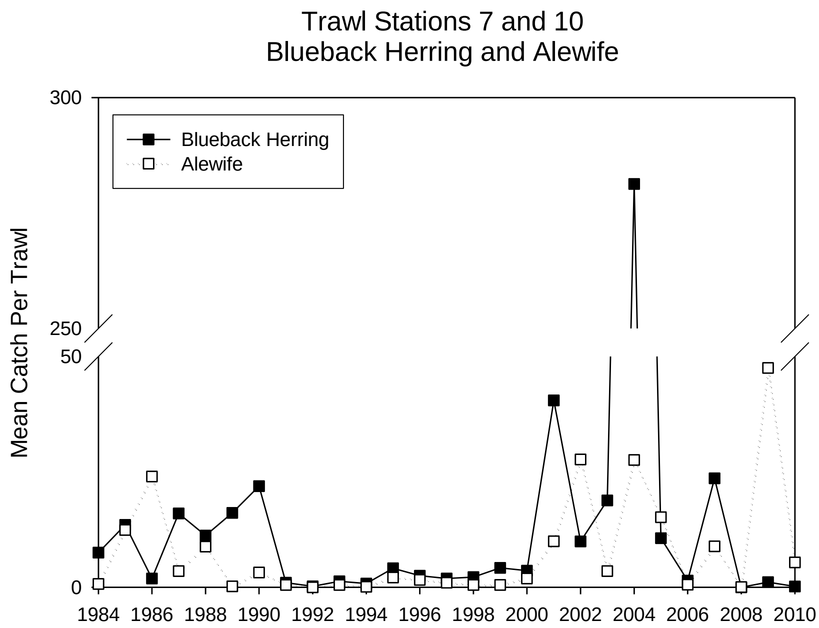


Figure 154a. Trawls. Annual Averages. Blueback Herring and Alewife. Cove Stations.

Although the strong year-class effects varied by species for the anadromous fishes, the same three phases of abundance for white perch were also evident for juvenile river herring (collectively, alewife and blueback herring). Moderate catch rates until 1990 were followed by a period of consistently low catch rates until 2000, after which catch rates have been moderate to high. It cannot be determined from these data whether low catch rates in 2006 and 2009 signify the start of a period of low catch rates, as time averaged trends still indicate the most recent period is higher than in any previous time during the survey (Figures 154 b & c).

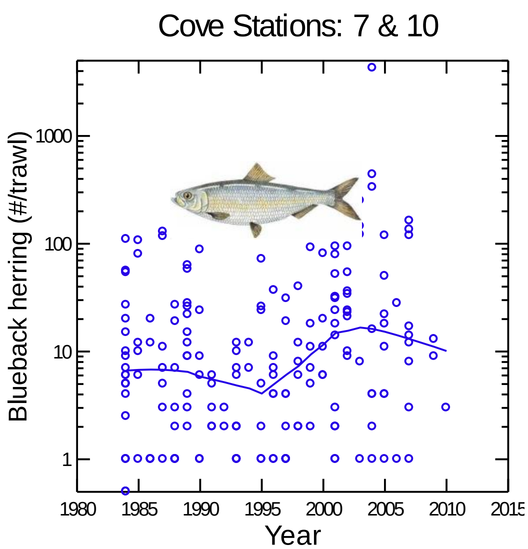


Figure 154b. Trawls. Long term trend in Blueback Herring (*Alosa aestivalis*). Cove Stations.

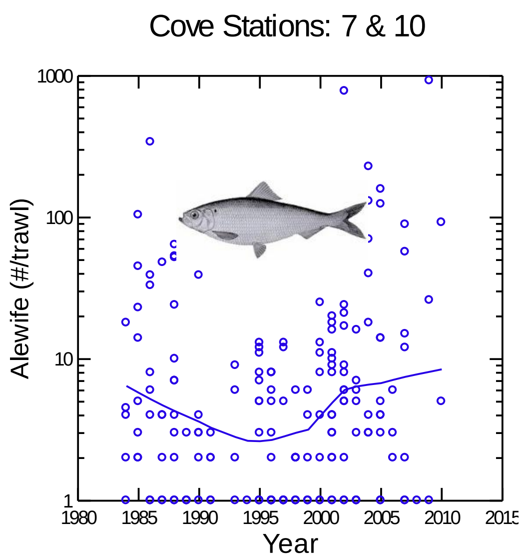


Figure 154c. Trawls. Long term trend in Alewife (*Alosa pseudoharengus*). Cove Stations.

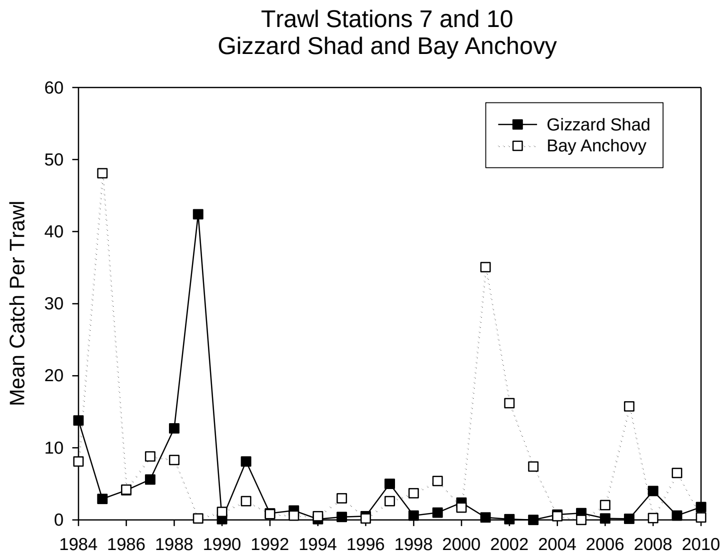


Figure 155a. Trawls. Annual Averages. Gizzard Shad and Bay Anchovy. Cove Stations.

Gizzard shad catch rates in trawls in 2010 contribute to a pattern of low and variable abundance that appears to have started in 1992 or earlier (Figure 155a,b). Trend analysis with LOWESS emphasized declining gizzard shad catch rates for stations 7 and 10. Bay anchovy catch rates were also low in 2009 at inner cove stations, but LOWESS trend analysis suggests a recent upward trend. Although they are primarily resident in more saline portions of the estuary, their sporadic occurrence in tidal freshwater may represent significant transport of productivity from the lower regions of the Potomac. In addition, as they are an annual species, the parabolic trend in mean catch rates over the course of the survey (Figure 155c) is more indicative of prevailing environments (favorable versus unfavorable for early life stages and estuarine transport) than spawning stock abundance.

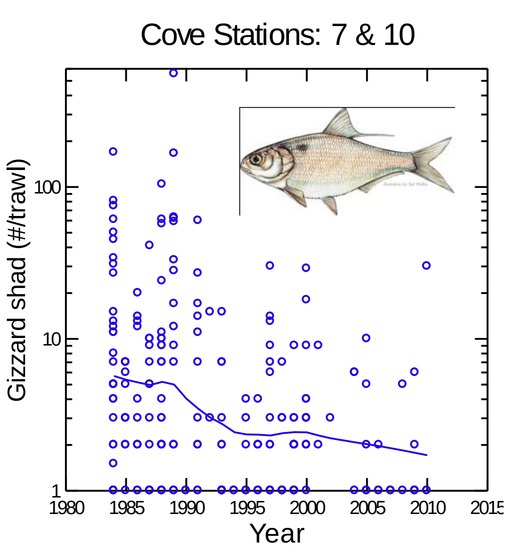


Figure 155b. Trawls. Long term trend in Gizzard Shad (*Dorosoma cepedianum*).

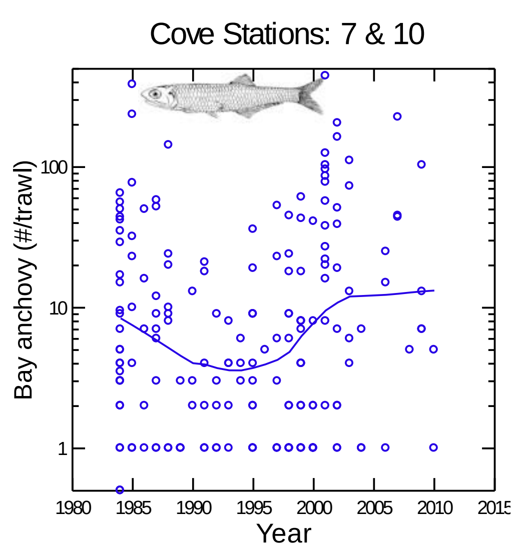


Figure 155c. Trawls. Long term trend in Bay Anchovy (*Anchoa mitchilli*).

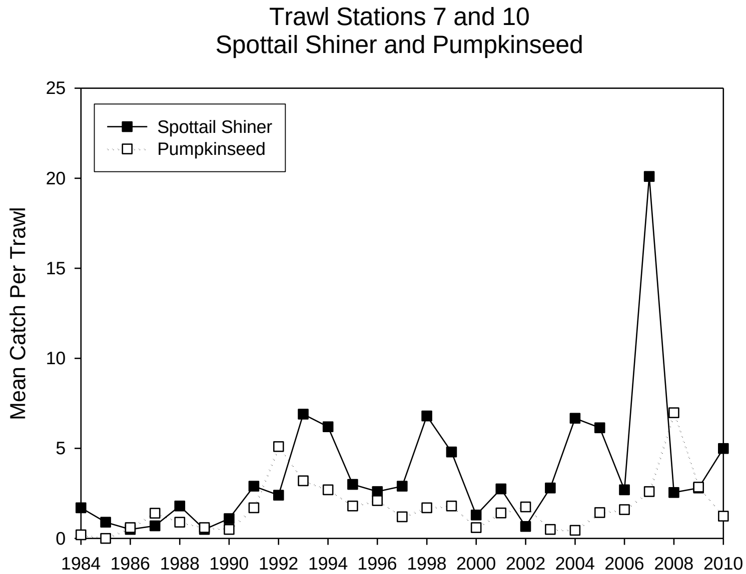


Figure 156a. Trawls. Annual Averages. Spottail Shiner and Pumpkinseed. Cove Stations.

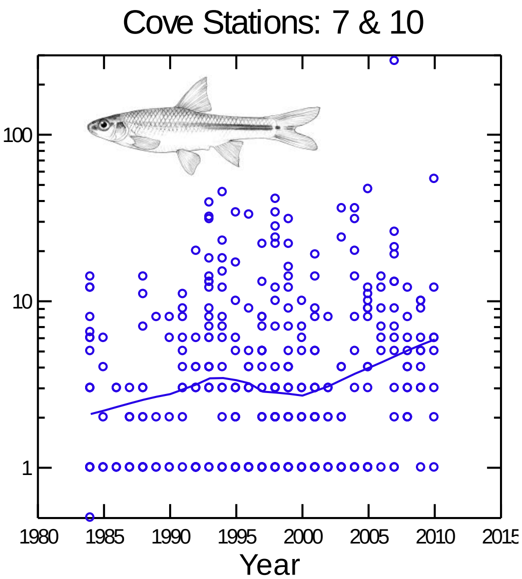


Figure 156b. Trawls. Long-term Trends in Spottail Shiner (*Notropis hudsonius*). Cove Stations.

