DISCUSSION

A. 2012 Data

The year 2012 was characterized by above normal temperatures from March through October with highest monthly average of 28.9°C in July. Monthly precipitation was below normal for most of this same period with 20.2 cm occurring during the summer months (June – August) in 2012 compared with the long term average of 26 cm. Rainfall was above normal in both September and October. Mean monthly discharge of the mainstem Potomac at Little Falls was also below normal during this period reaching a minimum of 2986 cfs in July. Local tributary inflow into tidal Gunston Cove was generally below normal although May and June were slightly above normal. August had lowest mean monthly flow at less than 10 cfs. Highest flows occurred October as a function of Hurricane Sandy.

Mean water temperature peaked in early July and early August at times of the highest air temperatures of the year. There was little difference between the two sites on a given date. Specific conductance was generally in the 300-400 µS/cm range at both sites. A decline in early June may be ascribable to elevated Potomac mainstem flows for a brief period in late May and early June. Chlorides showed a similar decline at this time. Specific conductance and chloride continued to increase through August and dropped back slightly in September. Indicators of photosynthetic intensity (dissolved oxygen-percent saturation and field pH) showed an initial peak in the cove in early May and then a period of sustained increased through the summer. In the river, there was little seasonal change in these parameters. Light penetration was generally slightly higher in the river than in the cove as indicated by Secchi disk depth and light attenuation coefficient. Secchi depth was consistently above 80 cm in the river, but more like 70 cm in the cove. Total alkalinity was generally 60-80 mg/L as $CaCO_3$ with somewhat higher values in the river on most dates.

Ammonia nitrogen was very low (<0.05 mg/L) on most dates in both cove and river. The un-ionized form was extremely scarce. Nitrate was found at moderate levels at both sites in the spring and decreased steadily in the early summer to very low levels before rebounding in the fall. River values were consistently about 0.2 mg/L greater than those in the cove. Nitrite nitrogen was much lower being less than 0.02 mg/L in the cove and reaching a peak of 0.04 mg/L in the river. Organic nitrogen showed an inverse temporal trend at the two sites. In the river the peak value was in early May at nearly 1.2 mg/L followed by a gradual decline through September. In the cove an early May value of less than 0.6 mg/L was succeeded by an increase to about 0.9 mg/L by late August. Total phosphorus followed similar seasonal trends and values at both sites. Spring and fall values were 0.05-0.07 mg/L while summer values approached 0.10 mg/L. SRP values were generally much lower being mostly below 0.01 mg/L in the cove and 0.01-0.02 mg/L in the river. N to P ratio (by weight) showed a steady seasonal decline at both sites from about 30 in early May to 10 July and early August. Values approached, but did not attain, those associated with the onset of nitrogen limitation (7.2). BOD showed much fluctuation between dates, but a consistent spatial pattern of higher values at Station 7. Total suspended solids were very similar in almost all months. TSS was

consistently slightly higher in the cove in late summer and fall. VSS was slight, but consistently higher in the cove with little seasonal pattern.

Algal populations as measured by chlorophyll a were consistently higher in the cove than in the river with an annual average of about 30 µg/L in the cove and 20 µg/L in the river. After a peak in early May, chlorophyll in the cove increased through September attaining 45 ug/L in September. In the river the high was about 30 µg/L in early July. Phytoplankton density was closely matched at the two sites from April through early July. In late July the cove station increased abruptly peaking at nearly 1.6×10^6 cells/mL in early August. In the river there was a slower increase that reached a maximum of about 6×10^5 cells/mL in late August. Biovolume was a somewhat different story with river values often greater than those in the cove and the highest peak of both sites in the spring. Phytoplankton cell density at the Gunston Cove site was dominated by cyanobacteria on all dates and at both sites due to their small size. The dominant taxa in spring was *Anabaena* while *Microcystis* was most important in mid-summer, and *Merismopedia* in the fall. *Oscillatoria* attained substantial numbers in most samples from the cove. In the river *Oscillatoria* was dominant in the spring and into the summer. In August dominance shifted to *Microcystis* and *Aphanocapsa*. Non cyanobacterial density was dominated by a mixed assemblage of the diatom *Melosira*, the cryptophyte Cryptomonas with Spherocystis being highly abundant on one date (early August) in the cove. Diatoms dominated biovolume in the cove and river for much of the year, being very abundant in late April and again in July and August. Cyanobacteria and cyptophytes were important on some dates. *Oscillatoria* was greatest in cyanobacterial biovolume on most dates with *Anabaena*, *Spirulina*, and *Anabaenopsis* being important in early August. In the river *Oscillatoria* was also the dominant in cyanobacterial biovolume. Noncyanobacterial biovolume was generally dominated by *Melosira* or by discoid centric diatoms with another diatom *Gyrosigma* being important in April and September. A similar dominance by *Melosira* and discoid centrics was observed in the river.

Rotifers were the most numerous zooplankton in the study area with abundances in the cove general twice those in the river. A general seasonal pattern was observed at both sites with an increase to a maximum in late May, a drastic decline (perhaps due to flushing) in early June, and a partial recovery and slow decline through the remainder of the year. *Brachionus* and *Keratella* were the most abundant at both sites and on most dates with *Keratella* clearly more abundant in the river and *Brachionus* more frequently dominant in the cove. The small cladoceran *Bosmina* was quite abundant in both study areas in spring and in the river was again abundant in early July. River densities were greater than cove densities on each date. The larger abundant cladoceran *Diaphanosoma* was also generally more abundant in the river reaching a maximum of just over $10{,}000/m^3$ in early July in the river. The other herbaceous cladocera, *Daphnia*, *Ceriodaphnia*, and *Moina* were quite low except for *Moina* in early June which reached $3000/m^3$ in the river. *Leptodora*, the predaceous cladoceran, peaked at 1500 in the cove in early June, much higher than the river peak. The seasonal pattern of nauplii (immature copepods) was quite different in cove and river. In the river nauplii densities increased to a peak in early June and then decreased for the remainder of the year. In the cove the increase was more gradual and continued into September. *Eurytemora*, a calanoid copepod reached similar peaks in both study areas of about $5000/m^3$ in early June. Other

calanoids were also at peak abundance at that time. Cyclopoid copepods were quite abundant in the river, especially in late June and July.

In 2012 ichthyoplankton was dominated by *Dorosoma* sp. (gizzard shad) and, to a lesser extent, alosids (alewife, blueback herring, and shad) and white perch. Other taxa were found in very low numbers similar to the previous year. What is different from 2011 is the shift of the highest abundance to earlier in the season. The highest abundance of all larval species occurred in May, while this is usually June. The mild winter may have been responsible for an earlier spawning season than usual.

In trawls, the overwhelming majority of the adult and juvenile fish collected were represented by 3 taxa: white perch (*Morone Americana*), bay anchovy (*Anchoa mitchilli*) and spottail shiner (*Notropis hudsonius*). Other numerically abundant species included various species of sunfish and blue catfish (*Ictalurus furcatus*). Other catfishes and bullheads were found in very low numbers, and only two species were represented (channel catfish and brown bullhead). There is a visible trend of increasing numbers of blue catfish and decreasing numbers of other catfish, which may be a sign that blue catfish is outcompeting similar species. As usual, white perch was found throughout the year and at all stations. Spottail shiner were found throughout the year, but almost all specimens were collected at station 7. Blue catfish was found most frequently in June, and mainly in the river. There were very low numbers of adult *Alosa* sp., which is indication of the stock collapse of these species. The moratorium (no catch allowed) that is now in place for alewife and blueback herring may help in the recovery, as we have seen a high abundance of larvae in our samples, that may successfully recruit to adults now that fishing has stopped.

In seines, the most abundant species by far was banded killifish (*Fundulus diaphonus*), followed by inland silverside. Banded killifish was not abundant in trawls, which emphasizes the preference of banded killifish for the shallow littoral zone (which is the area sampled with a seine, while trawls sample the open water). This is also evident from the fact that banded killifish was least abundant in Station 11, which is close to the mainstem. Banded killifish, inland silverside and white perch were collected at all stations and throughout the year. The abundance peak of banded killifish was in May, while inland silverside and white perch had higher abundances in July and August.

This year we included fyke nets to the sampling regime for the first time. One of the questions we tried to answer by adding these fyke nets is whether the abundance of banded killifish is indeed reduced in July and August as the seine data suggests, or if they are more successful at finding refuge within the SAV beds, which have expanded in July and August. With the inclusion of fyke nets the SAV beds are samples directly, while over abundance may be lower because this is passive gear (fish need to enter the net to be caught).

Banded killifish are not the most abundant species in the fyke nets, and their abundance is fairly evenly distributed from June to September. The reduced abundance in June, July and August in the seine nets is not compensated by an increase abundance of banded killifish in the fyke nets. High numbers of banded killifish adults congregate in the cove when it is suitable for spawning, which was in May in 2012. After that the numbers dissipate. High

numbers of sunfish were found in the fyke nets, which also make use of the vegetation to spawn. The highest abundance of sunfish was in August. It would be interesting to include ichthyoplankton sampling specifically in the vegetation, to capture the use of spawning habitat of species abundant within the SAV beds like banded killifish and sunfish. The 5-hour time frame the nets are set seems sufficient to capture an abundant amount of specimens; the average catch per unit effort was 125 specimens.

Chironomids were unusually abundant taxon in the benthos at Station 7 during 2012 averaging over 100 per petite ponar grab. Oligochaetes were also quite abundant in the cove with a small additional contribution from amphipods, bivalves, and leeches. In the river, oligochaetes were the most abundant benthic taxon. Chironomids were uncommon in the river, but other taxa were much more abundant in than in the cove including amphipods, bivalves, gastropods, isopods and flatworms. Submersed aquatic vegetation covered about 179 acres in 2012 similar to other recent years.

B. Water Quality Trends: 1983-2012

To assess long-term trends in water quality, data from 1983 to 2012 were pooled into two data files: one for Mason data and one for Noman Cole laboratory data. Then, subgroups were selected based on season and station. For water quality parameters, we focused on summer (June-September) data as this period is the most stable and often presents the greatest water quality challenges and the highest biological activity and abundances. We examined the cove and river separately with the cove represented by Station 7 and the river by Station 9. We tried several methods for tracking long-term trends, settling on a scatterplot with LOWESS trend line. Each observation in a particular year is plotted as an open circle on the scatterplot. The LOWESS (locally weighted sum of squares) line is drawn by a series of linear regressions moving through the years. We also calculated the Pearson correlation coefficient and performed linear regressions to test for statistical significance of a linear relationship over the entire period of record (Tables 14 and 15). This was similar to the analysis performed in previous reports.

Table 14
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1984-2012
GMU Water Quality Data
June-September

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Temperature	0.199	0.068	<0.001	0.131	0.040	0.049
Conductivity, standardized to 25°C	0.109	2.83	0.002	0.029	----	NS
Dissolved oxygen, mg/L	0.006	----	NS	0.177	0.027	0.008
Dissolved oxygen, percent saturation	0.076	----	NS	0.201	0.391	0.003
Secchi disk depth	0.697	1.52	<0.001	0.346	0.615	<0.001
Light extinction coefficient	0.621	0.101	<0.001	0.097	----	NS
pH, Field	-0.113	----	NS	0.190	0.011	0.011
Chlorophyll, depth-integrated	-0.525	-3.94	<0.001	-0.149	-0.482	0.029
Chlorophyll, surface	-0.526	-4.12	<0.001	-0.148	-0.566	0.025

*marginal significance
For Station 7, n=258-277 except pH, Field where n=211 and Light extinction coefficient where n=197.
For Station 9, n=216-230 except pH, Field where n=178 and Light extinction coefficient where n=165.

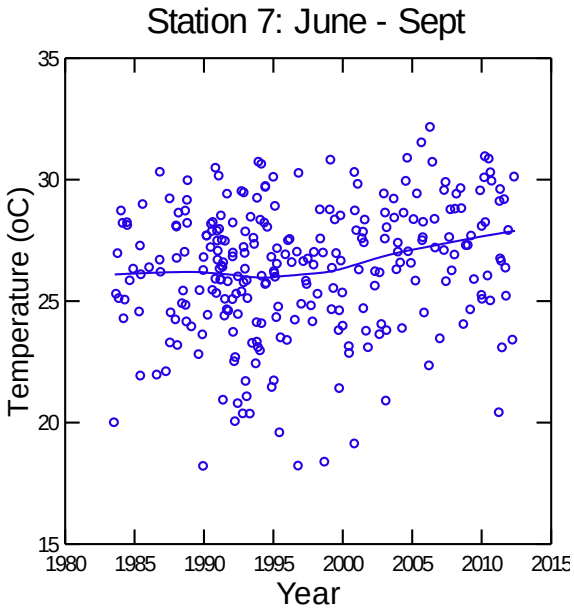
Significance column indicates the probability that a correlation coefficient this large could be due to chance alone. If this probability is greater than 0.05, then NS (not significant) is indicated.

Table 15
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1983-2012
Fairfax County Environmental Laboratory Data
June-September

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Chloride	+0.005	----	NS	+0.008	----	NS
Lab pH	-0.365	-0.028	<0.001	-0.255	-0.015	<0.001
Alkalinity	+0.091	----	NS	+0.198	0.296	<0.001
BOD	-0.615	-0.182	<0.001	-0.453	-0.057	<0.001
Total Suspended Solids	-0.292	-0.924	<0.001	-0.074	----	NS
Volatile Suspended Solids	-0.376	-0.698	<0.001	-0.322	-0.137	<0.001
Total Phosphorus	-0.496	-0.004	<0.001	-0.162	-0.0006	<0.001
Soluble Reactive Phosphorus	-0.029	----	NS	0.148	0.0003	0.003
Ammonia Nitrogen	-0.269	-0.018	<0.001	-0.277	-0.003	<0.001
Un-ionized Ammonia Nitrogen	-0.296	-0.005	<0.001	-0.329	-0.0004	<0.001
Nitrite Nitrogen	-0.377	-0.003	<0.001	-0.270	-0.002	<0.001
Nitrate Nitrogen	-0.525	-0.036	<0.001	-0.637	-0.042	<0.001
Organic Nitrogen	-0.508	-0.049	<0.001	-0.259	-0.010	<0.001
N to P Ratio	-0.295	-0.384	<0.001	-0.585	-0.739	<0.001

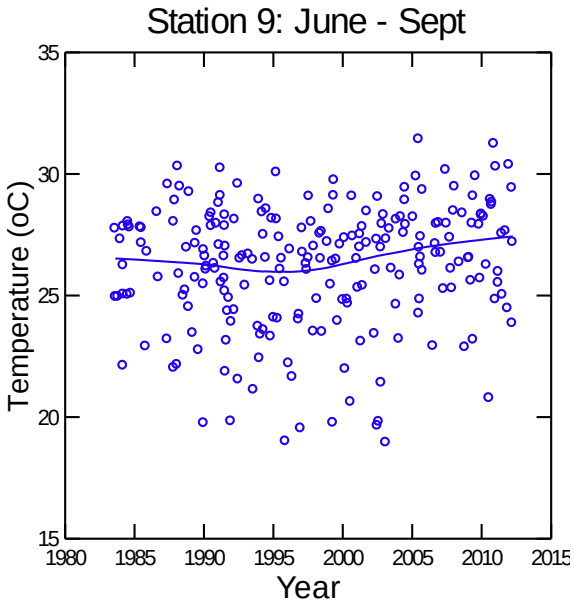
For Station 7, n=377-420 except Nitrite Nitrogen where n=342.
For Station 9, n=378-427 except Nitrite Nitrogen where n=342.

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.