Spottail shiner and sunfish (bluegill and pumpkinseed) are typically captured in low numbers relative to anadromous species, but they are consistently observed in the majority of all trawl and seine samples (Figure 156 a,b,c,d). In all three species, an increasing (albeit minor) trend has been observed since the beginning of the survey. In recent years (since 2000), smoothed trends suggest a more sharply increasing pattern in the midst of high variability for all of these species. These individuals were mostly juveniles, indicating relatively high reproductive success as measured by this survey.

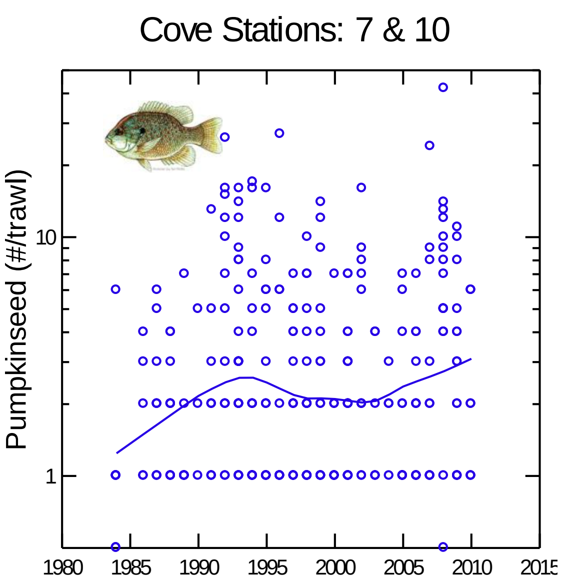


Figure 156c. Trawls. Long term trend in Pumpkinseed (*Lepomis gibbosus*). Cove.

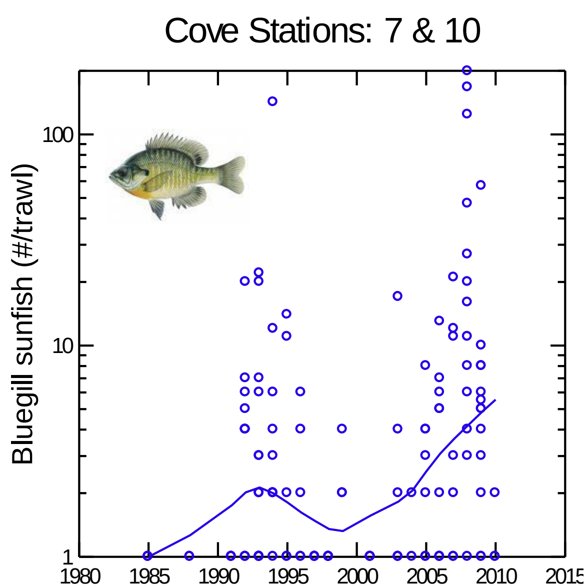


Figure 156d. Trawls. Long term trend in Bluegill (*Lepomis macrochirus*). Cove.

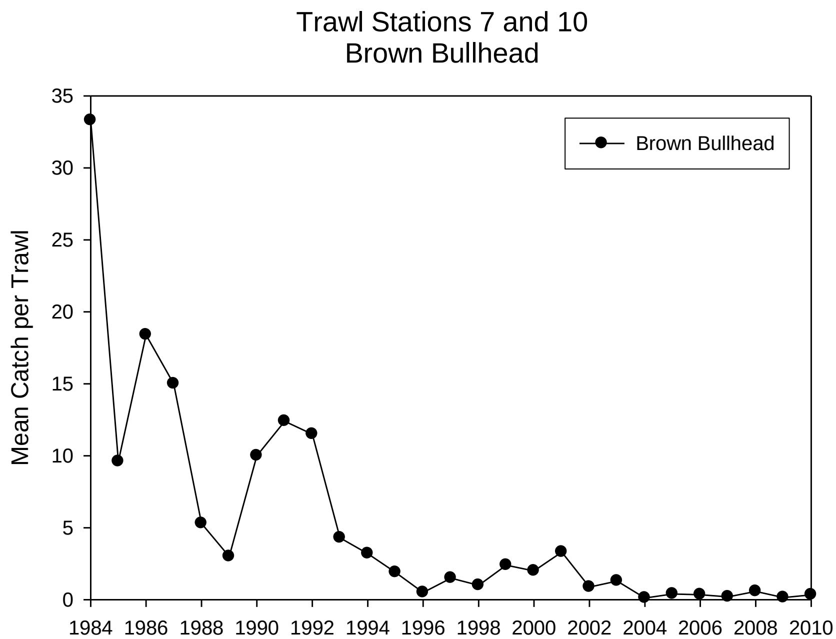


Figure 157a. Annual Averages. Brown Bullhead. Cove Stations.

Very few brown bullhead were captured during 2010, continuing a declining trend that has proceeded continuously since the start of the survey. This trend is evident both in the mean catch rate as well as the density of bullhead in non-zero catches (Figure 157a,b). Tessellated darter were consistently encountered at low abundance in trawl samples - at typical abundances of 1 to 2 individuals per trawl when observed at stations 7 and 10 (Figure 157c).

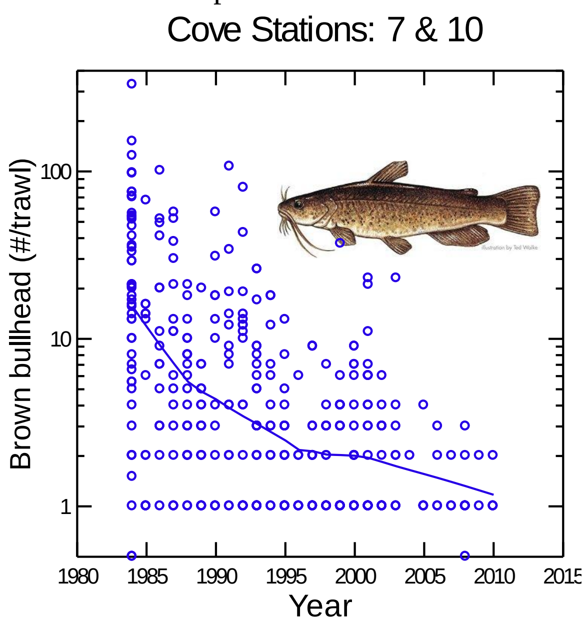


Figure 157b. Trawls. Long term trend in Brown Bullhead (*Ameirus nebulosus*).

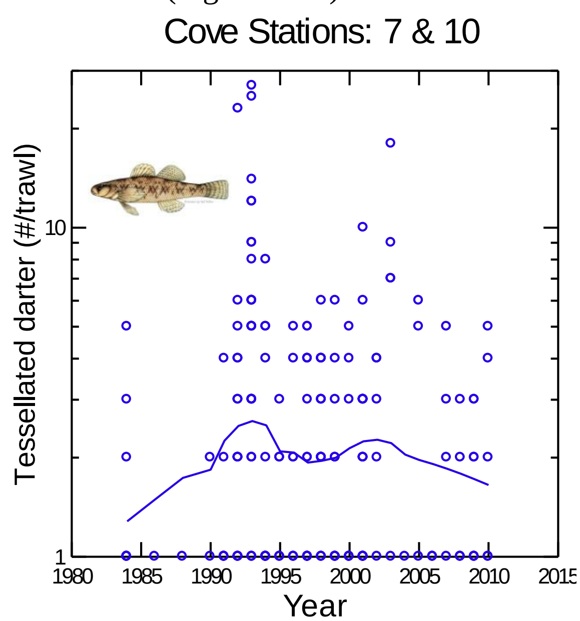


Figure 157c. Trawls. Long term trend in Tessellated Darter (*Etheostoma olmstedi*).

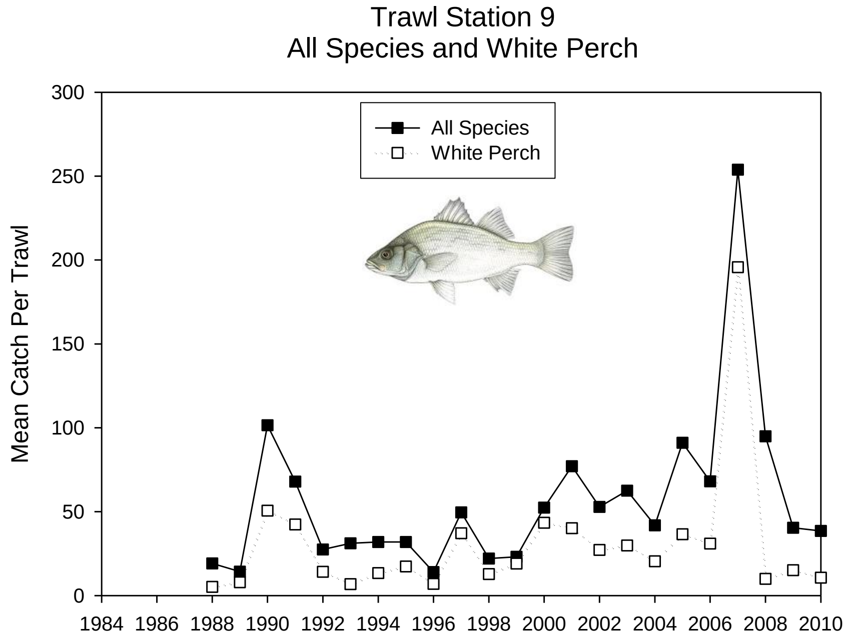


Figure 158a. Trawls. Annual Averages. All Species and White Perch. River Station.

At the river channel station (station 9), 2010 marks a four-year downward trend in total fish catch rate (Figure 158a). Overall, catch rates of white perch and all species combined at station 9 were typically lower and less variable than at inner cove stations. Much of the variation at station 9 is directly attributable to the catch of white perch, but other species have become more important in recent years. These trends are not evident in the density of fish in positive catches, which has remained relatively constant around 11per trawl for all species combined and around 10 per trawl for white perch (Figures 158b,c). Trends in mean catch rate for total catch and white perch at station 9 have fluctuated a small amount but generally remained flat through the history of the survey.

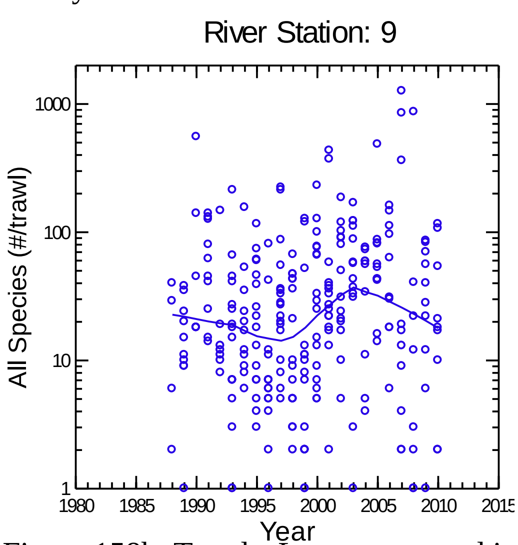


Figure 158b. Trawls. Long term trend in Total Catch. River Station.

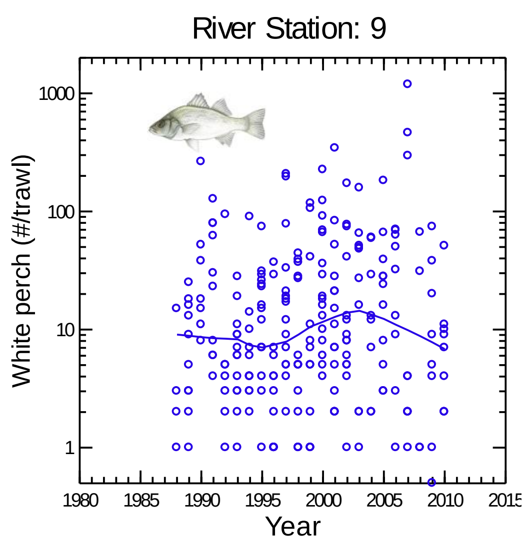


Figure 158c. Trawls. Long term trend in White Perch (*Morone americana*). River Sta.

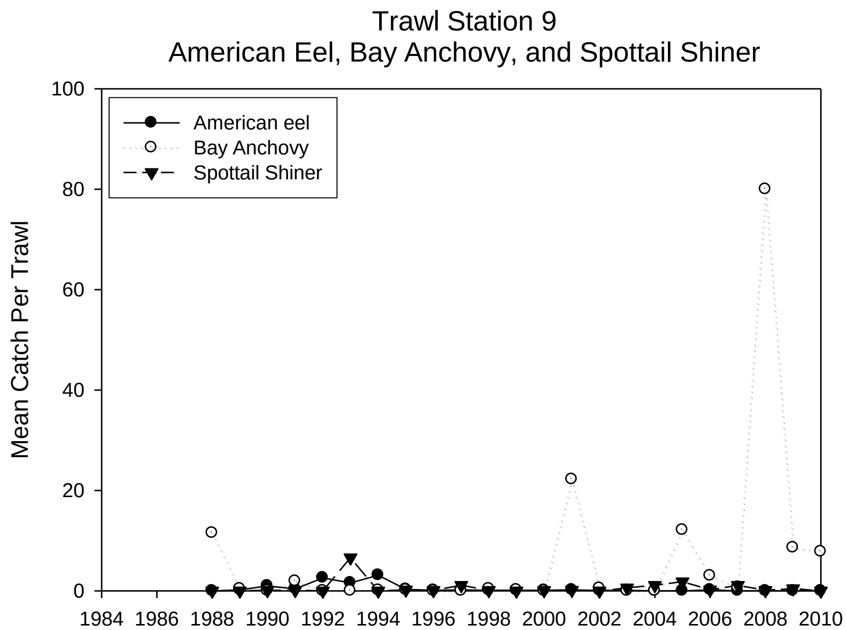


Figure 159a. Trawls. Annual Averages. Eel, Bay Anchovy, and Spottail Shiner. River Station.

Since 1988 when station 9 was incorporated as part of the survey, bay anchovy, spottail shiner, and American eel have occurred sporadically at station 9 (Figures 159a,b,c). Trends in mean catch rates for bay anchovy and spottail shiner were qualitatively similar to stations 7 and 10, but the absolute values were lower with one notable exception. A record catch of bay anchovy in September of 2008 was the highest on record and indicates strong reproductive success and/or upstream transport.

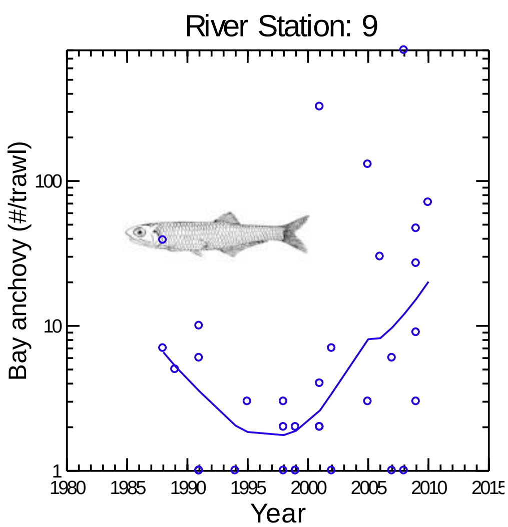


Figure 159b. Trawls. Long term trend in Bay Anchovy (*Anchoa mitchilli*). River.

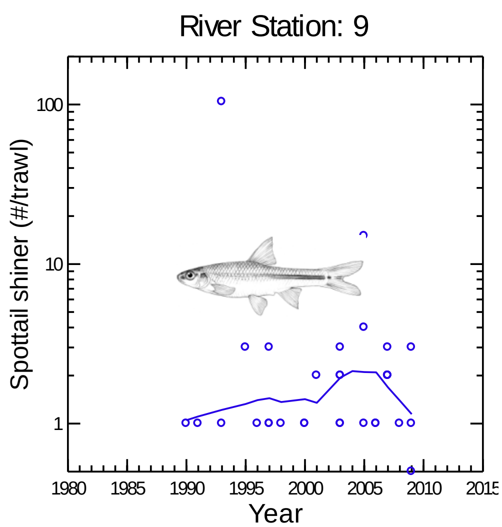
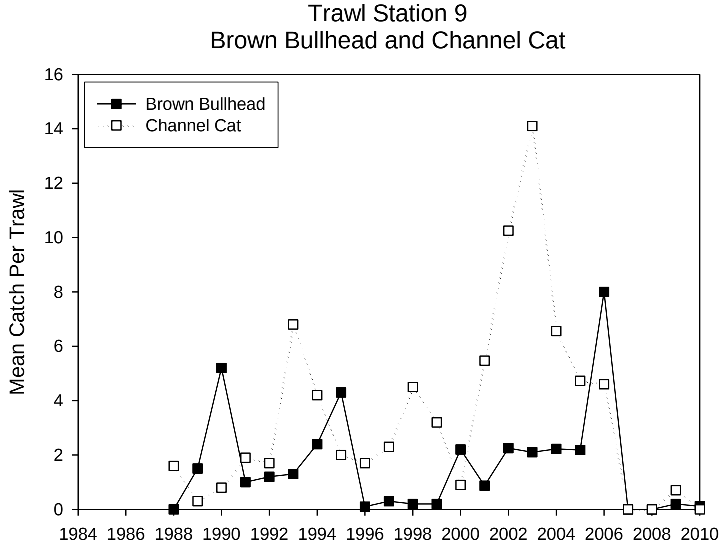


Figure 159c. Trawls. Long term trend in Spottail Shiner (*Notropis hudsonius*). River.



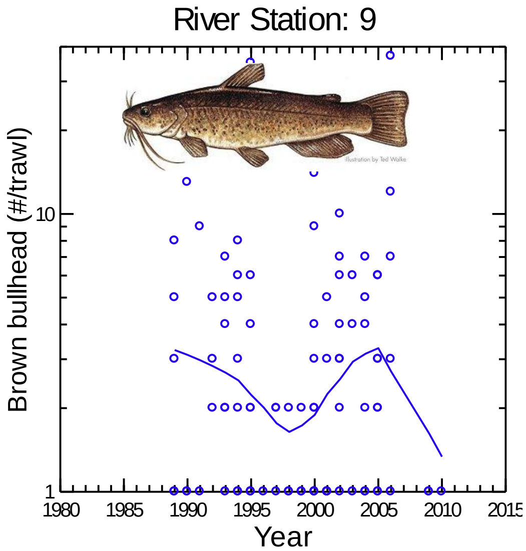
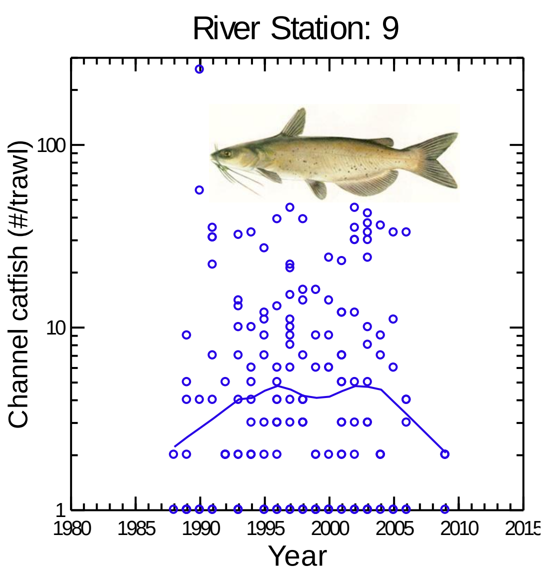


Figure 160a. Trawls. Annual Averages. Brown Bullhead and Channel Cat. River Station.

Figure 160b. Trawls. Long term Trend in Brown Bullhead (*Ameiurus nebulosus*).

Overall at station 9, catch rates for all catfish species have been variable and at low levels (mean of 2 to 4 per trawl) compared to most other species that were observed (Figure 160a,b,c,d). In particular, 2010 ranked as one of the 6 lowest years in mean catch rate for brown bullhead and channel catfish at station 9. Long-term mean trends were also variable and thus are difficult to characterize. One species that warrants close attention is the invasive, blue catfish, which was positively identified on the survey in 2001 and has been captured each year since then.



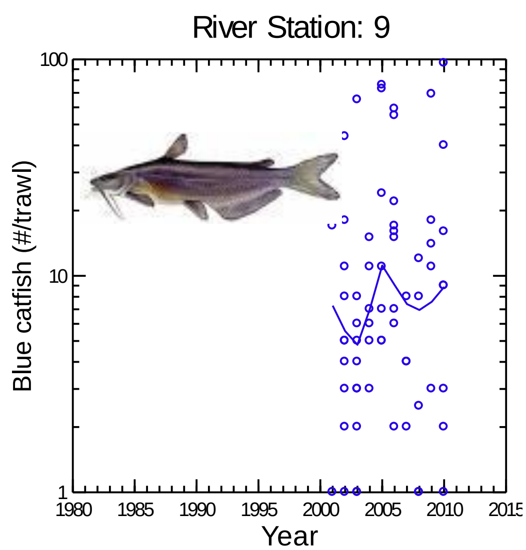


Figure 160c. Trawls. Long term trend in Channel Cat (*Ictalurus punctatus*). River Station.

Figure 160d. Trawls. Long term trend in Blue Catfish (*Ictalurus furcatus*). River Station.