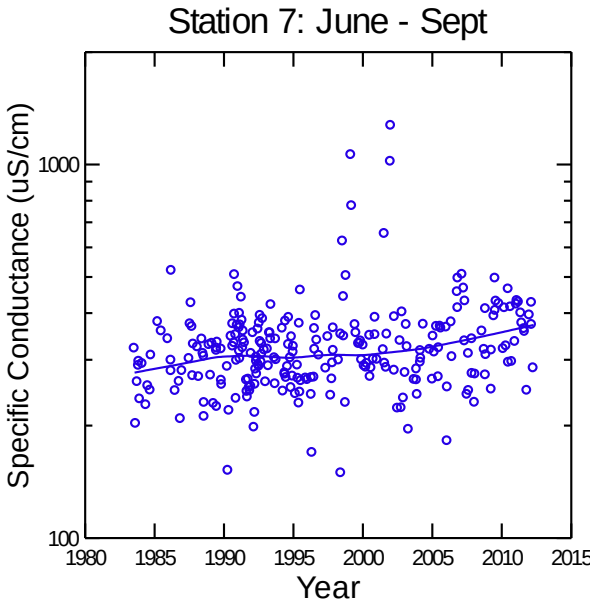
Water temperatures during the summer months generally varied between 20 and 30°C over the study period (Figure 66). The LOWESS curve indicated an average of about 26°C during the period 1984-2000 with a distinct upward trend in the last few years approaching 28ºC. Linear regression analysis indicated a significant linear trend in water temperature in the cove when the entire period of record is considered (Table 14). The slope of this relationship is 0.07°C/year.

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



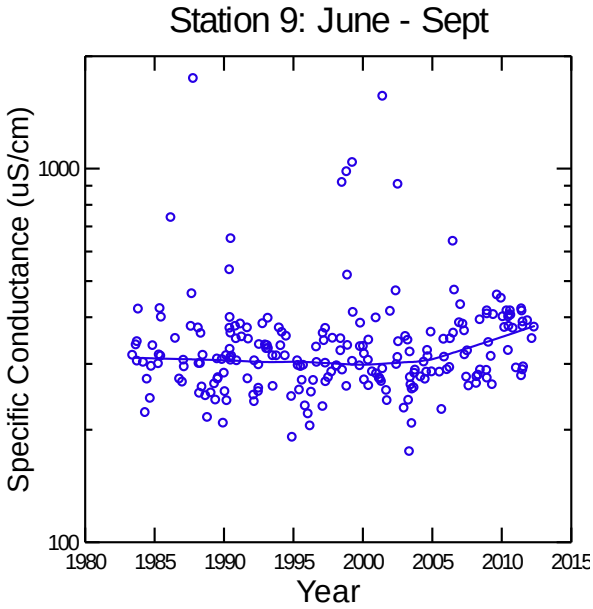
In the river summer temperatures have been slightly cooler than in the cove (Figure 67). The trend line again started out at about 26°C, but has increased less strongly. There appear to be somewhat fewer readings above 30° C in the river. Linear regression over the study period became significant for the first time in 2012 with a slope of 0.04°C/yr (Table 14).

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



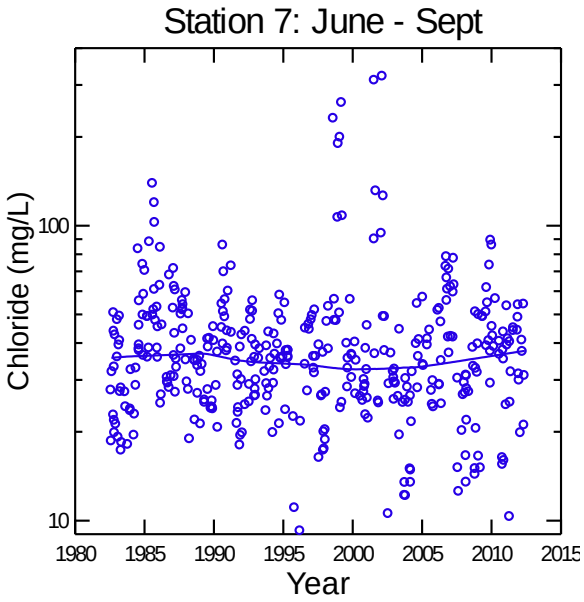
Specific conductance was generally in the range 200-500 µS/cm over the study period (Figure 68). Some significantly higher readings have been observed sporadically. A slight increase in specific conductance was suggested by the LOWESS line over the study period. This was confirmed by linear regression analysis which found a significant linear increase of 2.8 µS/cm per year over the long term study period (Table 14). The results for 2012 were centered around the trend line.

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



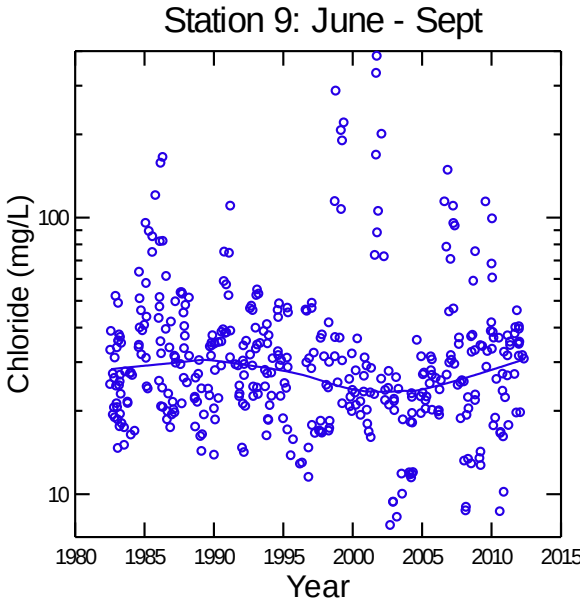
Conductivity values in the river were in the same general range as in the cove (Figure 69). Most values were between 200 and 500 µS/cm with a few much higher values. These higher values are probably attributable to intrusions of brackish water from downstream during years of low river flow. Linear regression did not reveal a significant trend in river conductivity (Table 14). However, the trend line has moved up in recent years from about 300 µS/cm to nearly 400 µS/cm. The 2011 results were generally centered around the long term trend line.

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



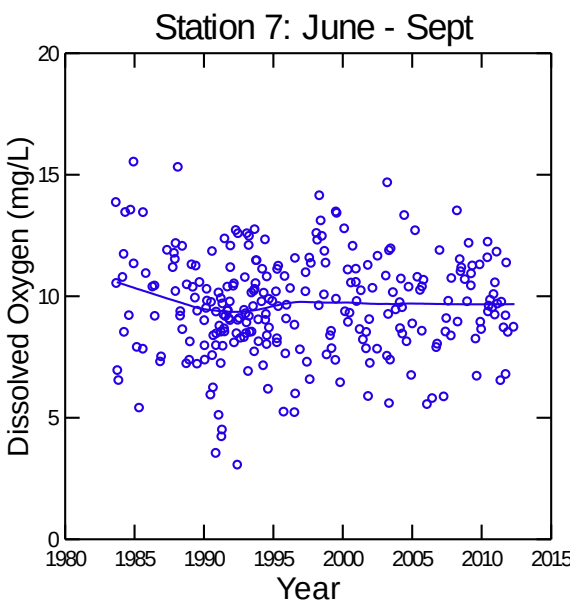
Chloride levels were clustered in a relatively narrow range of 20-60 mg/L for the entire study period (Figure 70). Higher values observed in some years were probably due to the estuarine water intrusions that occur in dry years. The trend is nearly flat and a linear regression was not statistically significant (Table 15). 2010 levels were above the trend line.

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



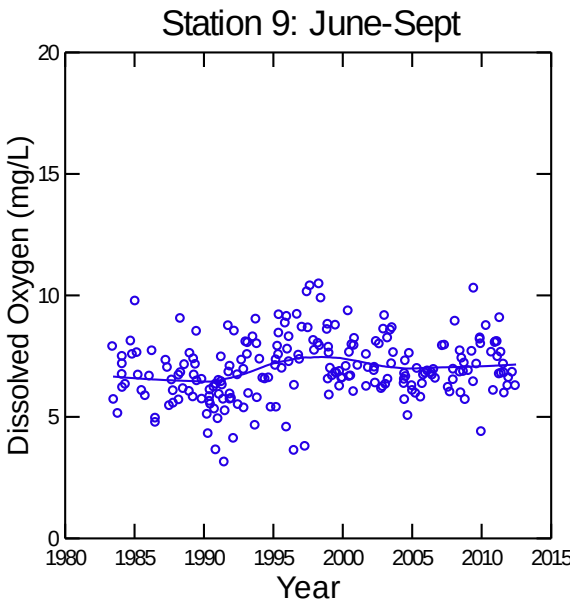
Chloride in the river has been slightly more variable than that in the cove, but in the same general range (Figure 68). The higher readings are again due to brackish water intrusions in dry years. A slight trend of increasing values in the 1980's followed by decreases in the 1990's and increases since 2005 was suggested by the LOWESS trend line. However, temporal regression analysis was not statistically significant (Table 12). The 2012 values were slightly above the trend line.

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



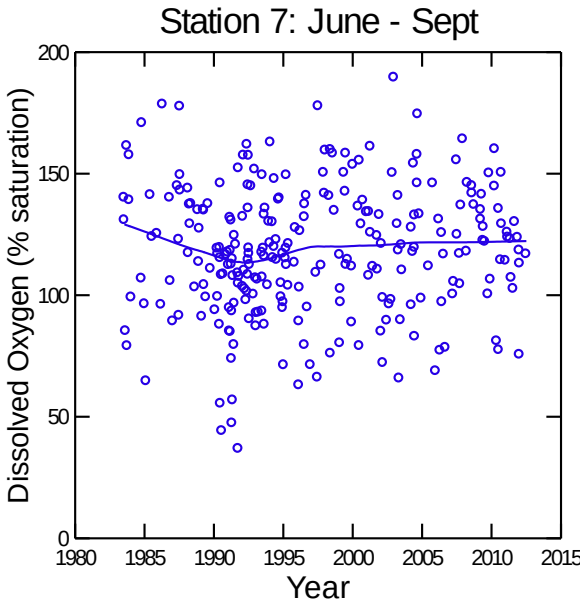
Dissolved oxygen in the cove has generally been in the range 8-12 mg/L during the summer months (Figure 72). A slight downward trend was observed through 1990, but since then the trend line has flattened, suggesting little consistent change and a mean of about 10 mg/L. In the cove dissolved oxygen (mg/L) did not exhibit a significant linear trend over the long term study period (Table 14).

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



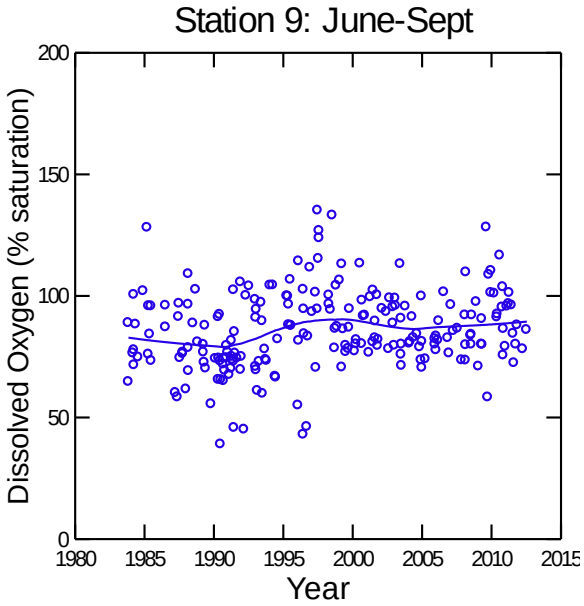
In the river dissolved oxygen values generally were in the range 5-9 mg/L over the long term study period (Figure 73). The LOWESS trend line suggested a slight decline in the 1980's, an increase in the early to mid 1990's, a slight decline in the early 2000's and steady values since. The linear regression analysis over the entire period indicated a significant positive trend with slope of 0.027 mg/L per year (Table 14). 2012 readings were slightly below the long term trend line.

Figure 73. Long term trend in Dissolved Oxygen, mg/L (GMU Data). Station 9. River mainstem.



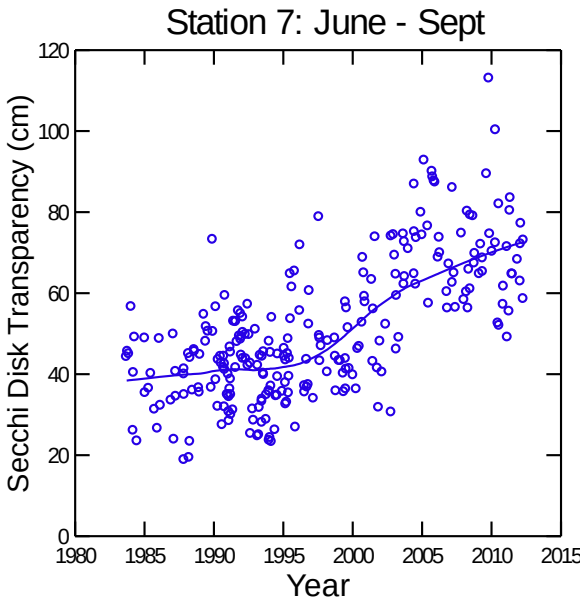
Dissolved oxygen was generally in the range 100-150% saturation in the cove over the long term study period indicating the importance of photosynthesis in the cove (Figure 74). A decline was indicated by the trend line through 1990 followed by a slight recovery in subsequent years. Percent saturation DO did not exhibit a significant linear trend over the long term study period (Table 14). 2012 values fell around the trend line.

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



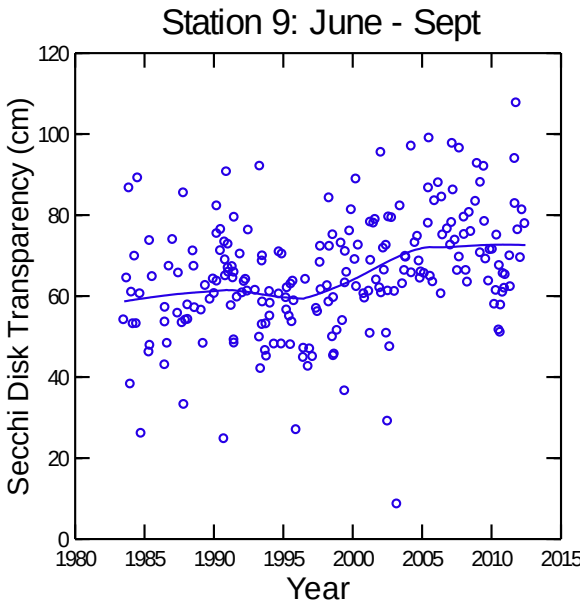
In the river dissolved oxygen was generally less than 100% indicating that photosynthesis was much less important in the river than in the cove (Figure 75). The temporal pattern showed a slight decline in the 1980's, an increase in the 1990's, and a subsequent slight decline in the 2000's. In the river a significant linear increase was indicated by regression analysis with a slope of 0.4% per year (Table 14). 2012 readings were slightly below the long term trend line.

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



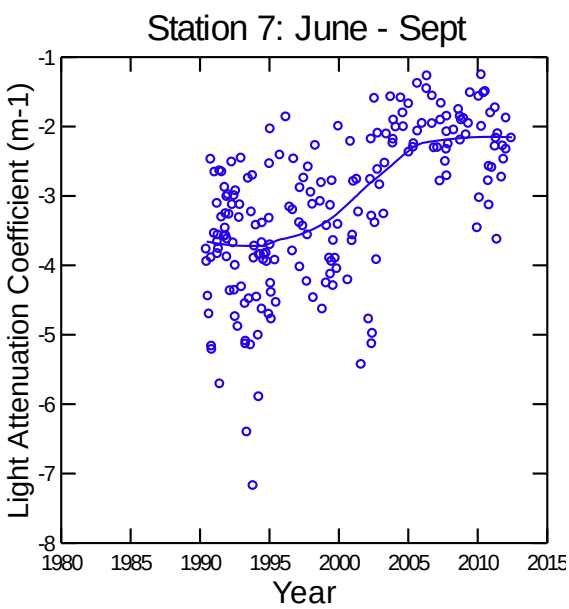
Secchi disk transparency is a measure of water clarity. Secchi disk was fairly constant from 1984 through 1995 with the trend line at about 40 cm (Figure 76). Since 1995 there has been a steady increase in the trend line from 40 cm to nearly 80 cm in 2011. Linear regression was highly significant with a predicted increase of 1.5 cm per year or a total of 43 cm over the study period (Table 14). In 2012 most readings were centered around the trend line.