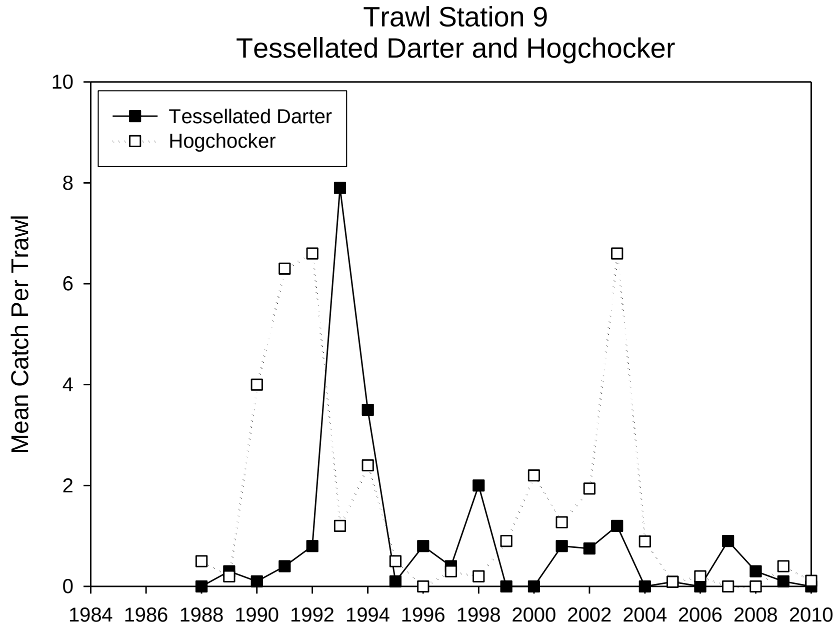
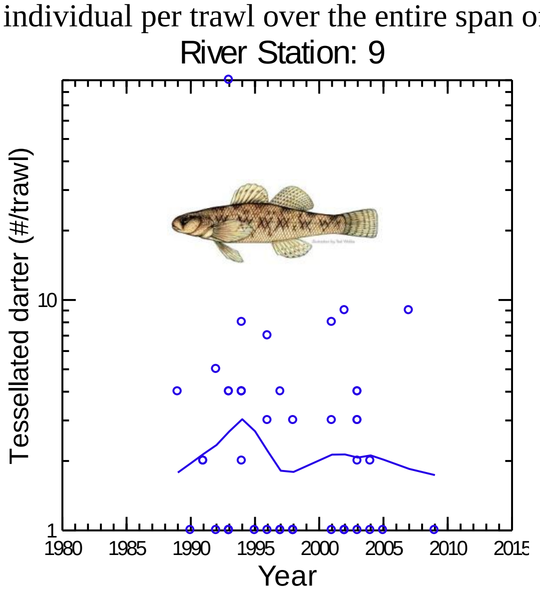


Figure 161a. Trawls. Annual Averages. Tessellated Darter and Hogchoker. River Station.

Station 9 represented low but consistent catch rates for demersal species, tessellated darter and hogchoker (Figure 161a,b,c). On rare occasions, catches exceeded 50 individuals per trawl, but when encountered typical catch rates for either species were less than 4 per trawl. The mean annual trend is relatively flat for each of these species, not varying on average more than one individual per trawl over the entire span of time.



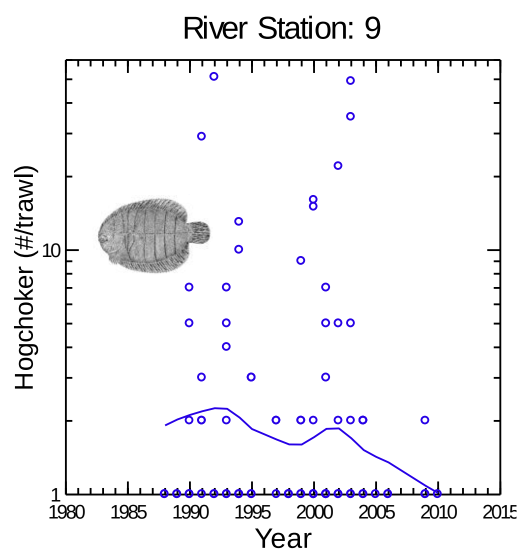


Figure 161b. Trawls. Long term trend in Tessellated Darter (*Etheostoma olmstedi*). River Station.

Figure 161c. Trawls. Long term trend in Hogchoker (*Trinectes maculatus*). River Station.

Seines

Mean annual seine catch rates were generally less variable than trawl catch rates, but the long-term trend with a period of lower catch rates during the mid-1990s is reflected in seine samples (Figures 162 and 163). The drop in the moving average (LOWESS trend) of catch rates during the middle of the series reflected a lower density of fish in non-zero catches (Figure 163) - a pattern that is only weakly evident from the lowest annual mean catch rates (zeros included) for 1993 and 1995 (Figure 162). Of the three most abundant years, 1994 was driven primarily by a single large catch of alewife, whereas high catch rates in 1991 and 2004 were a result of high catch rates of spottail shiner, blueback herring and (in 2004) alewife (Table 19). Overall, white perch and banded killifish have been the dominant species in seine samples throughout the survey, and this pattern also held in 2010.

Over the course of the survey mean annual seine catch rates of white perch have exhibited a gradual decline (Figures 164a), and the density of white perch in non-zero catches has declined at a faster rate over this period (Figure 164b). As this declining pattern is also reflected in the trawl data for the inner cove and there is a flat trend for white perch at station 9, it may be that white perch distribution has shifted towards the main stem of the Potomac and/or that abundance at a larger spatial scale has declined. Another important factor is the recent pronounced increase in SAV, which is not effectively sampled but may represent a significant alternative habitat for white perch. Efforts to quantify gear efficiency and alternative methods to sample vegetated habitats are needed to understand the relative importance of these factors. We have developed an approach to sample SAV using drop-ring sampling, which is reported in a manuscript that has recently been published in the journal Environmental Monitoring and Assessment (Kraus and Jones 2011). In addition, mean annual catch rates of banded killifish have exhibited a long-term increasing trend (Figure 164a), and the density of banded killifish in non-zero catches has also increased by approximately five-fold (Figure 164c). Banded killifish have been the dominant species in seine samples during the past ten years.

The relative success of banded killifish is coincidental (rather than functionally related) to declines in white perch as these species show very little overlap in ecological and life history characteristics. Instead, prominent increases in mean catch rates of banded killifish are associated with development of SAV in the cove since 2000. The SAV provides refuge for banded killifish adults and juveniles and may enhance feeding opportunities with epifaunal prey items.

Table 19
Mean catch of adult and juvenile fishes per seine at Stations 4, 6, and 11 and all months

Year	All Species	white perch	banded killifish	blueback herring	alewife	spottail shiner	inland silverside
2010	247.2	18.9	163.2	0.0	0.0	1.8	1.3
2009	169.9	22.5	61.3	0.3	0.2	4.2	9.0
2008	185.5	15.7	50.8	0.3	0.1	2.4	14.9
2007	113.4	10.6	32.2	8.0	2.6	3.6	2.6
2006	165.3	7.6	113.7	3.2	0.4	3.6	16.2
2005	230.4	45.3	139.9	1.2	6.7	10.7	6.6
2004	304.5	6.8	99.0	11.1	73.8	38.0	9.5
2003	97.9	6.8	43.3	2.4	3.0	6.7	3.2
2002	168.4	23.1	89.7	4.1	2.2	12.5	14.4
2001	131.6	29.5	53.4	0.4	4.8	14.0	7.4
2000	154.0	30.0	26.2	1.7	6.6	24.7	49.6
1999	100.6	17.1	17.6	13.5	0.4	11.4	23.0
1998	111.6	22.4	31.5	2.1	1.0	25.9	8.7
1997	119.2	19.1	36.0	27.7	0.8	5.0	13.7
1996	102.0	29.8	20.6	8.4	6.1	12.8	2.7
1995	66.4	20.6	7.0	1.6	2.0	5.5	10.5
1994	272.9	15.5	10.9	0.1	228.7	9.4	0.1
1993	61.5	6.9	20.0	2.8	1.7	8.9	8.8
1992	140.0	39.3	11.3	54.3	0.0	10.0	4.1
1991	249.1	38.1	24.1	97.0	0.2	26.0	8.5
1990	91.9	34.8	8.7	5.0	1.3	10.2	3.3
1989	131.9	47.9	8.1	2.4	0.6	9.9	2.1
1988	119.9	53.6	8.7	3.0	0.4	7.1	5.8
1987	91.9	41.9	6.0	0.1	0.0	9.1	13.8
1986	96.4	46.0	5.6	0.2	1.1	7.6	7.8
1985	96.7	50.2	0.6	0.4	0.4	12.3	14.7

2007-2010 averages do not include Station 4A

Table 20
The number of seines in each month at Station 4, 4A, 6, and 11 in each year

Year	Month												
		J	F	M	A	M	J	J	A	S	O	N	D
2010	All Sta			0	1	1	2*	2*	2*	1*	0	0	0
2009	Sta4, 6,&11			0	1	2	2*	2*	2*	1*	0	0	0
	Sta 4A			0	1	2	2	2	2	1	0	0	0
2008	Sta4,6,&11			0	1	2	2*	2*	2*	1*	0	0	0
	Sta 4A			0	1	2	2	2	2	1	0	0	0
2007	Sta 4,6,&11			0	1	2	1*	2*	2*	1*	0	0	0
	Sta 4A			0	0	0	0	2	2	1	0	0	0
2006	Sta 4			0	1	2	1*	1*	2**	1**	0	0	0
	Sta 6			0	1	2	2	0*	0*	0	0	0	0
	Sta 11			0	1	2	2	2	2	1	0	0	0
2005	Sta 4 & 6			0	1	2	2	2	0*	0*	0	0	0
	Sta 11			0	1	2	2	2	2	1	1	0	0
2004	Sta 4			0	1	1	2	1	0*	0*	0	0	0
	Sta 6			0	1	1	2	0*	0*	0*	0	0	0
	Sta 11			0	0	0	2	2	2	1	0	0	0
2003				1	2	2	2	2	1	1	1	1	1
2002				1	2	2	2	2	2	2	1	1	1
2001				1	1	2	1	2	3	2	1	1	1
2000				1	2	2	3	2	2	2	1	1	1
1999				1	2	2	2	2	2	2	1	1	1
1998				1	2	2	2	2	2	2	1	1	1
1997				1	2	2	2	2	2	2	2	1	1
1996	Sta 4 and 11			1	2	2	2	2	1	2	1	1	1
	Sta 6			1	2	2	2	2	1	2	1	1	
1995				1	2	2	2	2	2	2	2	1	
1994				1		1	1			1	1		
1993				1	2	2	1	3	2		1	1	1
1992				1	1	1	1	1	1	1	1	1	1
1991				1	1	1	1	1	1	1	1	1	
1990				1	1	1	1	1	1	1			
1989				1	1	1	1	1	1	1	1	1	
1988	Sta 4			1	1		2	2	1	1	1	1	
	Sta 6 and 11			1	1	1	2	2	2	1	1	1	
1987	Sta 4 and 11			1	1	1	1				1	1	
	Sta 6			1	1	1	1				1		
1986	Sta 4		1		1		1			1	1		
	Sta 6 and 11												
		1	1		1	1	1		1	1	1		
1985									1	1	1	2	

* Heavy growth of submersed aquatic vegetation obstructed seining
**Station 4 moved to canoe launch beach

Table 21
Mean catch of adult and juvenile fishes per seine in all months at each station

Year	Station 4	Station 6	Station 11
2010	240.7	227.7	273.4
2009	132.2	124.4	253.0
2008	93.3	303.1	160.0
2007	146.8	104.6	89.0
2006	121.6	206.3	160.6
2005	268.6	231.6	184.4
2004	247.8	238.0	365.6
2003	65.8	119.1	108.8
2002	126.6	206.1	172.5
2001	141.9	137.6	115.5
2000	222.7	140.5	98.8
1999	168.9	78.1	54.7
1998	165.4	115.0	54.4
1997	185.9	126.4	45.3
1996	106.1	109.3	91.2
1995	62.4	77.5	59.3
1994	81.2	609.1	46.3
1993	91.1	32.6	60.9
1992	181.6	113.9	122.8
1991	253.8	155.8	327.3
1990	103.3	96.1	76.3
1989	113.9	162.2	119.6
1988	118.7	129.6	111.2
1987	102.3	105.0	70.5
1986	112.1	102.5	80.3
1985	65.2	122.8	95.7

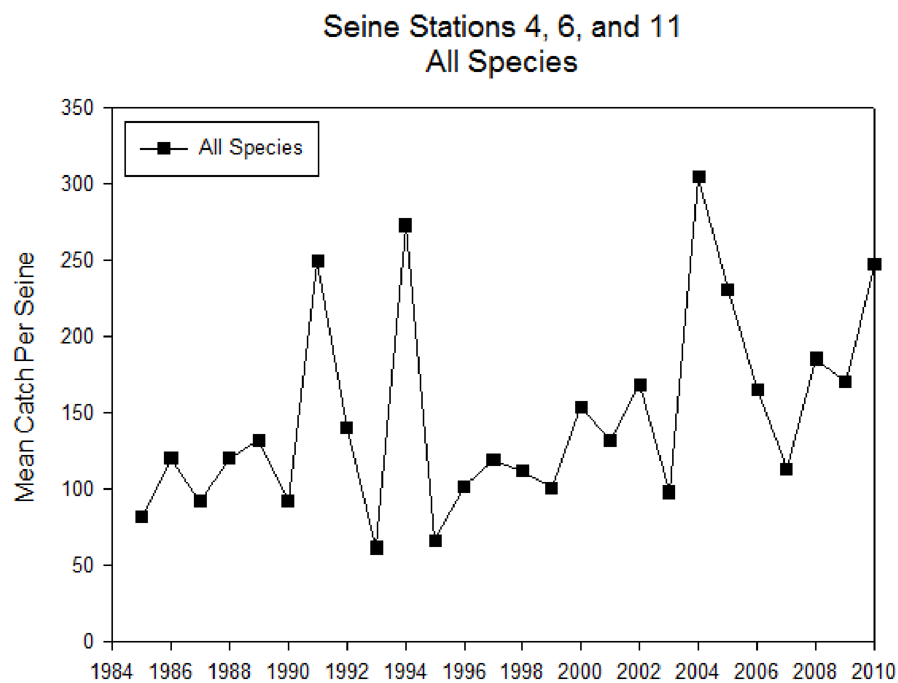


Figure 162. Seines. Annual Average over All Stations. All Species.

The recent declining trend in mean catch rate of all species combined between 2004 and 2007, rebounded between 2008 and 2010 (Figure 162). Since the mid 1990's, the smoothed curve indicates a steadily increasing catch rate for all species combined (Figure 163).

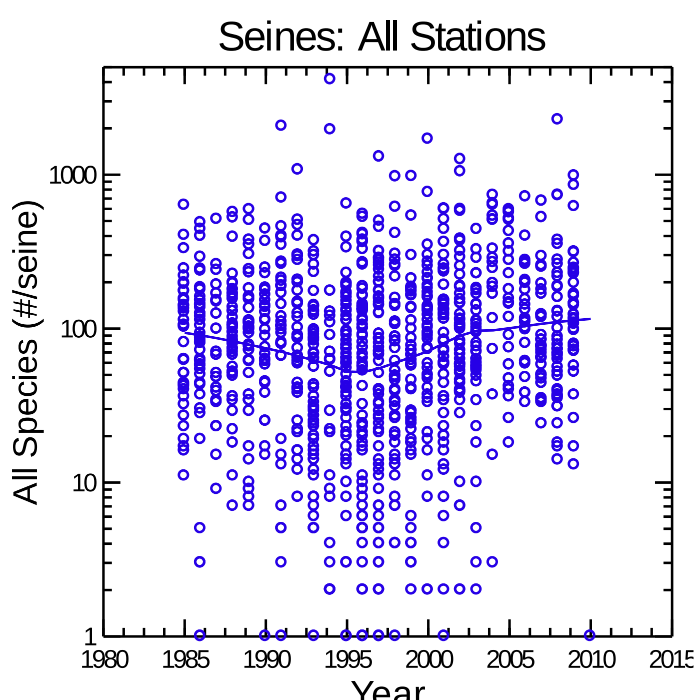


Figure 163. Seines. Long term trend in Total Seine Catch.

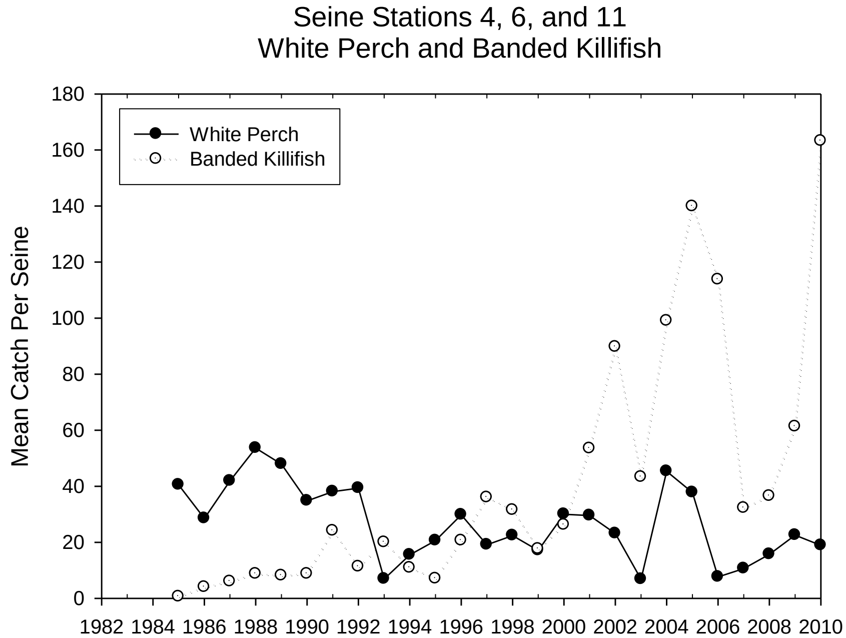


Figure 164a. Seines. Annual Average over All Stations. White Perch and Banded Killifish.

Long-term trends in mean annual catch rates (Figure 164a) and long-term densities in non-zero catches (Figures 164b,c) for the two dominant species in seine hauls have exhibited a negative association (r=-0.33) over the course of the survey (Figure 164a). White perch mean catchs have declined steadily since the beginning of the survey, and between 1990 and 1996 an accelerated decline in mean number per seine in non-zero catches is evident (Figure 164b). By comparison, banded killifish numbers were relatively low and mean number per seine in non-zero catches was constant until about 1998 when a prominent increase began (Figure 164c).

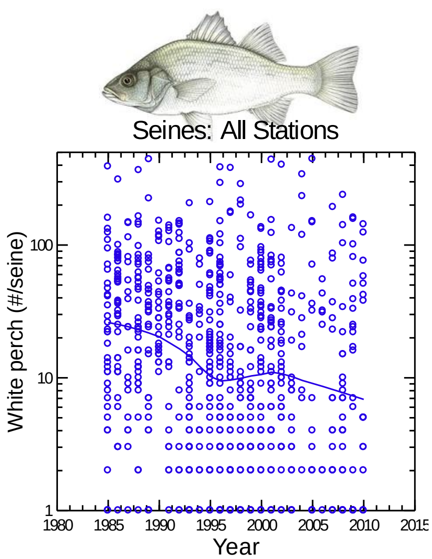


Figure 164b. Seines. Long term trend in White Perch (*Morone americana*). All Stations.

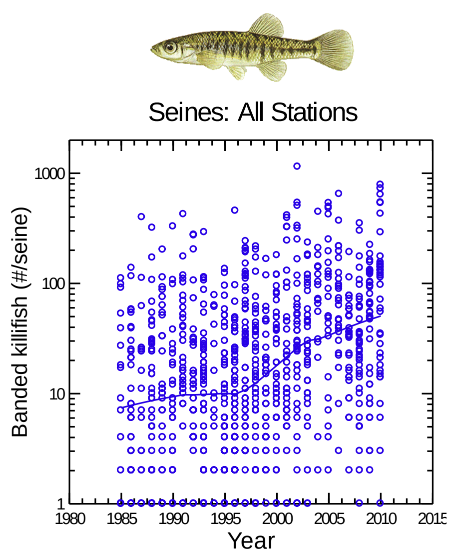


Figure 164c. Seines. Long term trend in Banded Killifish (*Fundulus diaphanus*). All Stations.

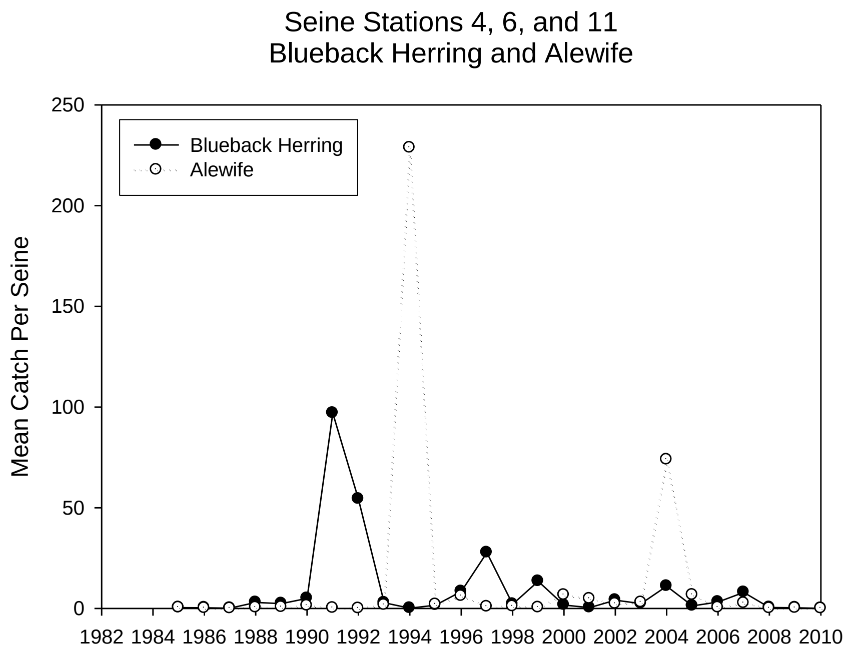


Figure 165a. Seines. Annual Average over All Stations. Blueback Herring and Alewife.