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



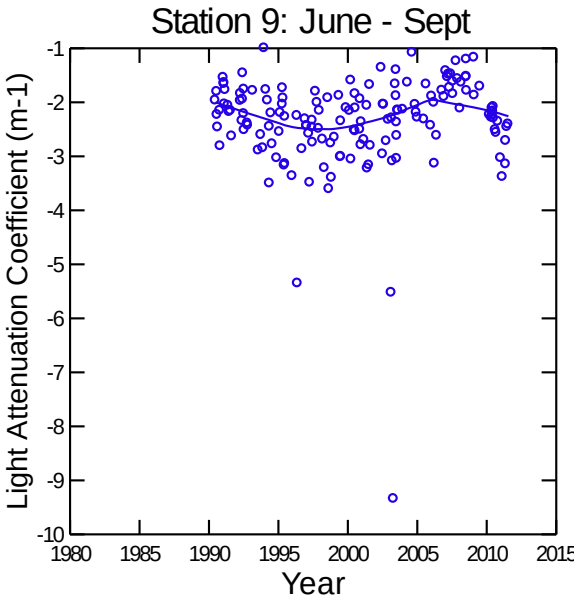
In the river Secchi depth was somewhat greater than in the cove initially (Figure 77). The trend line was fairly constant at about 60 cm until about 2000. A rise to about 75 cm was observed by 2005 and the trend line has remained fairly constant since. Values in 2012 were generally above the trend line. Linear regression revealed a significant increase of 0.61 cm per year with total increase of 18 cm predicted over of the study period (Table 14).

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



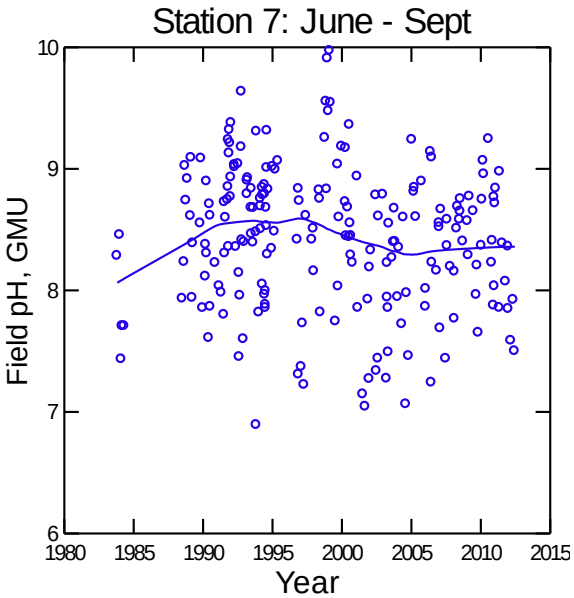
Light attenuation coefficient, another measure of water clarity, reinforces the conclusion that water clarity has been improving in the cove since 1995 (Figure 78). Trend line for the coefficient rose from about -4 to than -2 m^{-1} during this time. Consistent with this was the regression analysis which revealed a significant linear increase in light attenuation coefficient over the period 1991-2012 with a slope of 0.1 per year yielding a prediction that light attenuation improved by about 2 units over this period (Table 14).

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



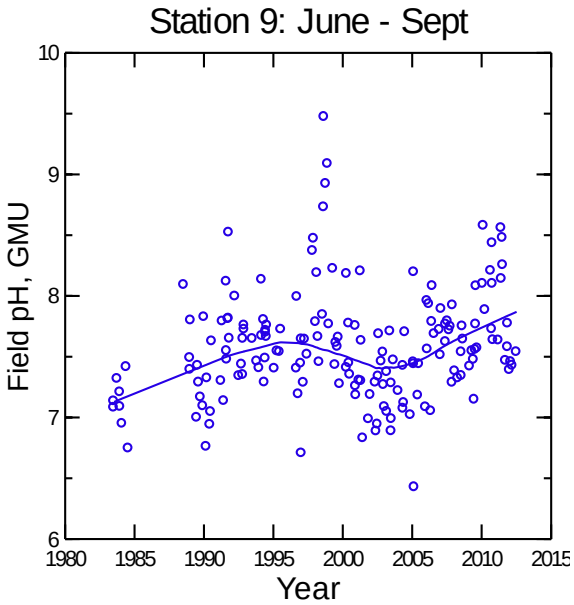
In the river light attenuation coefficient suggested a decline in light transparency between 1991 and 1997 followed by an increase through about 2008 (Figure 79). In recent years light transparency has decreased again in the river. Regression did not reveal a significant linear trend over the entire period (Table 14).

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



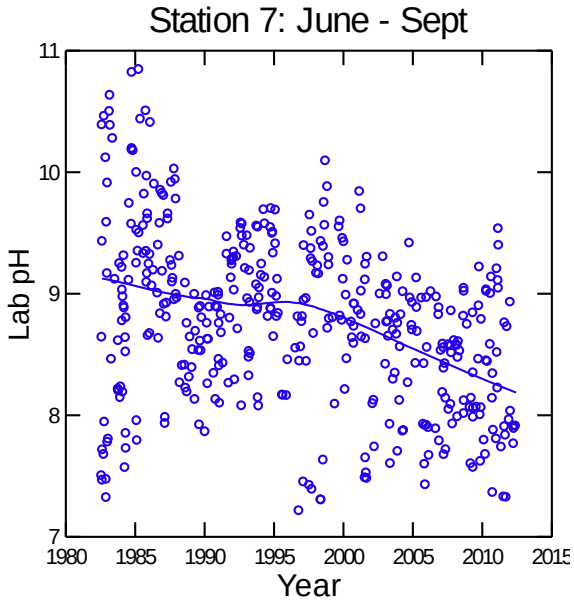
Field pH has not been measured as consistently over the entire study period as other parameters. There is little evidence for a consistent trend over the measurement period (Figure 80). Cove values have generally been in the 8-9 range. Linear regression analysis did not provide evidence of a linear trend when the entire study period was (Table 14).

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



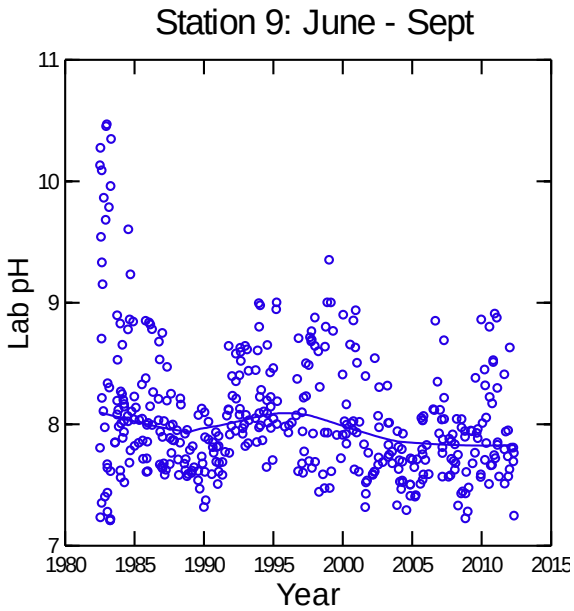
In the river a similar pattern has been observed over this period (Figure 81). pH in the river has been consistently lower by about 1 pH unit than in the cove. A gradual increase from 7.2 in 1989 to 7.7 in 1998 was followed by a decline to about 7.4. In recent years pH has again increased markedly with the trend line rising to 7.9. When all years were considered, field pH in the river shows a significant increase at a rate of 0.01 units per year (Table 14). 2012 values were below the trend line.

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



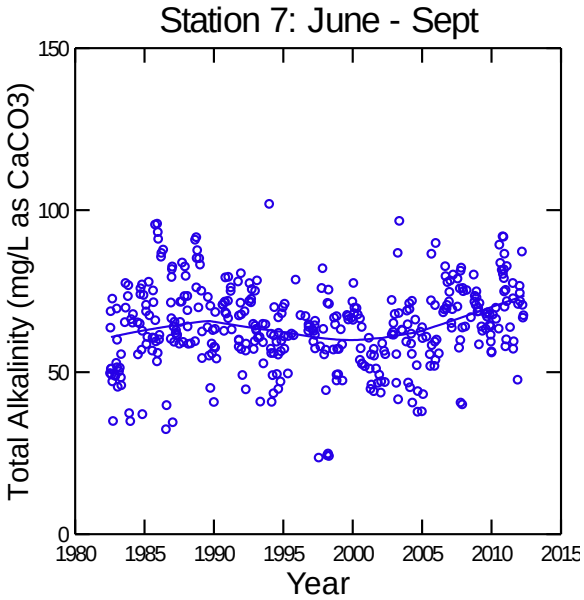
Lab pH as measured by Fairfax County personnel were generally in the range 8 to 10 over the long term study period (Figure 82). Since about 1996 a decline is very evident with the trend line decreasing from about 9 to about 8.2. Linear regression indicated a significant decline in lab pH over the study period at a rate of about 0.028 pH units per year or a total of 0.84 units over the study period (Table 15).

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



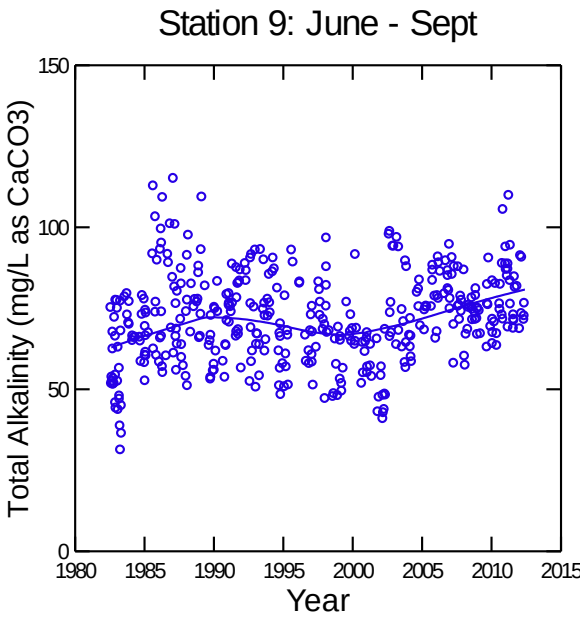
In the river, long term pH trends as measured by Fairfax County lab personnel indicate that most values fell between 7 and 9 (Figure 83). The trend line has increased and decreased slightly over the years with data since 1998 showing a slight decline. Values in 2012 were mostly below the trend line. pH in the river showed a significant linear decline with a rate of 0.015 per year yielding a total decline of 0.45 units over the long term study period (Table 15).

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



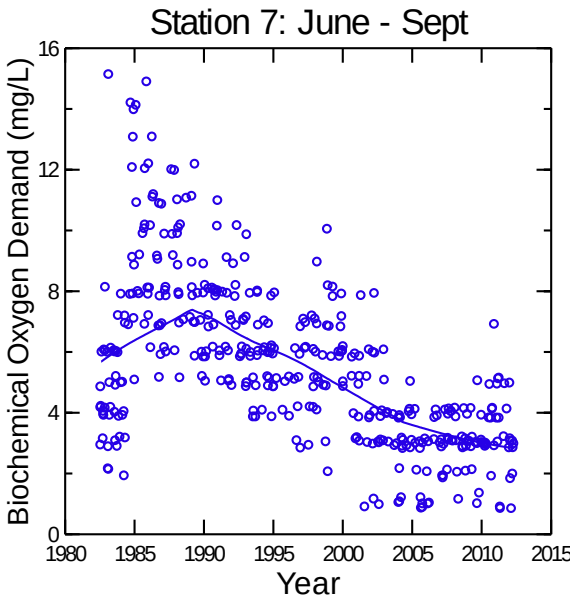
Total alkalinity as measured by Fairfax County personnel exhibited a rise from 1983 to 1990, a slow decline during the 1990's and a slow increase since 2000 (Figure 84). The trend line at 2012 was slightly higher than it was in 1983. Overall, there has not been a statistically significant linear trend in total alkalinity in the cove over this period (Table 15).

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



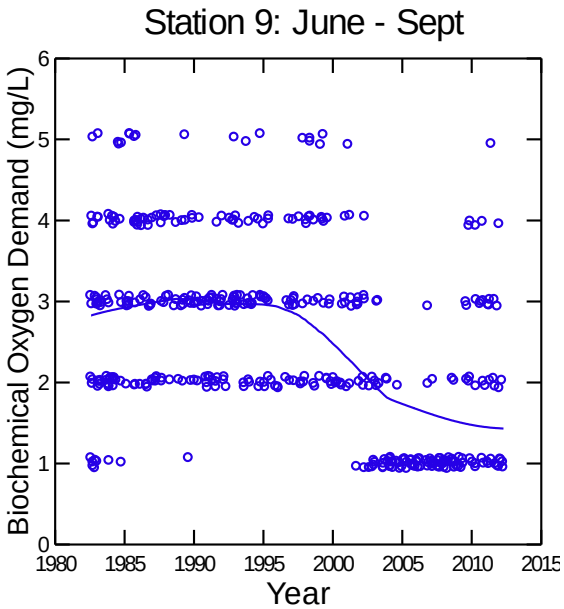
In the river a similar pattern has been observed over the three decadal intervals (Figure 85). However, there is a significant linear trend over the period with a slope of 0.30 mg/L suggesting a modest increase of about 9 mg/L over the entire study period (Table 15).

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



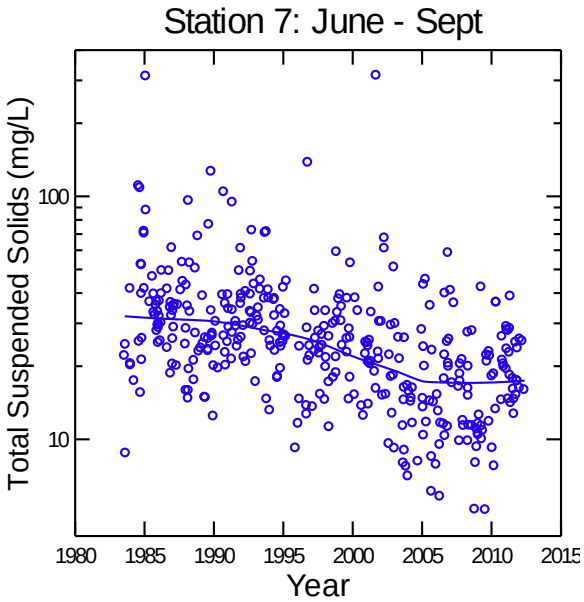
Biochemical oxygen demand has shown a distinct pattern over the long term study period in Gunston Cove (Figure 86). In the 1980's the trend line rose from about 5 mg/L to 8 mg/L by 1989. Since then there has been a steady decline such that the trend line has dropped back to about 3 mg/L. Recently, values of 5 or above have become more common. BOD has shown a significant linear decline over the entire study period at a rate of 0.18 mg/L per year yielding a net decline of about 5 mg/L over the entire period of record (Table 15).

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



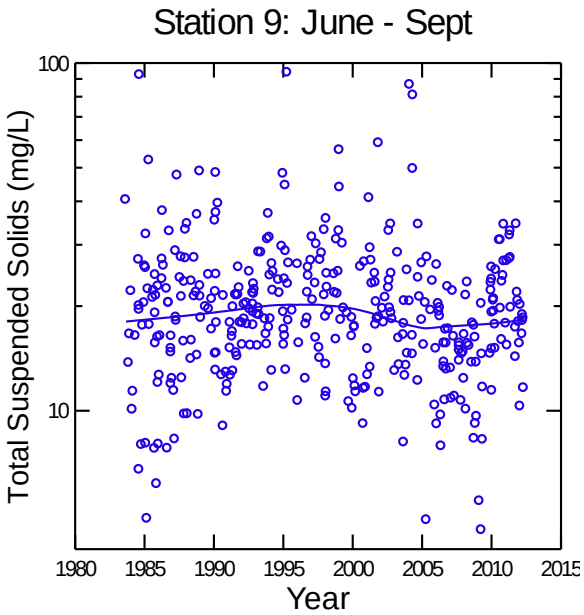
In the river biochemical oxygen demand exhibited a less distinct pattern through the mid 1990's (Figure 87). However, since that time it has decreased steadily to a trend line value of about 1.5 mg/L. BOD in the river has exhibited a significant linear decrease at a rate of 0.06 units when the entire period of record was considered (Table 15). Recently, there has been a recurrence of BOD of 2 or greater which were absent in the mid 2000's.