Mean annual catch rates for river herring (alewife and blueback herring) have exhibited sporadic peaks related to the capture of a large schools of fish (exceeding 200 for alewife and approaching 100 individuals for blueback herring) in single hauls (Figure 165a). Typically, less than 10 of either species were captured in a single sample (Figures 165b,c). Though numbers are low, densities in non-zero seine catches of alewife have exhibited a subtle increasing trend whereas with blueback herring the trend has been relatively flat.

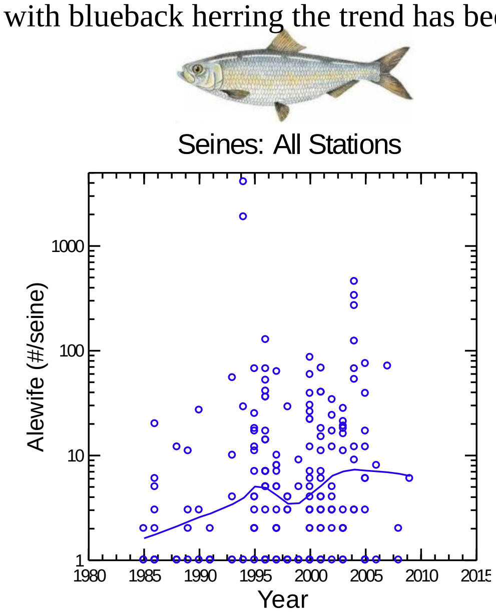


Figure 165b. Seines. Long term trend in Blueback Herring (*Alosa aestivalis*). All Stations.

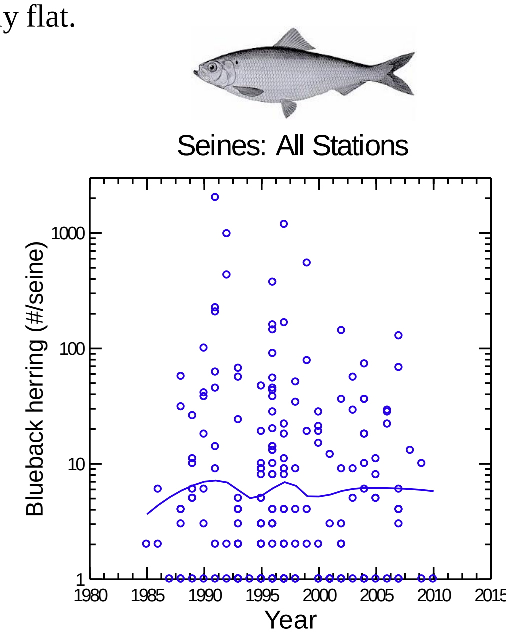


Figure 165c. Seines. Long term trend in Alewife (*Alosa pseudoharengus*). All Stations.

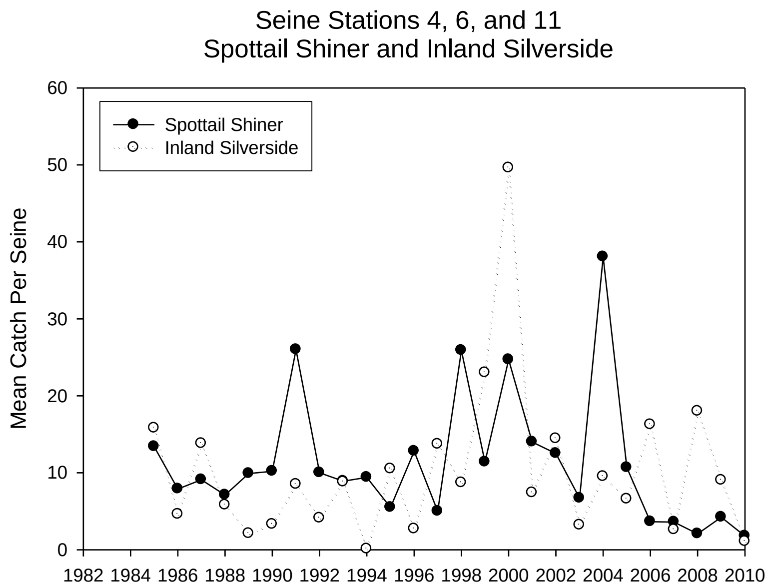


Figure 166a. Seines. Annual Average over All Stations. Spottail Shiner and Inland Silverside.

Owing to their affinity for marginal and littoral zone habitats, spottail shiner and inland silverside were consistently captured at moderate abundances throughout the course of the survey (Figure 166a). Although a few high abundance years (1991, 2000, and 2004) have occurred and a subtle declining trend in density in non-zero catches was present (Figure 166c,b), the overall pattern of abundance indices in seines has been relatively unchanging during the course of monitoring (166a). An exception to this overall pattern can be observed in the low catch rates since 2006 for spottail shiner.

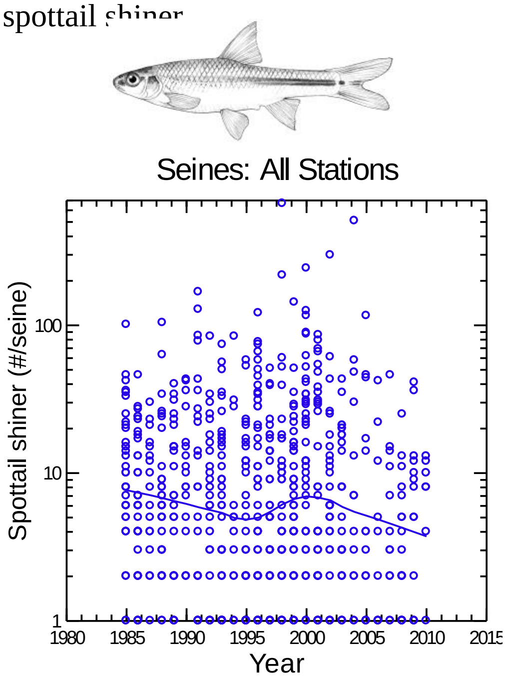


Figure 166b. Seines. Long term trend in Spottail Shiner (*Notropis hudsonius*).

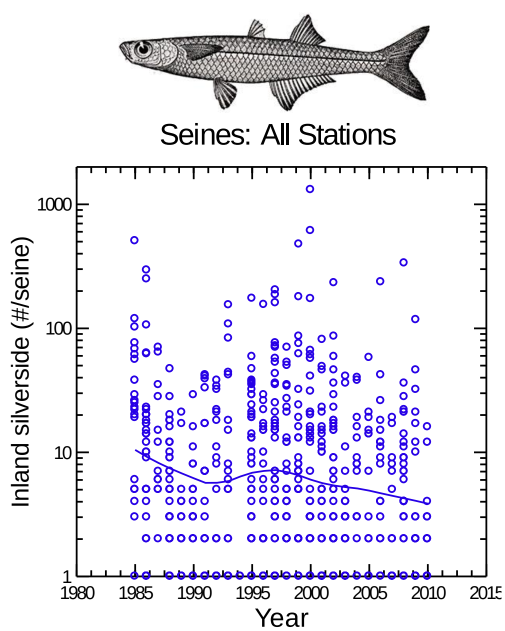


Figure 166c. Seines. Long term trend in Inland Silverside. (*Menidia beryllina*).

In summary, trawl and seine catches continue to provide valuable information about long-term trends in the fish assemblage of Gunston Cove. The development of extensive beds of SAV over the past nine years should be providing more favorable conditions for banded killifish, spottail shiner, inland silverside, and several species of sunfish (bluegill and pumpkinseed) and largemouth bass. Indeed, seine and trawl sampling has indicated a coincident and relative increase in many of these species. In addition, juvenile anadromous species continue to be an important component of the fish assemblage with more diverse catches (owing to the occurrence of American and hickory shad) and a slight indication of greater abundance of juvenile river herring. Although anadromous white perch appear to be declining in the cove, a large amount of available SAV habitat is not adequately sampled and may represent another important habitat type utilized by white perch. Current efforts to incorporate drop-ring sampling to quantify fishes in vegetated habitats and efforts to quantify catch efficiency should lead to higher quality data that will provide a more accurate long-term view of the fish assemblage and trends for the dominant species.

Drop ring sampling methodology was developed in a mini-study during 2007 and conducted through 2009. These data provided information on juvenile fish abundance from areas of Gunston Cove and habitats (SAV beds) that are not sampled (or not sampled well) by fixed station seine and trawl sampling. Consequently, drop ring data complement the fixed station sampling which provides information from shoreline and deeper non-vegetated habitats. The results demonstrated that the current level of sampling effort provides a minimally sufficient precision to detect inter-annual changes in abundance of many of the key species (e.g., banded killifish) as well as some important fishery species that occurred with low frequency (e.g., American eel). A manuscript reporting the seine catch efficiency and drop ring sampling work for 2007, 2008, and 2009 has recently been published in the journal *Environmental Monitoring and Assessment* and this paper details methodological aspects as well as comparisons of fish catches between areas sampled with seines and beds of SAV (Kraus and Jones 2011).

F. Submersed Aquatic Vegetation (SAV) Trends: 1994-2009

A comprehensive set of annual surveys of submersed aquatic vegetation in the Gunston Cove area is available on the web at http://www.vims.edu/bio/sav/. This is part of an ongoing effort to document the status and trends of SAV as a measure of Bay recovery. Maps of SAV coverage in the Gunston Cove area are available on the web site for the years 1994-2008 except for 2001. Tables are also provided summarizing the extent of each bed. The map for 2010 was provided earlier in this report (Figure 64). To examine the long-term trends in SAV in Gunston Cove, the coverage of SAV in “inner” Gunston Cove was gleaned from the tables of individual beds for each year from the web site. For 1996 and 2005, coverage area was estimated from maps as no tables for individual beds were available. Inner Cove was delineated by a line from Gunston Hall to the Coast Guard station (did not include the bed across the mouth of the cove).

Changes in total SAV coverage in the inner portion of Gunston Cove over the period 1994-2010 are shown in Figure 167. SAV coverage remained relatively constant over the period from 1994 to 2003. However, significant increases were found in 2004 and 2005 and coverage remained high through 2010. In fact the increases may have started earlier. Aerial photography for the years 2002-2004 were collected unusually late, from mid October to mid November after plant beds had started breaking up. In earlier years and in 2005, aerial photography from mid August to mid September (when beds would normally be at their greatest) was utilized. This means that the increase in SAV coverage may have begun several years earlier. In 2006, imagery was taken in October so this may account for the decline from 2005. Note that the increase in SAV coverage corresponds with a clear decline in phytoplankton and a clear increase in water clarity (Secchi depth). In 2008, chlorophyll was higher than in any year since 2004. While this did not result in less light availability as measured by Secchi depth, it needs to be watched closely. Chlorophyll a decreased in 2009 and Secchi depth increased; there was a slight increase in SAV coverage. In 2010 both Secchi depth and SAV coverage continued to increase. SAV mapping in 2009 and 2010 was done in early to mid September.