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



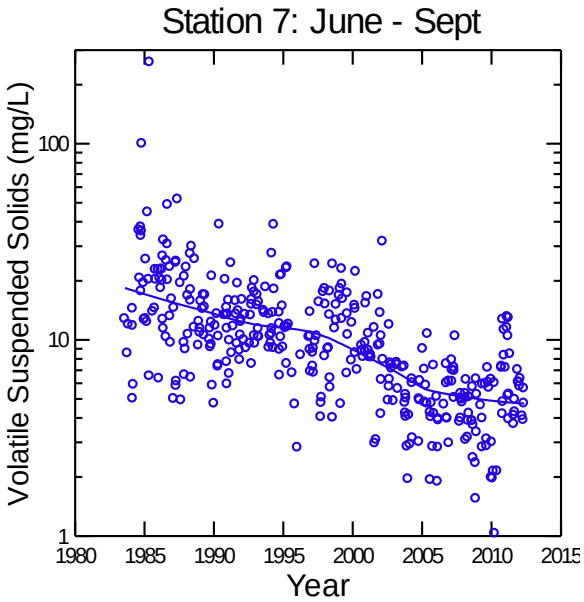
Total suspended solids (TSS) has shown a great deal of variability over the long term study period. Nonetheless, a decreasing trend has been detected in TSS in the cove with the trend line decreasing from about 30 mg/L in 1983 to about 18 mg/L in 2012 (Figure 88). Linear regression was significant indicating a decline of 0.9 mg/L per year yielding a total decline of 25 mg/L since 1984 (Table 15).

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



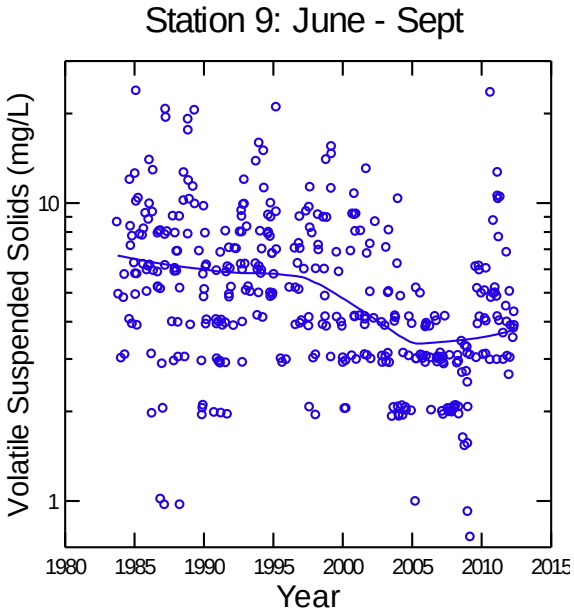
In the river TSS trends have not been as apparent (Figure 89). While much higher values have been observed sporadically, the LOWESS line remained steady at about 20 mg/L through 2000. Since then a slight decline is suggested. In the river TSS did not exhibit a significant linear trend over the period of record (Table 15). Most readings in 2010 and 2011 were above the trend line but in 2012 they were nearer the line.

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



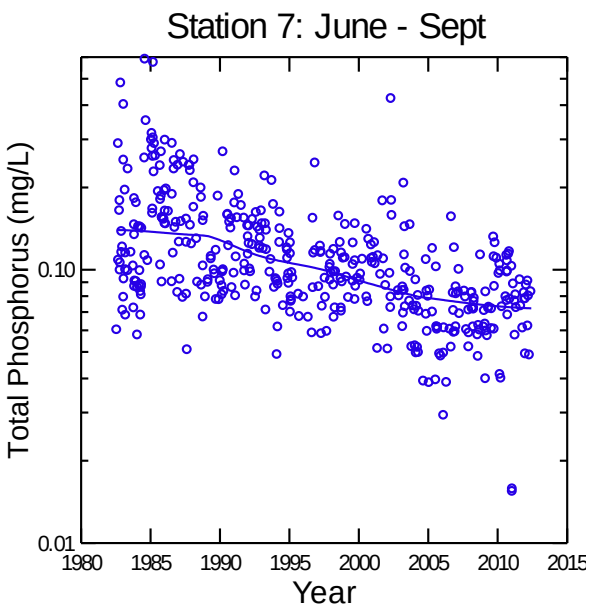
Volatile suspended solids have consistently declined over the study period (Figure 90). Higher values found in 2010 and 2011 were not repeated in 2012. The LOWESS trend line has declined from 20 mg/L in 1984 to 5 mg/L in 2012. VSS has demonstrated a significant linear decline at a rate of 0.7 mg/L per year or a total of 20 mg/L over the study period (Table 15).

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



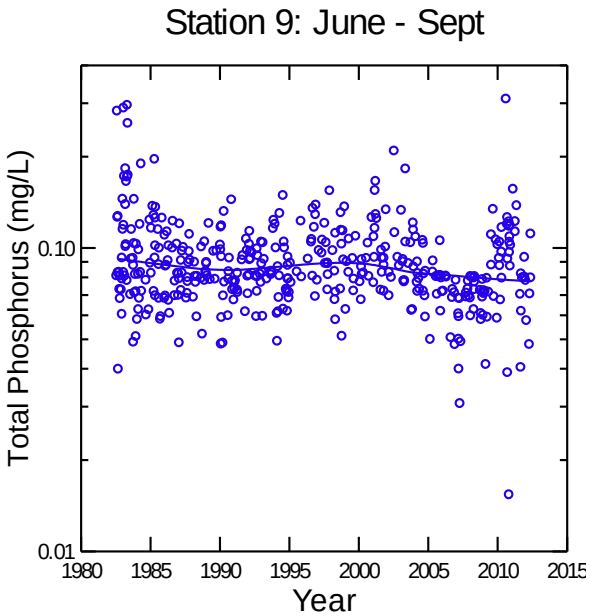
In the river the trend line for volatile suspended solids (VSS) was steady from 1984 through the mid 1990's, but has decreased consistently since then. Trend line values of about 7 mg/L in 1984 dropped to about 3 mg/L by 2005 (Figure 91). In the last 2-3 years, VSS has been somewhat higher. VSS in the river demonstrated a significant linear decline at a rate of 0.14 mg/L per year or 4 mg/L since 1984 (Table 15). Note that almost all VSS readings in 2011 were above the trend line.

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



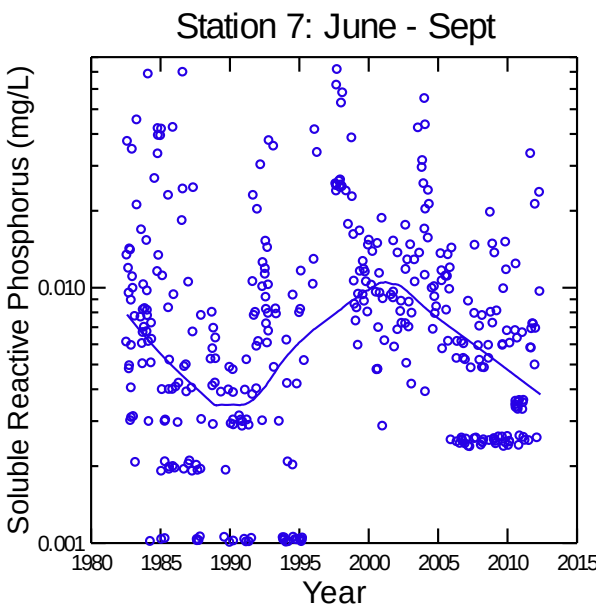
In the cove, total phosphorus (TP) has undergone a consistent steady decline since the late 1980's in the cove (Figure 92). By 2012 the trend line had dropped to 0.07 mg/L. In 2010 and 2011, values were generally elevated above the trend line, but closer in 2012. Linear regression over the entire period 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 15).

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



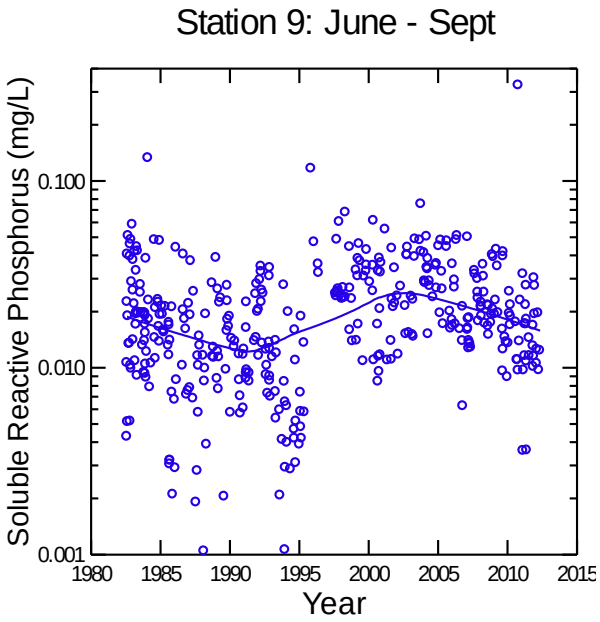
Total phosphorus (TP) values in the river have shown less of a trend over time (Figure 93). Values were steady through about 2000, then declined and have recently shown in increase. TP exhibited a slight, but significant linear decrease in the river over the long term study period with a very modest slope of 0.0006 mg/L per year (Table 15).

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



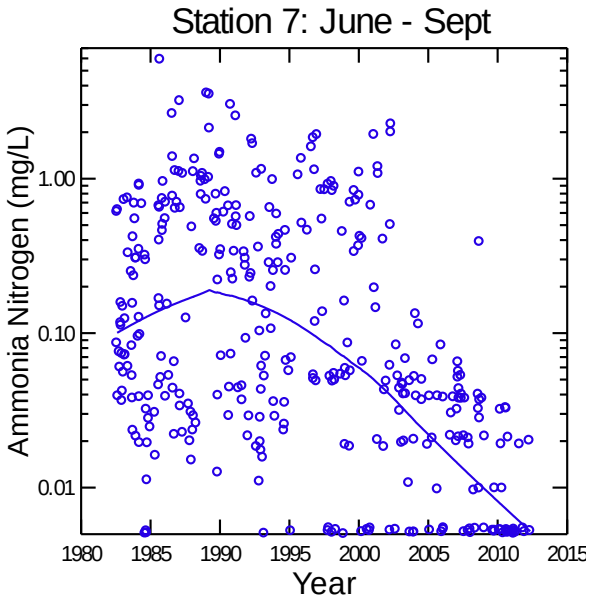
Soluble reactive phosphorus (SRP) declined in the cove during the first few years of the long term data set, but demonstrated an increase to near its initial level by 2000 (Figure 94). Since then a decline has ensued. The pattern through 2000 was consistent with the concept that SRP is negatively correlated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

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



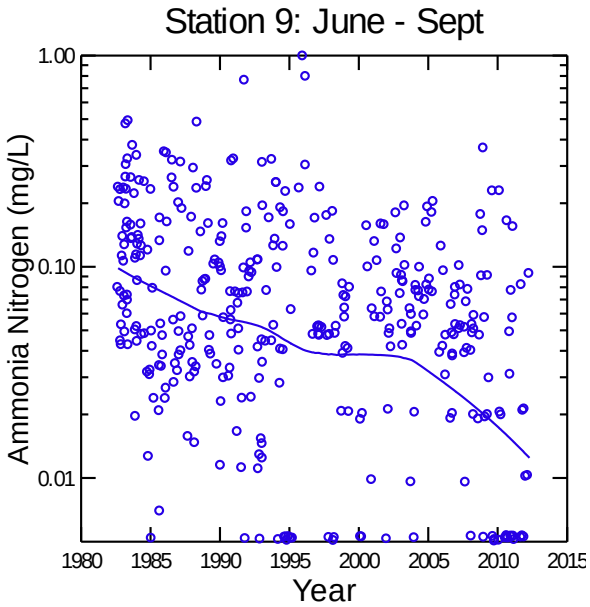
Soluble reactive phosphorus (SRP) in the river has generally been present at higher levels than in the cove, but has undergone a similar decline and resurgence (Figure 95). By 2012 the trend line in the river was at 0.015 mg/L compared to less than 0.01 mg/L in the cove. Again, this may reflect less demand for P in the river; algae in the river may be more light-limited. Values in the river in 2012 were similar to those in the early 1980's. Even so, in the river SRP showed a positive linear trend over the study period (Table 15).

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



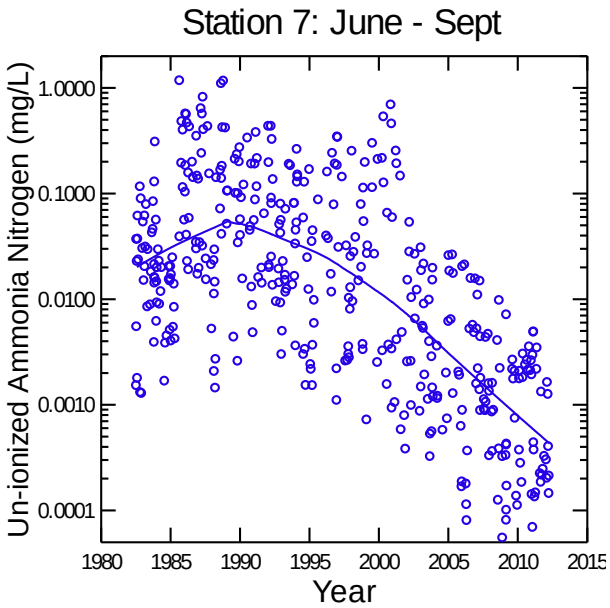
Ammonia nitrogen levels were very variable over the long term study period in the cove, but a trend of decreasing values is evident from the LOWESS trend line (Figure 96). Since 1989 the trend line has decreased from about 0.2 mg/L to less 0.01 mg/L. Linear regression has revealed a significant decline over the entire period of record with a rate of 0.018 mg/L per year yielding a total decline of 0.54 mg/L (Table 15).

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



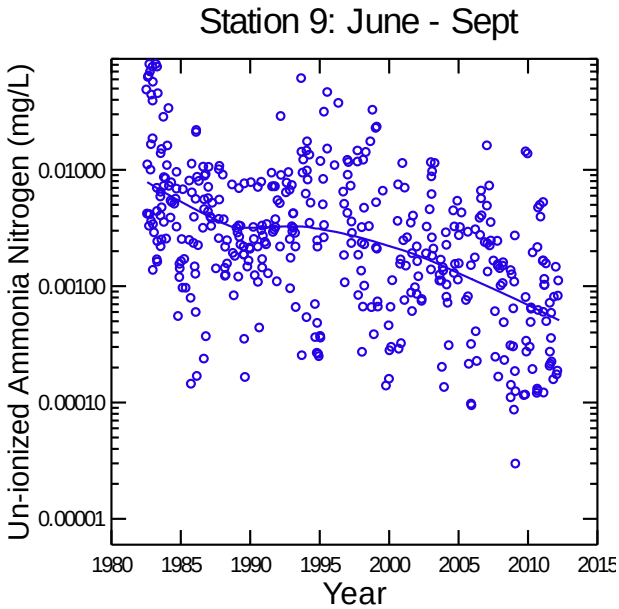
In the river a decreasing trend in ammonia nitrogen has also been observed over most of the study period (Figure 97). Between 1983 and 1999 the trend line dropped from 0.1 mg/L to 0.04 mg/L. Since 1999 it has continued to decline and is now less than 0.02 mg/L. (Note that many values are below detection limit). Overall, in the river ammonia nitrogen has demonstrated a significant decline over the study period at a rate of 0.003 mg/L per year or a total of 0.09 over the study period (Table 15).

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



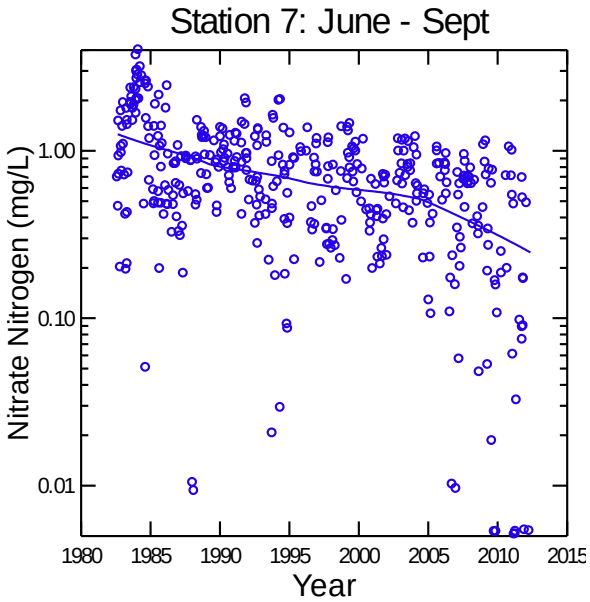
Un-ionized ammonia nitrogen in the cove demonstrated a clear increase in the 1980's with a continuous decline since that time (Figure 98). The LOWESS trend peaked at about 0.07 mg/L and is now less than 0.001 mg/L. When considered over the entire time period, there was a significant decline at a rate of 0.005 mg/L per year or a total of 0.15 mg/L over the 30 years (Table 15).

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



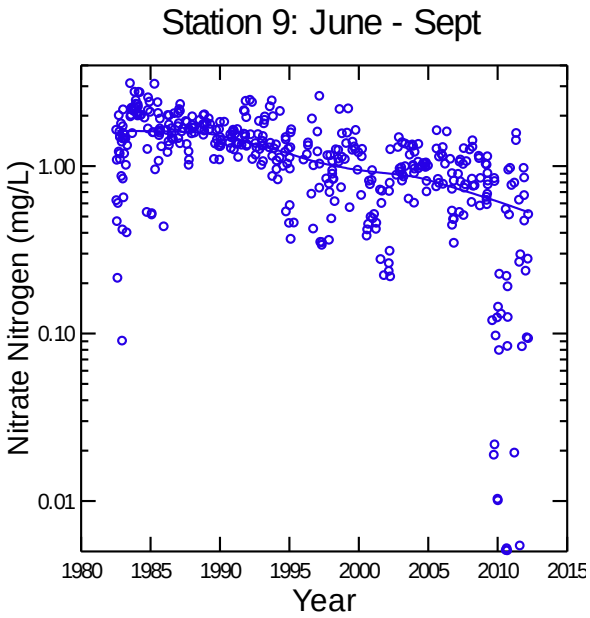
Un-ionized ammonia nitrogen in the river declined during the 1980's, was stable in the early 1990's and has declined since (Figure 99). LOWESS values have dropped from about 0.009 mg/L to less than 0.001 mg/L. Linear regression analysis over the entire period of record suggested a significant decline at a rate of 0.0004 units per year (Table 15).

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



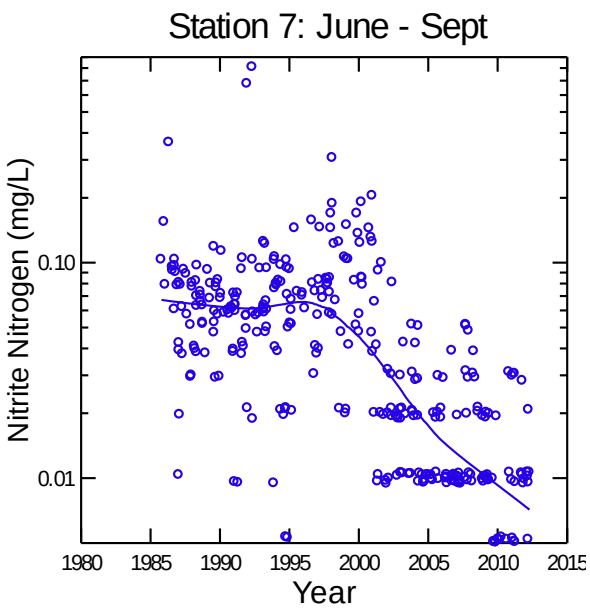
Nitrate nitrogen has demonstrated a steady decline in the cove over the entire period of record (Figure 100). The trend line was at 1.3 mg/L in 1983 and by 2011 was at 0.3 mg/L. Linear regression suggested a decline rate of 0.036 mg/L per year yielding a total decline of 1.1 mg/L over the long term study period (Table 15).

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



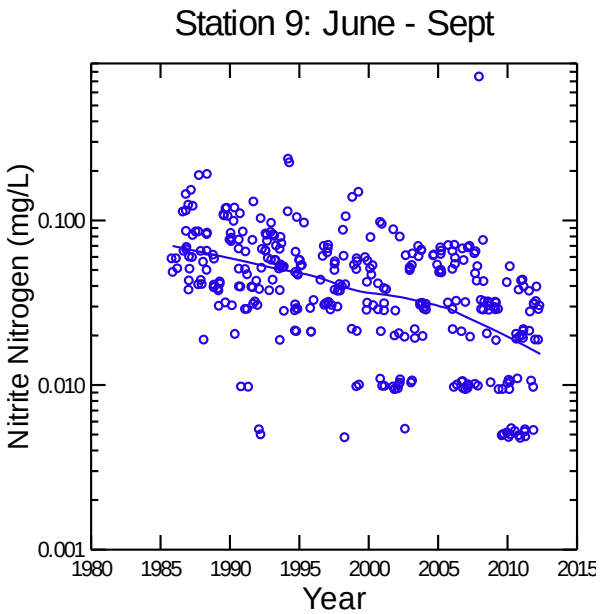
In the river nitrate nitrogen has declined steadily since about 1990 (Figure 101). The trend line dropped from 1.5 mg/L in the mid 1980's to 0.6 mg/L in 2012. Recently, there has been an increased occurrence of very low values (0.1 mg/L or less). Linear regression indicated a rate of decline which would have yielded a 1.3 mg/L decrease in nitrate nitrogen over the study period (Table 15).

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



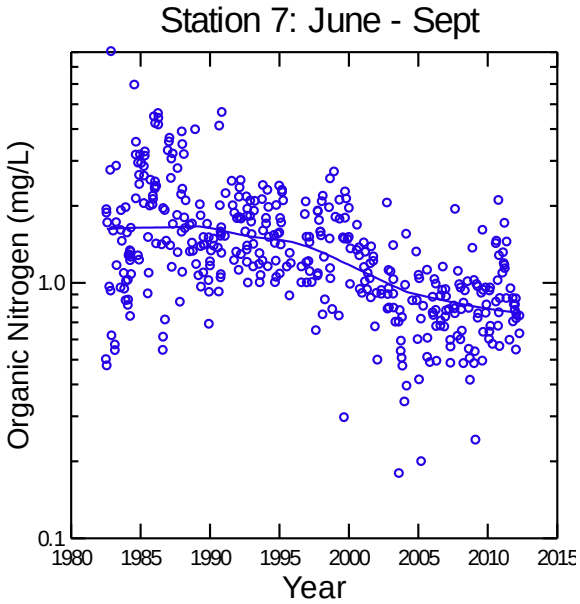
The trend line for nitrite nitrogen indicated steady values at about 0.06-0.07 mg/L through 1999 (Figure 102). Since then there is clear evidence for a decline with the LOWESS line reaching below 0.01 in 2012. Linear regression revealed a significant decline with a slope of 0.003 mg/L per year when the entire period of record was considered (Table 15).

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



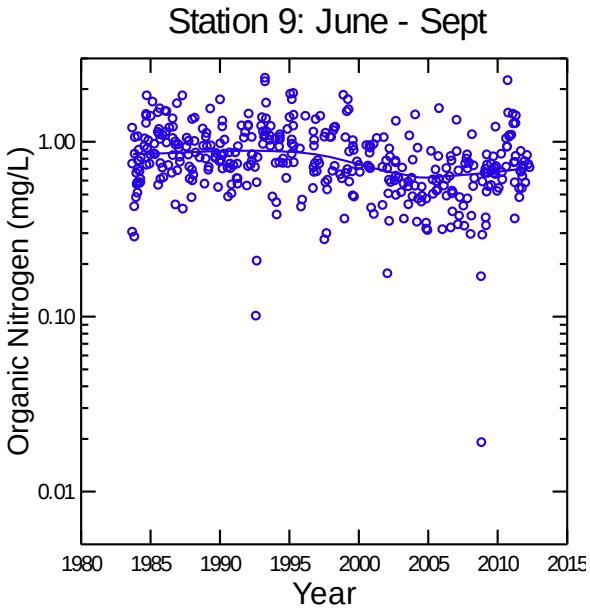
Nitrite nitrogen in the river demonstrated a pattern of decrease during the long term study period (Figure 103). The LOWESS line dropped from 0.07 mg/L in 1986 to 0.015 mg/L in 2012. Linear regression indicated a significant linear decline at a rate of 0.002 mg/L per year or 0.06 mg/L over the study period (Table 15).

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



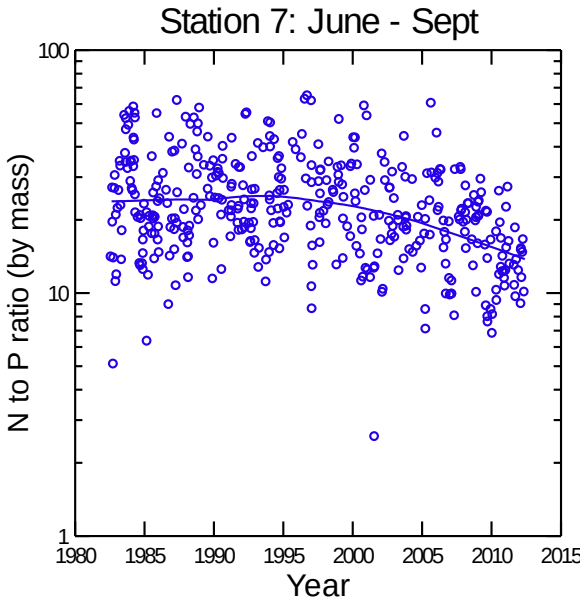
Organic nitrogen in the cove was fairly high in the 1980's and has since undergone a consistent decline through 2012 (Figure 104). In 1983 the trend line was at 1.5 mg/L and dropped below 0.8 mg/L in 2012. Regression analysis indicated a significant decline over the study period at a rate of about 0.049 mg/L per year or a total of 1.5 mg/L over the whole study period (Table 15).

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



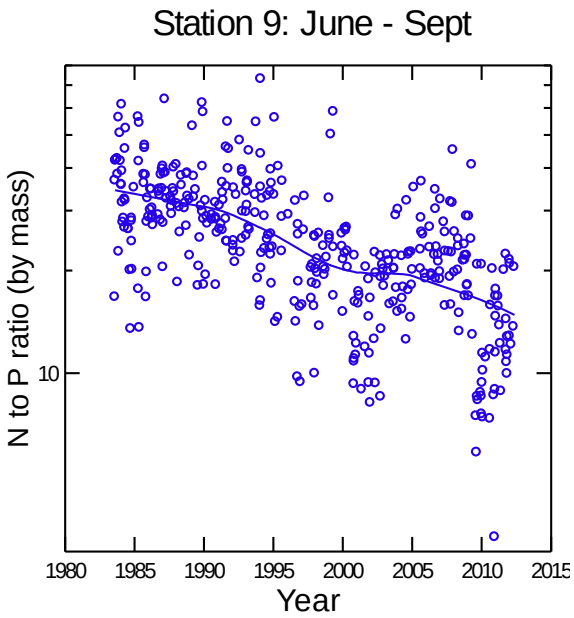
In the river organic nitrogen was steady from 1984 through 1995 and since then has shown a modest decline (Figure 105). The LOWESS line peaked at about 0.9 mg/L and has dropped to about 0.6 mg/L. Regression analysis indicated a significant linear decline at a rate of 0.01 mg/L when the entire period of record was considered for a total decline of 0.3 mg/L (Table 15).

Figure 105. Long term trend in Organic Nitrogen (Fairfax County Lab Data). Station 9. River mainstem.



Nitrogen to phosphorus ratio (N/P ratio) in the cove exhibited large variability, but the trend line was flat until about 1998. Since then, there has been a clear decline with the LOWESS line approaching 12 by 2012 (Figure 106). Regression analysis over the period of record indicates a statistically significant decline at a rate of 0.38 per year or about 11.4 units over the entire period (Table 15).

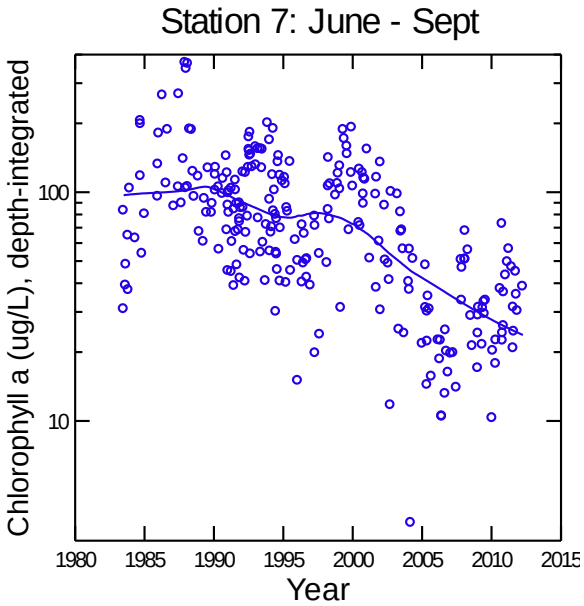
Figure 106. Long term trend in N to P Ratio (Fairfax County Lab Data). Station 7. Gunston Cove.



Nitrogen to phosphorus ratio in the river exhibited a strong continuous decline through about 2000 and has declined more slowly since then (Figure 107). The LOWESS trend line declined from about 35 in 1984 to 15 in 2012. Linear regression analysis confirmed this decline and suggested a rate of 0.74 units per year or a total of 21 units over the long term study period (Table 15). Values since 2010 are substantially below the trend line at times reaching levels indicative of N limitation.

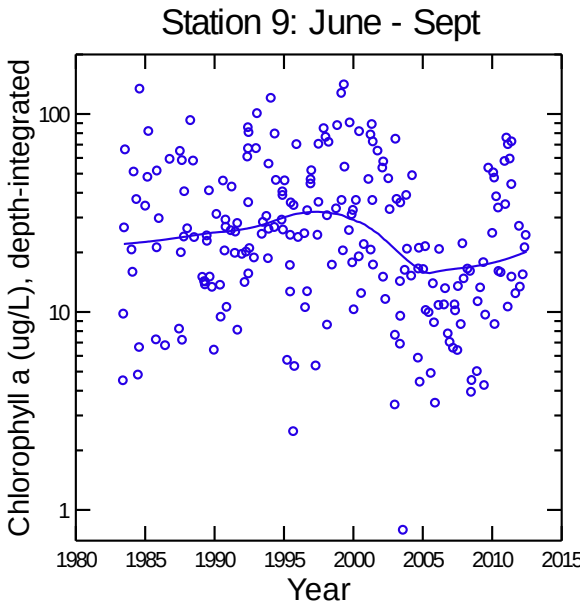
Figure 107. Long term trend in N to P Ratio (Fairfax County Lab Data). Station 9. River mainstem.

C. Phytoplankton Trends: 1984-2012



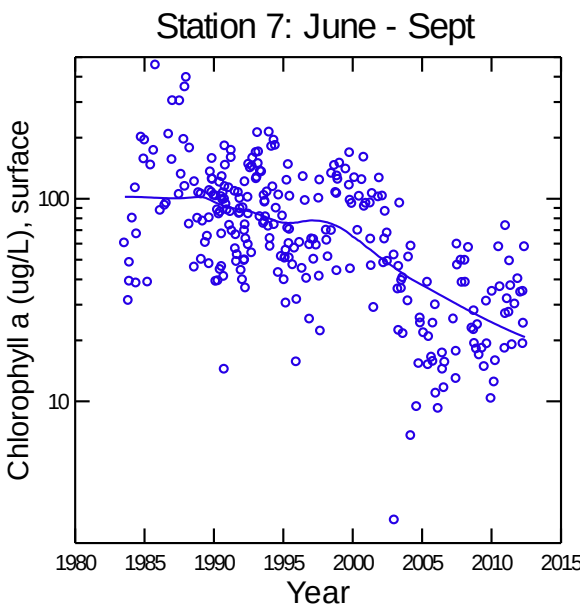
After increasing through much of the 1980's, depth-integrated chlorophyll *a* in the cove demonstrated a gradual decline from 1988 to 2000 and a much stronger decrease since then (Figure 108). The LOWESS line has declined from about 100 µg/L to a level of about 25 µg/L in 2012. The observed decrease has resulted in chlorophyll values within the range of water clarity criteria which are 43 µg/L and 11 µg/L to allow SAV growth to 0.5 m and 1.0 m, respectively (CBP 2006). Regression analysis has revealed a clear linear trend of decreasing values at the rate of 3.9 µg/L per year or 113 µg/L over the 29-year long term data set (Table 14).