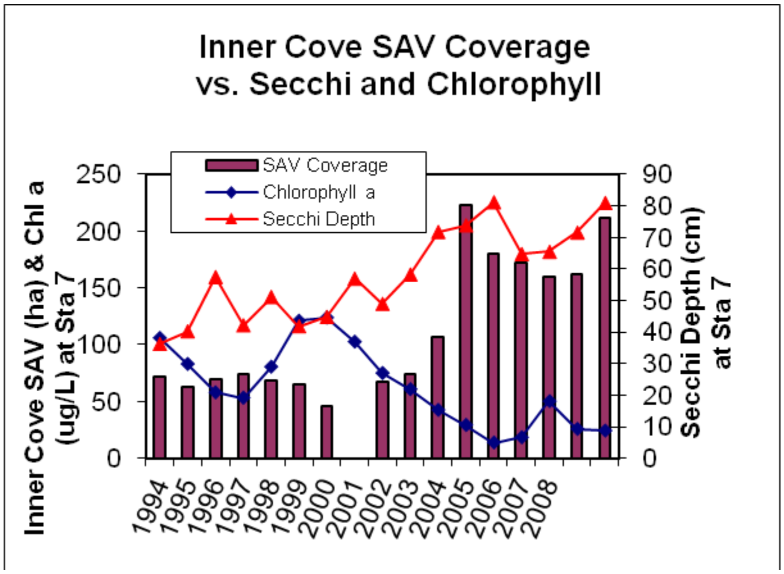


Figure 167. Inner Cove SAV Coverage. 1994-2010. Graphed with average summer (June-September) Depth-integrated Chlorophyll a (µg/L) and Secchi Depth (cm) measured at Station 7 in Gunston Cove.

The following scenario, based on prevailing concepts of SAV-phytoplankton-light interactions, seems most likely to explain these observations. Declining phytoplankton populations have led to an increase in water clarity which allows SAV to grow to greater depths and spread. The SAV coverage will tend to further inhibit phytoplankton by shading and further increase water clarity (Secchi depth). This will allow spread of SAV into even deeper areas. For the last several years, the SAV acreage has remained fairly constant suggesting that the cove has stabilized at a stage of increased SAV, but not full restoration. Full restoration would occur when SAV covers the entire cove as was apparently the case in the early part of the 20th century (Carter et al. 1983, Cummings et al. 1916).

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Anadromous Fish Survey 2010

Background

The commercially valuable anadromous fishes in the herring family (Clupeidae) live as adults in the coastal ocean, but return to freshwater creeks and rivers to spawn. In the mid-Atlantic region, four species are present: American shad, blueback herring, alewife, and hickory shad.

The American shad grows to be the largest and spawns in the shallow flats along the Potomac River channel. In the 1700s and early 1800s, incredibly large numbers of American shad were caught each spring as they came up the river to spawn. The records from 1814-1824 of just one fishery located at Chapman's Landing opposite Mason Neck, Virginia indicate that the annual catch varied from 27,939 to 180,755 American shad (Massmann 1961). By 1982, the numbers caught in the entire river had dwindled so much that a moratorium was placed on both commercial and sport harvest of the species. In 1995, the Interstate Commission on the Potomac River Basin began a process of capturing ripe American shad in gill nets off Dogue Creek and Fort Belvoir, stripping eggs from the females, and fertilizing the eggs with milt from males. The resulting young were raised in hatcheries for several days and then released, as fry, in the river below Great Falls (Cummins 2005). Through the 2002 season, over 15.8 million fry were released into the river, and by 2003 - the year after the restoration program ended - the population was judged strong enough to support a limited commercial fishery as bycatch in gill net fisheries. Moreover, a replacement stocking program continues (Jim Cummins, pers. comm.). The Virginia Department of Game and Inland Fisheries has also released some of the larvae at the boat ramp in Pohick Bay Regional Park in Gunston Cove (Mike Odom, USFWS; pers. comm.). Prior to the 1900s, spawning occurred in the river as high as Great Falls (Smith and Bean 1899). In recent years spawning has occurred mostly downriver between Piscataway Creek and Mason Neck (Lippson et al. 1979). We do not normally catch individuals of this species as adults, juveniles, or larvae. The adults are not caught because our trawls mostly sample fishes that stay near the bottom of the water column, and the American shad remain in the river where the water column is deeper. The juveniles mostly remain in the channel also, but as reported above, in 2006 and 2007 some juvenile American shad were captured at our seine stations. Hickory shad has similar spawning habitats and co-occurs with American shad, but is far less common than American shad or river herring, and less is known about its life history. Coincident with the appearance of juvenile American shad at our seine stations, we have also observed small numbers of juvenile hickory shad in recent years.

The alewife and blueback herring, collectively called river herring, are commercially valuable, although typically less valuable than American shad. In past centuries, their numbers were apparently even greater than those of the American shad. Massmann (1961) reported that from 1814 to 1824, the annual catch at Chapman's Landing ranged from 343,341 to 1,068,932 fish. The alewife spawns in tributary creeks of the Potomac River and travels farther into these creeks than do the other species. The blueback herring also enters creeks to spawn, but may also utilize downstream tidal embayments to spawn.

Although there are no restrictions on their harvest in the Potomac, river herring were listed in

2006 by NOAA as species of concern due to widespread declining population indices. Population indices of river herring in the Potomac are available from seine surveys of juveniles conducted by MD-DNR. Juvenile catch rate indices are highly variable but have been lower in the most recent decade for both species (blueback herring mean: 1998-2008=0.77 vs. 1959-1997=1.57; alewife mean: 1998-2008=0.35 vs. 1959-1997=0.55). This pattern is not reflected in the seine and trawl catches in Gunston Cove, which have fluctuated very little or increased slightly since the inception of the survey. While the DNR indices may represent a basin wide pattern, it is not yet possible to determine the relative contribution of juveniles from Pohick and Accotink Creeks to the Gunston Cove or DNR surveys. Such information would provide a better understanding of the population dynamics of specific tributaries.

Another set of economically valuable fishes are the semi-anadromous white perch and striped bass, which are sought after by both the commercial fishery and the sport-fishery. Both spawn in the Potomac River. Striped bass spawn primarily in the river channel between Mason Neck and Maryland Point, while white perch spawn primarily further upriver, from Mason Neck to Alexandria, and also in the adjacent tidal embayments (Lippson et al. 1979). Although spawning is concentrated in a relatively small region of the river, offspring produced there spread out to occupy habitats throughout the estuary (including surf-zone habitats of barrier islands in some years; Kraus, personal observation). These juveniles generally spend the first few years of life in the estuary and may adopt a seasonal migratory pattern when mature. While most striped bass adults are migratory (spending non-reproductive periods in coastal seas), recent work indicates that a significant (albeit small) proportion of adults are resident in the estuaries. Specific information about striped bass migratory patterns in the Potomac is lacking.

Two other herring family species are semi-anadromous and spawn in the area of Gunston Cove. These are the gizzard shad and the threadfin shad. Both are very similar morphologically and ecologically, but in our collections, threadfin shad are found downriver of Mason Neck, and gizzard shad are found upriver of Mason Neck. Neither is commercially valuable, but both are important food sources of larger predatory fishes.

For several years, we have focused a monitoring program on the spawning of these species in Pohick Creek, Accotink Creek, and, less regularly, Dogue Creek. We have sampled for adult individuals each spring since 1988 and for eggs and larvae since 1992. After 16 years of using hoop nets to capture adults, we shifted in the spring of 2004 to visual observations and seine, dip-net, and cast-net collections. This change in procedures was done to allow more frequent monitoring of spawning activity and to try to determine the length of time the spawning continued. We had to drop Accotink Creek from our sampling in 2005, 2006, and 2007 because of security-related access controls at Fort Belvoir. Fortunately, access to historical sampling locations from Fort Belvoir was regained in 2008. Results for 2010 sampling are presented below. A summary of historical results was provided in the 2007 annual report for this project.

Introduction

Since 1988, George Mason University researchers have been surveying spawning river herring in Pohick Creek and adjacent tributaries of the Potomac River. The results have provided information on the annual occurrence and seasonal timing of spawning runs for alewife (*Alsoa pseudoharengus*) and blueback herring (*A. aestivalis*), but inferences on abundance have been limited for several reasons. The amount of effort to sample spawners has varied greatly between years and the methods have changed such that it is difficult to standardize the numbers captured or observed in order to understand annual fluctuations in abundance. In addition, ichthyoplankton sampling in the creeks has been contemporaneous with spawning runs, and thus it has not reflected outdrift of larvae which may continue after the spawners leave. River discharge was also not measured during the previous ichthyoplankton sampling. To maintain coherence with historical efforts while increasing the value of the data from surveys of Pohick and Accotink Creeks, we developed a modified protocol with two main objectives: 1) quantify the magnitude of outdrifting larvae and coincident creek discharge rate in order to calculate total larval production; 2) quantify seasonal spawning run timing, size distribution and sex ratio of adult river herring using hoop nets (a putatively non-selective gear used throughout the majority of the survey). These modifications were accomplished with little additional cost and provided results that are more comparable to assessments in other parts of the range of these species. Quantico and Dogue creeks were also sampled previously, but the frequency was more sporadic. Due to logistics and expense required to conduct comparable sampling efforts, we did not attempt any sampling at Quantico and Dogue creeks and instead focused entirely on Pohick and Accotink creeks.

Methods

We conducted approximately weekly sampling trips from March 11th to May 13th in 2010. Sampling locations in each creek were located near the limit of tidal influence and as close as possible to historical locations. On one day each week, we sampled ichthyoplankton by holding a conical plankton net with a mouth diameter of 0.25 m and a square mesh size of 0.333 mm in the stream current for 10 minutes. A mechanical flow meter designed for low velocity measurements was suspended in the net opening and provided estimates of water volume filtered by the net. Depending upon flow conditions (we only sampled where creek depth allowed complete submergence of the net opening), we collected 2 to 3 ichthyoplankton samples per week in each creek, and these were spaced out evenly along the stream cross-section. Coincident with plankton samples, we calculated stream discharge rate from measurements of stream cross-section area and current velocity (at 12 to 20 locations along the cross-section). The ichthyoplankton samples were preserved in 10% formalin and transported to the GMU laboratory for identification and enumeration of fish larvae. Identification of larvae was accomplished with multiple taxonomic resources: primarily Lippson & Moran (1974), Jones et al. (1978), and Walsh et al. (2005). River herring (both species) have demersal eggs (tend to sink to the bottom) that are frequently adhesive. As this situation presents a significant bias, we made no attempts to quantify egg abundance in the samples. We estimated total larval production (P) in each creek using the formula: $P = D * V * I$, where D is the density of larvae (per cubic meter), V is the mean river discharge rate (cubic meters per second), and I is the sampling period in seconds. The hoop net was deployed once each week in the morning and retrieved the following morning (see **Picture 1**). All fish in the hoop net were identified, enumerated, and measured. Any river herring were retained for reproductive examination in the laboratory, while all other species were released. We used published estimates of fecundity and observed sex ratios in our catches to estimate spawner abundance. Spawner abundance (*A*) was estimated for river herring species and gizzard shad (a sympatric anadromous species with similar spawning behavior) using the formula: $A = P / (R * S)$, where R is the mean fecundity based upon mean female size in the catch, and S is the observed sex ratio (%female). Alewife fecundity estimates were derived from Kissil (1974), using an unpublished length conversion from this work where fork length = 0.88 * total length. In addition, we adjusted fecundity for alewife based upon Jessop (1993), who estimated that the number of eggs actually spawned is 0.67% of the total fecundity estimated from oocyte counts in gonad samples. Less reproductive information for gizzard shad was available and we did not evaluate sex ratio in the catches because the gizzard shad were released alive. For estimates of gizzard shad spawner abundance we used size-based estimates of fecundity derived from landlocked populations as reported by Jons & Miranda (1997) and Michaletz (1998) and assumed a sex ratio of 50% female. This was accomplished by using the formula from the lake with the largest sample size in Michaletz (1998) and scaling the result by the expected mean proportion of eggs >0.65 mm diameter (i.e., "functional fecundity" in Jons & Miranda, 1997).