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



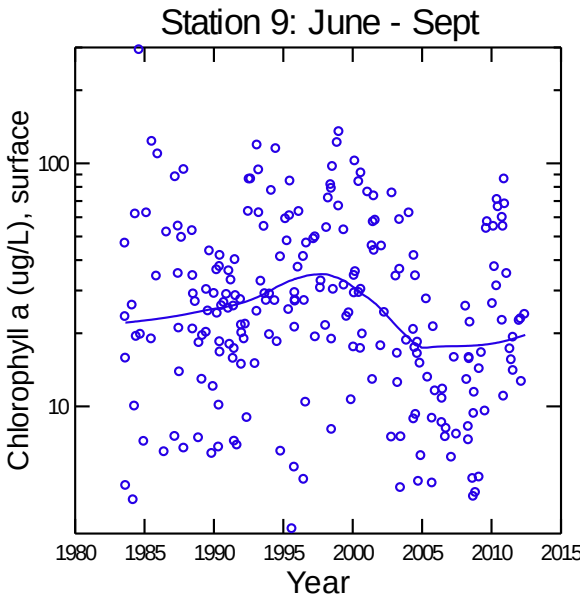
In the river depth-integrated chlorophyll *a* increased gradually through 2000 with the trend line rising from 20 to 30 µg/L (Figure 109). This was followed by a strong decline through about 2005, but a recent slight upswing has now been observed with trend line values now at about 20 µg/L. Note that in 2012 river chlorophylls were centered around this trend line. Regression analysis revealed a significant linear decline at a rate of 0.48 µg/L/yr when the entire period is considered (Table 14).

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



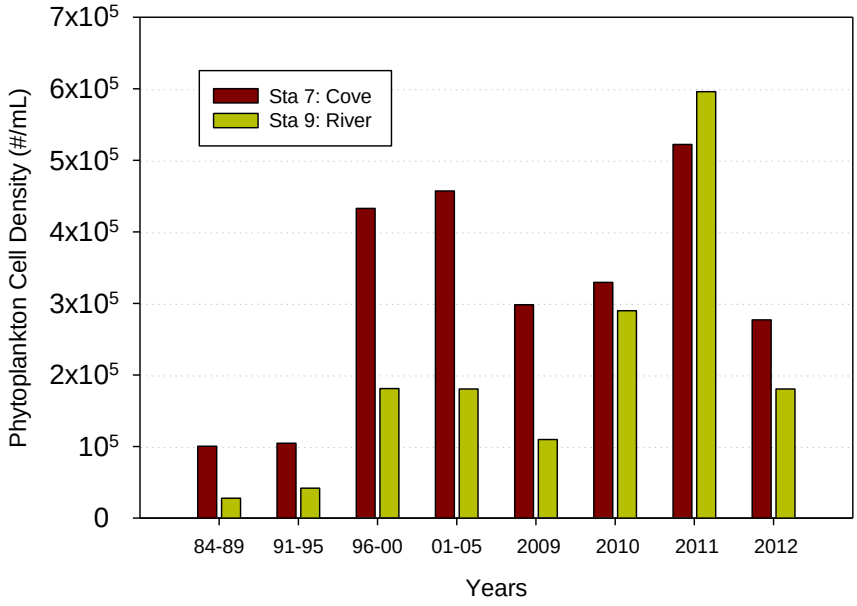
Surface chlorophyll *a* in the cove exhibited a clear decline over the long term study period, especially since 2000 (Figure 110). Trend line values of about 100 µg/L in 1988 dropped to about 20 µg/L in 2012. The observed decrease has brought chlorophyll values into the range of water clarity criteria which are 43 µg/L and 11 µg/L to allow SAV growth to 0.5 m and 1.0 m, respectively. Linear regression confirmed the linear decline and suggested a rate of 4.1 µg/L per year or 119 µg/L over the entire study (Table 14).

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



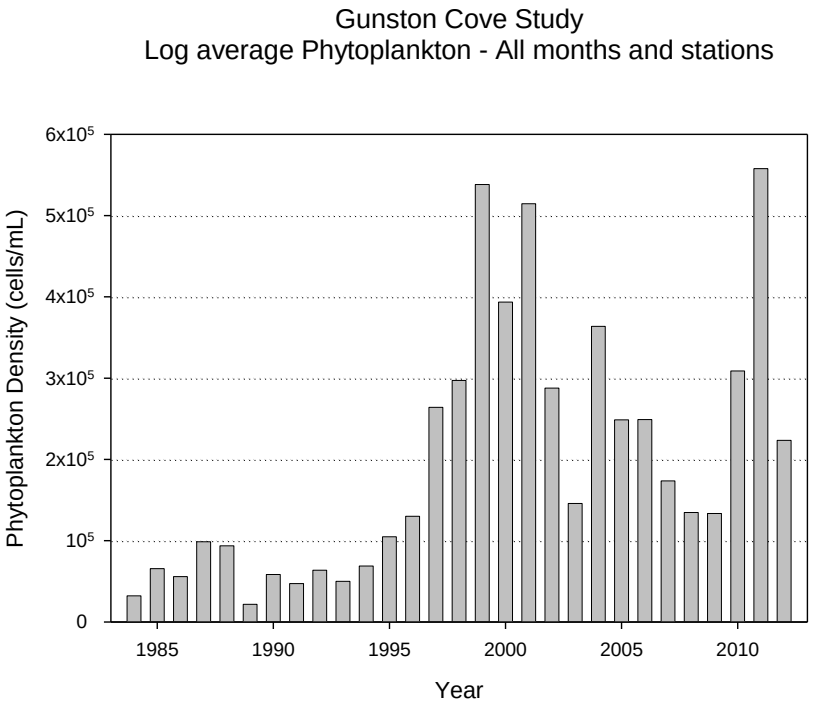
In the river the LOWESS line for surface chlorophyll *a* increased slowly from 1983 to 2000 and then declined markedly through 2005 (Figure 111). Values have stabilized since then at about 20 µg/L. Linear regression revealed a significant decline in surface chlorophyll across this period with a rate of 0.57 µg/L/yr or about 16 µg/L over the whole period (Table 14).

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



Phytoplankton cell density in both the cove and the river was lower in 2012 than in 2011 (Figure 112). Values in both areas were similar to 2010. Values in the river went back to their usual pattern of being somewhat lower than those in the cove after being higher in 2011.

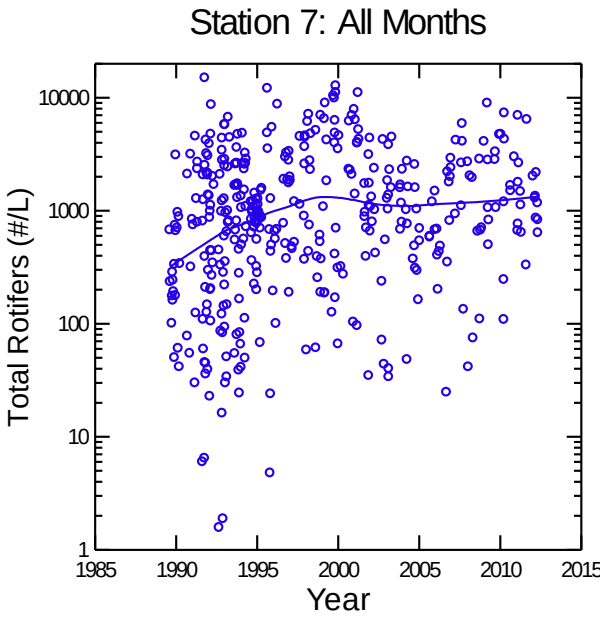
Figure 112. Interannual Comparison of Phytoplankton Density by Region.



By looking at individual years (Figure 113), we see that phytoplankton densities in the 2012 dropped back to levels more typical of recent years, down markedly from 2011 levels. This was due to moderate values at both stations.

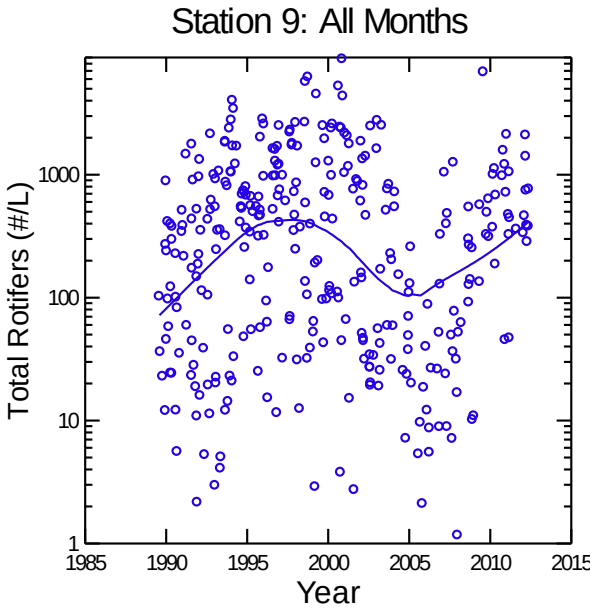
Figure 113. Interannual Trend in Average Phytoplankton Density.

D. Zooplankton Trends: 1990-2012



In the Cove total rotifers continued to show a leveling off after an initial decade (1990-2000) of steady increase (Figure 114). The LOWESS fit line indicated about 1000/L in 2012, 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 17).

Figure 114. Long term trend in Total Rotifers. Station 7. Gunston Cove.



In the Potomac mainstem, rotifers exhibited an initial increase from 1990 to 1998, followed by a decline from 1999 to 2005 and more recently another increase (Figure 115). Trend line values in 1990 were about 80/L and now are about 400/L approaching 1998 values. When the entire 1990-2012 period was considered, total rotifers did not exhibit a significant linear trend in the river (Table 16).

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

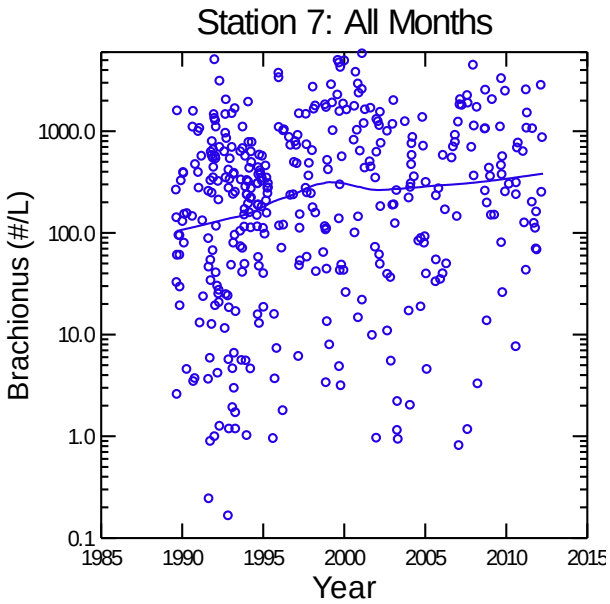
Table 16
Correlation and Linear Regression Coefficients
Zooplankton Parameters vs. Year for 1990-2012
All Nonzero Values Used, All Values Logged to Base 10

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Brachionus (m)	0.176 (385)	0.025	0.001	0.068 (309)	---	NS
Conochilidae (m)	0.245 (345)	0.026	<0.001	0.014 (265)	---	NS
Filinia (m)	0.196 (330)	0.027	<0.001	0.051 (214)	---	NS
Keratella (m)	0.332 (394)	0.040	<0.001	0.013 (319)	---	NS
Polyarthra (m)	0.265 (371)	0.031	<0.001	0.130 (301)	0.017	0.024
Total Rotifers (m)	0.211 (411)	0.022	<0.001	0.005 (331)	---	NS
Bosmina (m)	0.122 (228)	---	NS	0.175 (266)	0.020	0.004
Diaphanosoma (M)	0.043 (319)	---	NS	0.087 (222)	---	NS
Daphnia (M)	0.180 (258)	0.031	0.004	0.149 (165)	0.020	0.055*
Chydorid cladocera (M)	0.308 (222)	0.041	<0.001	0.390 (138)	0.042	<0.001
Leptodora (M)	0.056 (170)	---	NS	0.039 (118)	---	NS
Copepod nauplii (m)	0.440 (390)	0.042	<0.001	0.271 (327)	0.031	<0.001
Adult and copepodid copepods (M)	0.073 (507)	---	NS	0.139 (372)	0.017	0.007

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

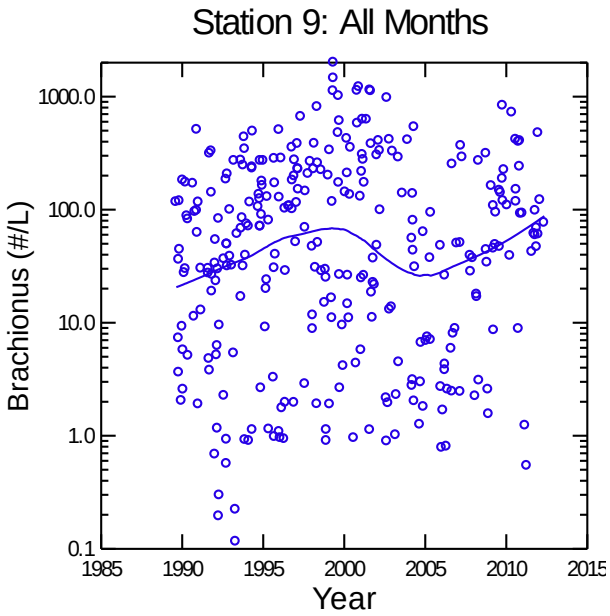
Significance column indicates the probability that a correlation coefficient this large could be due to chance alone. If this probability is greater than 0.05, then NS (not significant) is indicated. * = marginally significant.

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



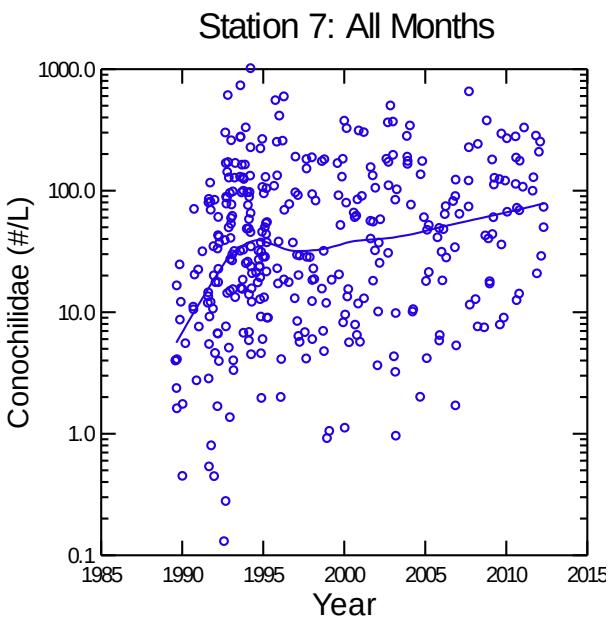
Brachionus is the dominant rotifer in Gunston Cove and the trends in total rotifers are generally mirrored in those in *Brachionus* (Figure 116). The LOWESS line for *Brachionus* suggested about 400/L in 2012, greater than the 100/L found in 1990. A statistically significant linear increase was found over the study period (Table 16).

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



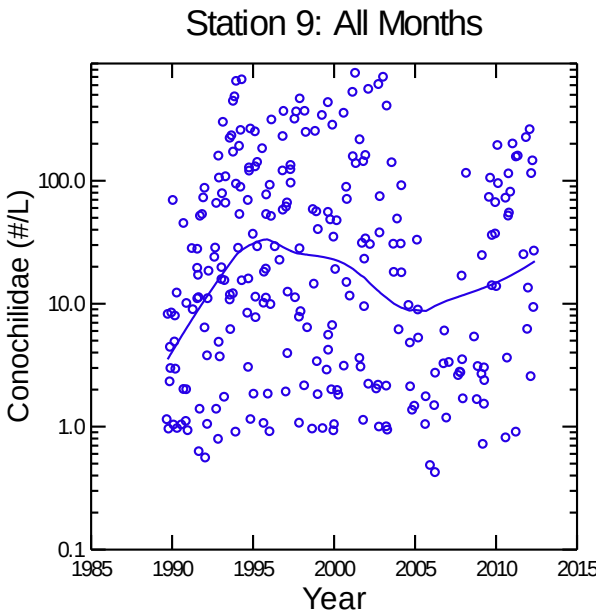
Brachionus was found at lower densities in the river. In the river the LOWESS line for *Brachionus* increased through 2000, but dropped markedly from 2000-2005.Since 2005 an increase has been noted, with the LOWESS value in 2012 of about 90/L, near the previous peak of 80/L in 1999 (Figure 117). No linear trend was indicated when the entire study period was considered (Table 16).

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



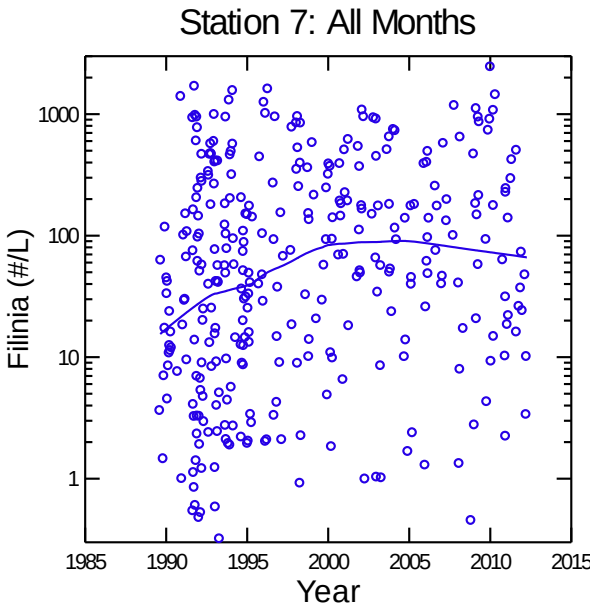
Conochilidae increased strongly from 1990-1995, leveled off, and is now showing a gradual increase. In 2012 the LOWESS trend line stood at about 80/L (Figure 118). This was well above levels of about 5/L in 1990. Over the entire period of record, a significant linear increase was found (Table 16).

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



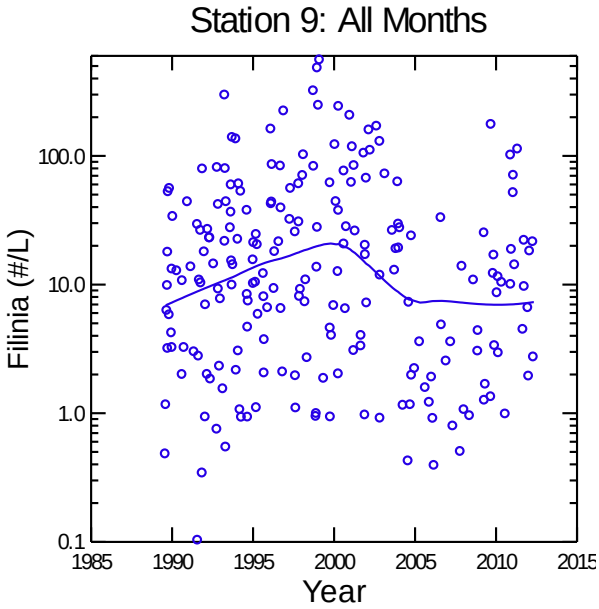
In the river, Conochilidae exhibited a strong increase in the early 1990's similar to that observed in the cove (Figure 119). This was followed by a period of decline and recently a renewed increase. The trend line has gone from 3/L in 1990 to 35/L in 1995 to 10/L in 2005 to 25/L in 2012. When the entire period of record was examined, there was not a significant linear trend (Table 16).

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



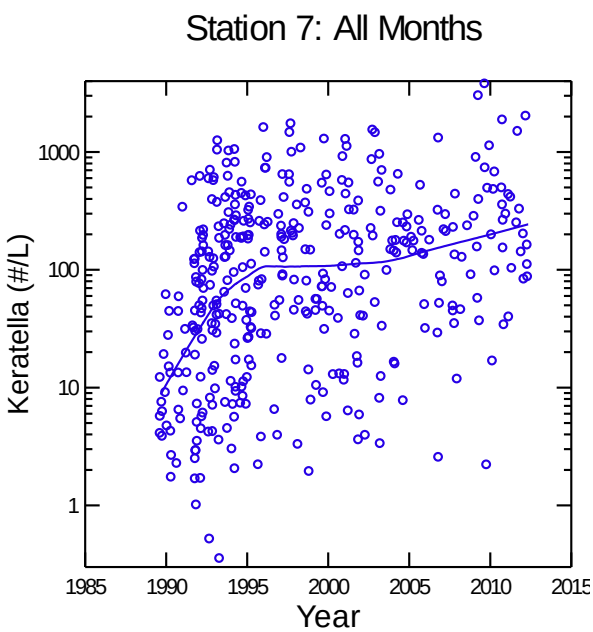
In the cove *Filinia* exhibited a steady increase from 1990 through 2000 rising from about 20/L to nearly 100/L (Figure 120). It has shown a slight decline in recent years to about 80/L. When the entire period of record was considered, there is firm evidence for a linear increase in the cove (Table 16).

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



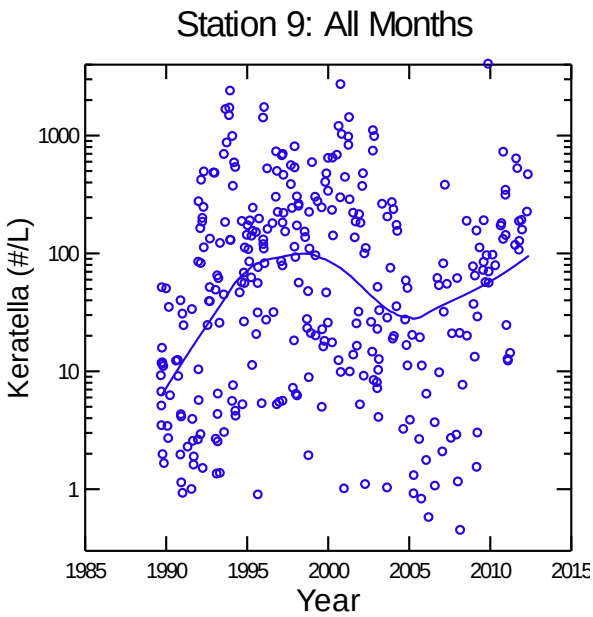
In the river *Filinia* demonstrated an increase through about 2001, declined from 2000-2005 and remained steady since. The trend line indicates about 7/L in 2011, about equal to the 7/L in 1990, but well below the peak of 20/L in 2000 (Figure 121). When the entire period of record was examined, there was not a significant linear trend (Table 16).

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



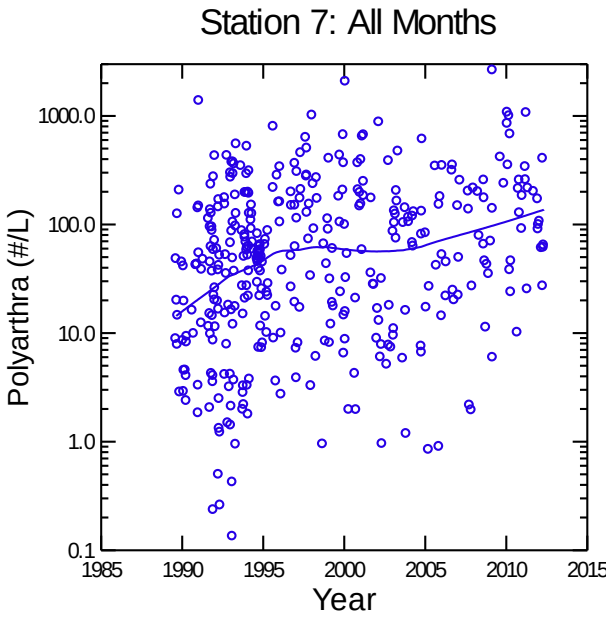
Keratella increased strongly from 1990 to 1995 and has shown a milder increase since then with the trend line approaching 200/L in 2011 (Figure 122). When the entire period of record was examined, there was a significant linear increase (Table 16).

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



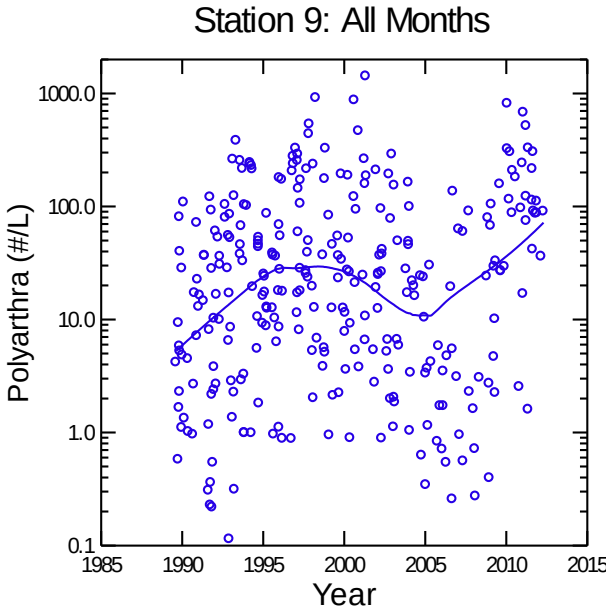
In the river *Keratella* increased from less than 10/L in 1990 to peak values of about 100/L in the mid to late 1990's (Figure 123). The trend line then declined to about 25/L, but since 2005 it has increased to about 100/L. Linear regression showed no significant trend when the entire study period was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

Figure 123. Long term trend in *Keratella*. Station 9. Gunston Cove.



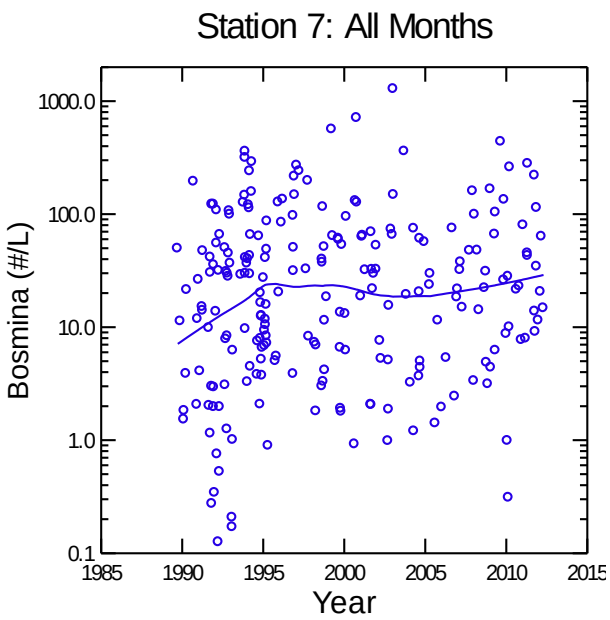
The trend line for *Polyarthra* in the cove increased steadily from 1990 to about 2000 rising from 15/L to about 60/L (Figure 124). Since 2000 densities have increased more slowly with the trend line reaching about 120/L by 2012. Regression analysis indicated a significant linear increase when the entire period of record was examined (Table 16).

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



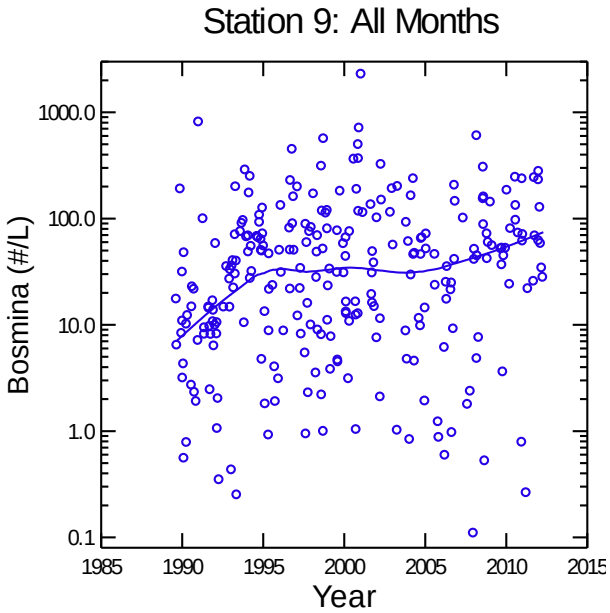
In the river *Polyarthra* showed a marked increase from 1990 to 2000 and then a decline to 2005. Recently values have increased again and by 2012 the trend line reached 80/L (Figure 125). Linear regression analysis indicated a significant trend over the period of record (Table 16).

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



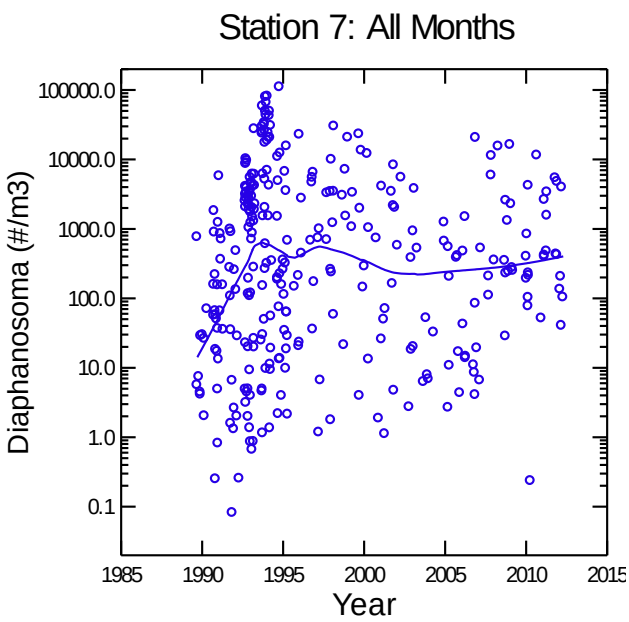
The trend line for *Bosmina* in the cove showed an increase from 7/L in 1990 to about 25/L in 2000 (Figure 126). Since 2000 densities have not changed much. Linear regression did not indicate a significant trend in the cove over the entire period of record (Table 16).

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



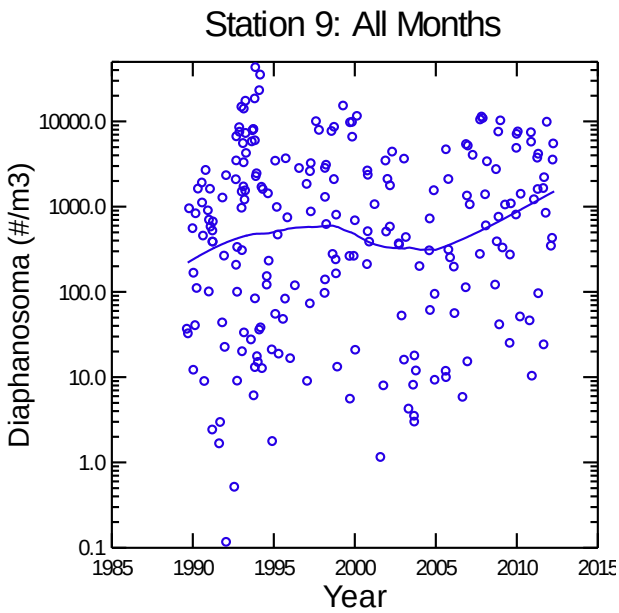
In the river mainstem the LOWESS curve for *Bosmina* increased from 1990 to 1995, and remained rather constant from 1995 to 2005 before increasing to about 67/L in 2012 (Figure 127). Regression analysis indicated a significant linear increase over the entire period of record (Table 16).