In response to problems with animals (probably otters) tearing holes in our nets in previous years, we developed a fence device that significantly reduced this problem. The device effectively excluded otters and similar destructive wildlife, but had slots that allowed up-running fish to be captured. The catch was primarily Clupeids with little or no bycatch of other species.

Picture 1. Hoop net deployed in Pohick creek. The top of the hoop net is exposed at both high and low tide to avoid drowning turtles, otters, or other air-breathing vertebrates. The hedging is angled downstream in order to funnel up-migrating herring into the opening of the net.

Results

Our creek sampling work in 2010 spanned a total of 10 weeks, during which we collected 54 ichthyoplankton samples, and a number of adult alewife in spawning condition. For the first time in the history of the survey we captured hickory shad (*Alosa mediocris*). Hickory shad are known to spawn in the mainstem of the Potomac River, and although their ecology is poorly understood, populations of this species in several other systems have become extirpated or their status is the object of concern. In total, we captured 31 hickory shad across three weeks in Pohick creek, and all were in spawning or spent condition. We did not observe any adult blueback herring. The two river herring species are remarkably similar during both larval and adult stages, and distinguishing larvae can be extraordinarily time consuming. Thus, for purposes of larval identification we assumed that all *Alosa* larvae were *A. pseudoharengus* (alewife). In addition, there was a remote possibility that two *Dorosoma* species could be present in our samples, and these are also extremely difficult to distinguish as larvae. Due to the absence of juveniles in seine and trawl samples from the adjacent Gunston Cove and adjacent Potomac River, we disregarded the possibility that threadfin shad (*D. petenense*) were present in our ichthyoplankton samples.

Densities of alewife and other alosids were low in 2010 creek ichthyoplankton samples. In total our samples yielded only 35 *Alosa* larvae, but by comparison we captured 79 *Dorosoma* larvae. The *Alosa* values were at the low end of the range of larval counts from previous sampling; in some years counts in the hundreds have been observed for these species (see previous annual reports). Alewife densities can also vary widely across weeks within a year and between years, and due to natural fluctuations in spawning processes and egg and larval survival, it is not considered unusual to observe order-of-magnitude fluctuations in larval density. If larval densities remain low for a period longer than the generation time of the population (in this case approximately 6 to 8 years), there may be cause for concern that the population is declining. Additionally, we recorded 2 sucker larvae (family Catostomidae), 54 minnow larvae (family Cyprinidae), and 1 sliverside larvae (*Menidia* sp.) and 3 banded killifish (*Fundulus diaphanus*) larvae, and 11 yellow perch larvae (*Perca flavescens*). In these data, we had the advantage of measurements of creek discharge measured at the same locations and times where ichthyoplankton samples were taken. Creek discharge was consistently higher in Pohick creek (except for the last sampling date) and ranged between 2.9 and 14.5 m^3s^{-1} (Figure 1). Larval density was low for *Alosa* exhibiting a single peak on April 7th (Figure 1). *Dorosoma* (not shown) larval density peaked near the end of the sampling period on May 5th and 6th, respectively in Accotink and Pohick creeks.

Averaged across the entire sampling period of 70 days, the total discharge was estimated to be on the order of 37 and 95 million cubic meters for Accotink and Pohick creeks, respectively (Table 1). Given the observed mean densities of larvae, the total production of *Alosa* larvae was estimated at approximately 0 and 7.4 million for Accotink and Pohick creeks, respectively. *Dorosoma* density was higher leading to total larval production estimates of 1 and 14 million for Accotink and Pohick creeks, respectively.

In the hoop net sets, a total of 187 alewife were captured. The proportion of females varied from 0.19 in Accotink to 0.3 in Pohick. Skewed sex ratios in fish populations are common. Based upon observed mean lengths, sex ratios, total larval production, and published estimates of fecundity (see Methods), the abundance of spawning alewife was estimated to be 197 in Pohick Creek during the period of sampling, and no spawning is predicted from Accotink creek based upon larval abundance. By comparison, there was greater variability between creeks for gizzard shad spawner abundance estimates, which ranged between 125 and 2,617 for Accotink and Pohick Creeks, respectively. Because the mortality rates of eggs and newly hatched larvae are unknown from these systems, these estimates should be considered minimum conservative values. Any adjustment for egg or post-hatch mortality would tend to increase the estimate of spawner abundance. Certainly, due to the presence of alewife in hoop net catches from Accotink some spawning was taking place, but this obviously did not lead to a detectable abundance of larvae. In addition for gizzard shad, a sex ratio skewed in favor of males (as we observed for alewife) would also tend to increase the estimated total spawner abundance, but this information was not collected in order to release gizzard shad as part of the hoop net by-catch.

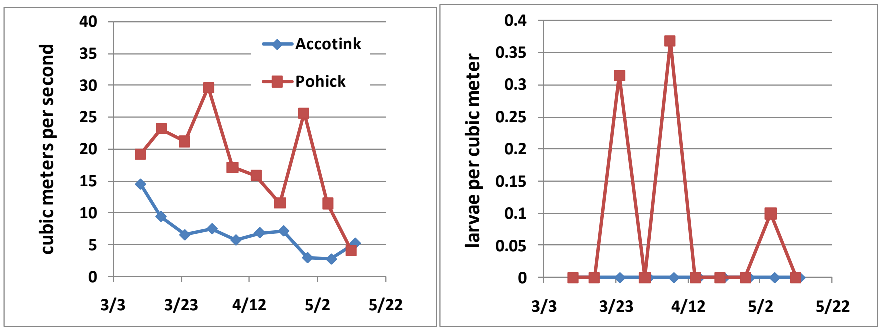

Figure 1. Discharge rate (left) and density of larval alewife (right) observed in Pohick and Accotink creeks during 2010.

Table 1. Estimation of alewife and gizzard shad spawner abundance from Accotink and Pohick creeks during spring 2010.

	Accotink Creek	Pohick Creek
Mean discharge (m^3/s)	6.8	17.9
Total discharge, 3/11 to 5/13 (m^3)	37,182,859	95,832,587
Alewife		
Mean density of larval *Alosa* (m^{-3})	0	0.078
Total larval production	0	7,493,575
Adult alewife mean fork length (mm)	276	272
Alewife fecundity	227,617	213,818
Sex ratio (%F)	0.19	0.30
Number of female alewife	0	35
Total number of alewife	0	54
Gizzard shad		
Mean density of larval *Dorosoma* (m^{-3})	0.029	0.149
Total larval production	1,064,833	14,293,053
Adult gizzard shad mean total length (mm)	311	360
Gizzard shad fecundity	17,060	22,244
Sex ratio (%F)	0.5	0.5
Number of female gizzard shad	62	643
Total number of gizzard shad	125	1,285

Discussion

With this third year of the new sampling protocol, some important trends are becoming apparent. Our modifications to the hoop nets to exclude destructive bycatch (namely, otters) appear to be successful as net tears and suspected loss of catch were minimal or absent in 2010. Further, the capture of adult hickory shad, which are similar in shape but approximately twice as large as the largest alewife, provides convincing evidence that the bycatch excluder is not affecting capture of the target species, adult river herring. In 2008, 2009, and 2010, and throughout the history of the survey, the consistent presence of alewife and lack of blueback herring suggests that Pohick and Accotink Creeks are a more suitable habitat for alewife than blueback herring (at least during the past 3 decades). The presence of spent and running ripe females in our catches also indicates that some spawning is occurring in tidal areas downstream. The importance of upstream spawning locations relative to tidal habitats is simply unknown for these systems, but previous work in other systems indicates that the most important spawning areas typically occur upstream of the influence of tides for river herring. The low catches of adults in hoop nets mirrors the low estimates of total spawner abundance from larval data (Table 1). Our data indicate that the number of adults utilizing Pohick and Accotink creeks, is typically ranges from several tens to a few thousand. Considering the phenomenal numbers of herring and shad captured in fisheries in previous centuries (see Massmann 1961), these creeks probably only ever represented an extremely small fraction of the total larval production of herring and shad in the Potomac River. To understand the contemporary importance of these systems, comparative work in other tributaries and the Potomac mainstem is needed. Finally, consistently higher numbers of alewife and gizzard shad spawners suggests that Pohick Creek provides a more productive spawning habitat for anadromous clupeids. Due to the recent (NOAA, 2006) listing of river herring as species of conservation concern, annual estimation of spawner abundance should be a continued priority for annual monitoring in these creeks.

Several factors contribute to uncertainty of the estimates of spawner abundance. Although some of these can be addressed with modifications of sampling protocol, other factors are beyond the scale of this project to address. Our weekly sampling efforts were adjusted based upon military training schedules at Fort Belvoir and flood events that prevented safe deployment of sampling gear. Our sampling approach provides information about low to moderate flow conditions only with no ability to examine higher frequency (< weekly) patterns. Alewife spawning, egg development, and hatching may happen in as little as 3 to 7 days; therefore, it is possible to miss a peak spawning event between sampling dates and during flood events. In addition, we do not have information from night time conditions at these sites, and larval outdrift may vary significantly on a diel cycle. Unfortunately, given the logistical constraints of access to our sites through military controlled training areas, it is unlikely that we would be able to address these potential biases in future efforts.

Low overall larval densities for alewife as well as other species may be related to the effectiveness of the sampling approach. Anadromous fishes typically exhibit strong year-class fluctuations, and reproductive success of freshwater spawning fishes (anadromous and otherwise) is strongly correlated with freshwater flow (Wood & Austin 2009). Thus, individual years of low larval output may be expected. Additional years of data collection (at least through 2 generation lengths of alewife ~ a decade), should provide a sufficient understanding of this variability. Comparative studies of other tidal Potomac tributaries would also help to resolve the relative importance of these creeks in the large Potomac River ecosystem. Higher sampling effort would improve the precision of larval production estimates, and a power analysis would aid in determining the number of samples needed to achieve a desired level of precision. Although the current evidence suggests marginal importance of Pohick and Accotink creeks to alewife populations, it is important to recognize that marginal habitats may sustain fish populations during periods of declining abundance and low recruitment (Kraus and Secor 2005), and this effect may be particularly important when considering the condition of Pohick and Accotink creeks that are less impacted than some other tributaries of the Potomac River where alewife are known to spawn.

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