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



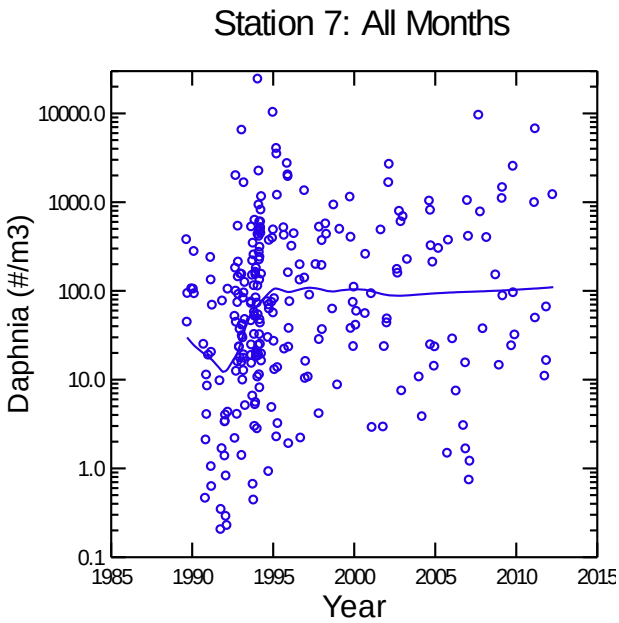
Diaphanosoma increased strongly in the early 1990s from about 15/m^3 nearly 1000/m^3. It gradually declined through 2005 to about 300/m^3 (Figure 128). Recent years have increased slightly. Linear regression analysis of the entire period of record indicated a no significant linear trend (Table 16).

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



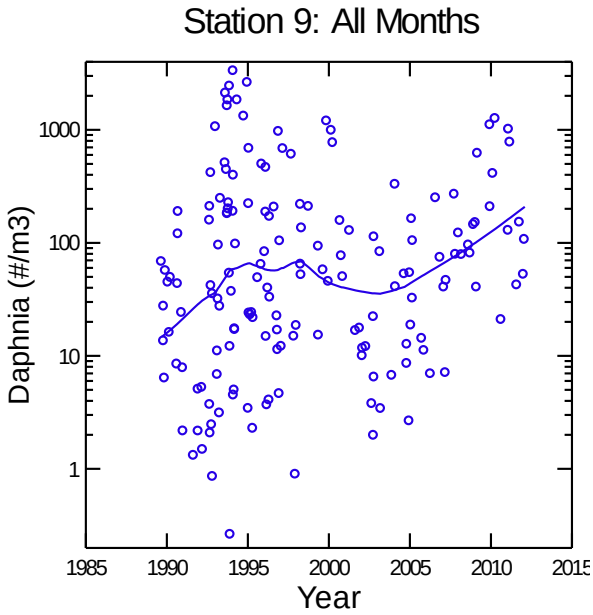
In the river the LOWESS line suggested a generally stable pattern in *Diaphanosoma* (Figure 129). The trend line value of 1500/m^3 found in 2012 compared with values as high as 800/m^3 in 1999 and 1993 and as low as the 200/m^3 in 1990. Regression analysis indicated no significant linear trend over the period of record (Table 16).

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



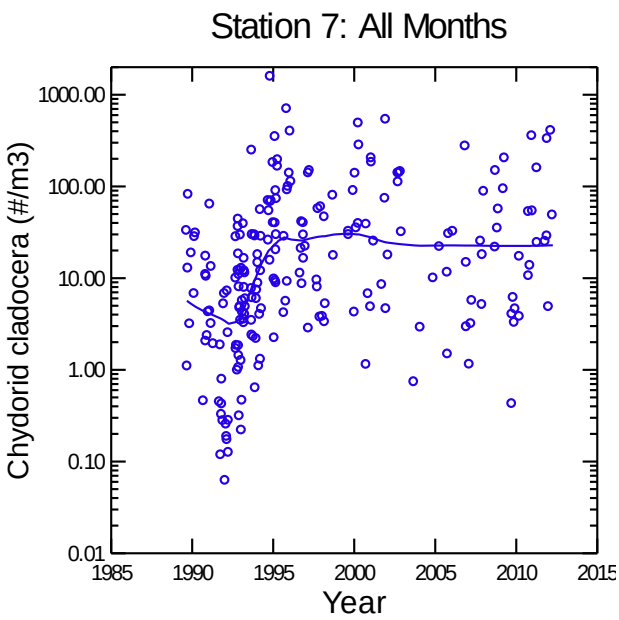
Daphnia in the cove has been relatively stable since 1995 at about 100/m^3 (Figure 130). This is up from the low of about 10/m^3 in 1992 and the starting value of 40/m^3 in 1990. Regression analysis examining the entire period of record gave support for a linear increase (Table 16).

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



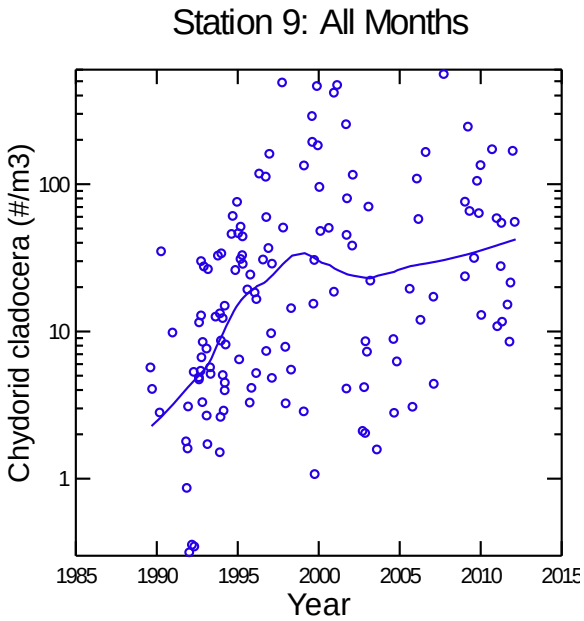
Daphnia in the river has shown a lot of variability over time, but with a suggestion of two periods of increase (Figure 131). The trend line in 2012 reached about 200/m^3, substantially higher than the level observed at the beginning of the record in 1990. Regression analysis indicated a marginally significant positive trend over the study period (Table 16).

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



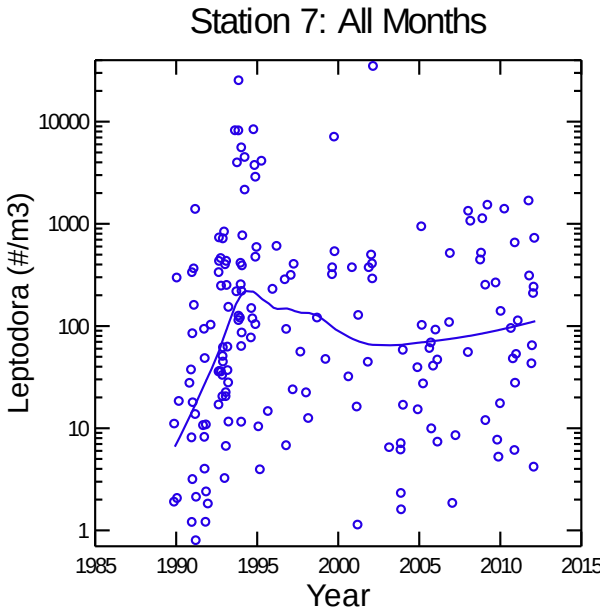
Chydorid cladocera in the cove have maintained a consistent population of about 20/m^3, substantially higher than the low of 3/m^3 in 1992 and the initial value of 8/m^3 in 1990, but below trend line values of 30/m^3 observed between 1995 and 2000 (Figure 132). Regression analysis gave evidence for a linear increase over the study period (Table 16).

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



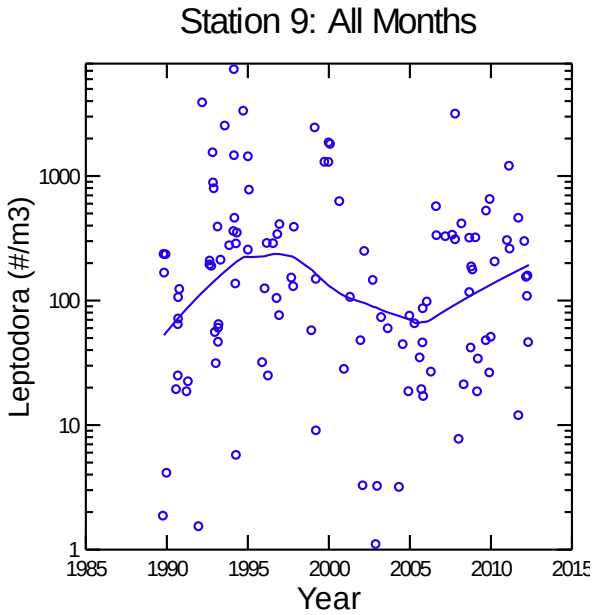
In the river chydorids continued a gradual increase to about 45/m^3, well above the low of about 4/m^3 in the early 1990's (Figure 130). There was evidence for a linear increase in chydorids over the entire study period as indicated by linear regression analysis (Table 16).

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



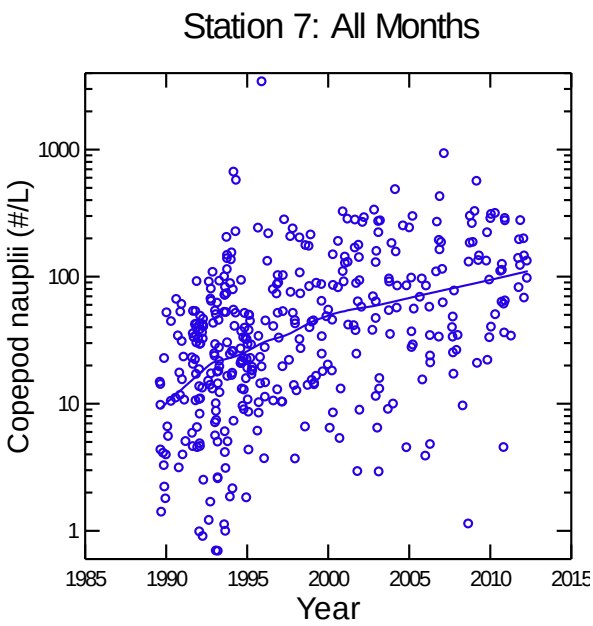
In the cove the trend line for *Leptodora*, the large predaceous cladoceran, has stabilized at about 100/m^3, down from its high of about 200/m^3 in 1994, but above the 1990 value of 10/m^3 (Figure 134). There was no evidence for a significant linear change in *Leptodora* over the entire study period (Table 16).

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



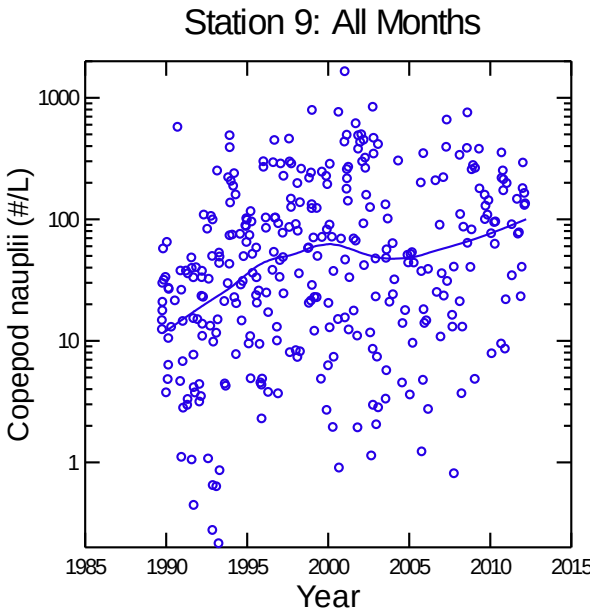
In the river, *Leptodora* densities continued to increase following a decline which began in 1995 resulting in trend line values of about 200/m^3 for 2012 (Figure 135). These values are well above those observed in 1990, and are approaching the peak of 300/m^3 in 1994. Linear regression analysis did not detect a significant linear trend when the whole study period was considered (Table 16).

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



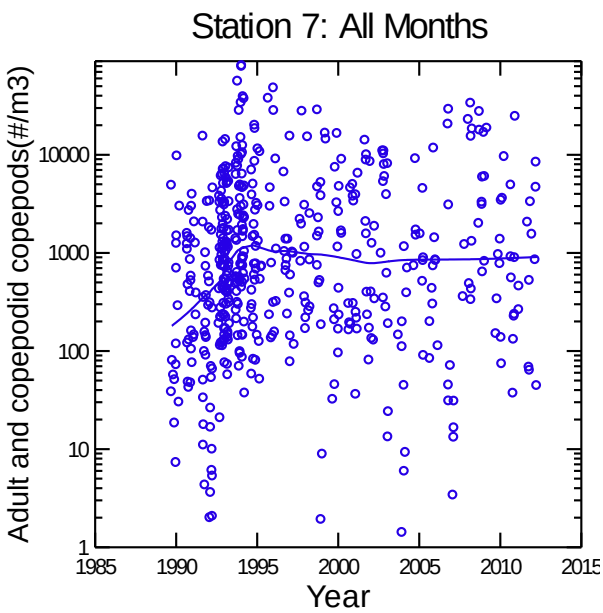
Copepod nauplii, the immature stages of copepods, continued their upward trend in 2012 (Figure 136). Trend line values reached 100/L in 2012 well above the initial level of 10/L observed in 1990. A strong linear increase was observed over the study period (Table 16).

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



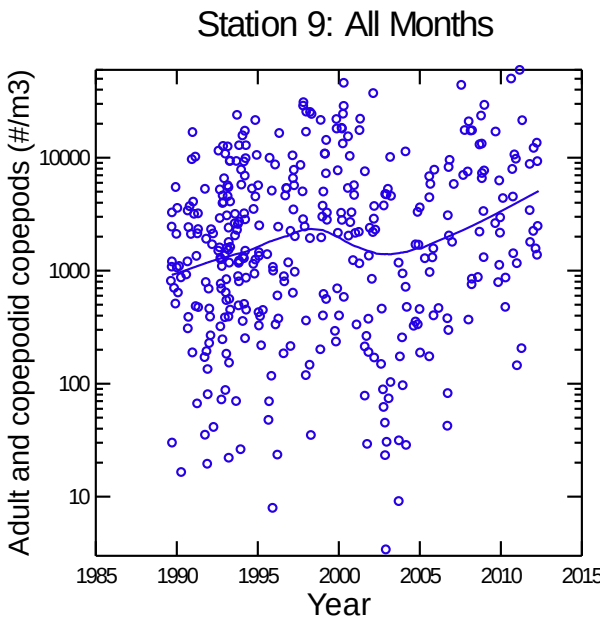
In the river, copepod nauplii showed a gradual increase following a decline begun in 2000 (Figure 137). The 2012 LOWESS trend line value was 100/L, up from an initial value of 10/L in 1990, overtaking the previous peak of about 70/L. A significant linear increase was found for nauplii over the study period (Table 16).

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



Adult and copepodid copepods increased strongly in the early 1990's and since have remained fairly constant at about 1000/m^3 (Figure 138). Copepods did not exhibit a significant linear trend in the cove over the study period (Table 16).

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



Adult and copepodid copepods continued to increase following a slight decline from 1998 to 2004 (Figure 139). The trend line in 2012 reached 5000/m^3, well above the previous maximum of 2500/m^3 in 1998. A significant linear increase was found when the entire study period was considered (Table 16).

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

E. Ichthyoplankton Trends

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 relatively flat trend over the course of monitoring on this survey. Some variation between years occurred: 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 in 1995 followed by a decline in numbers until 2011 .

More recent data indicate that higher densities of larval fish are returning (Table 17). The years 2011 and 2012 showed higher larval abundances than the five years before that, caused by a 2.2-fold increase in *Dorosoma* sp. from 2010 to 2011 (Table 17). The abundances were lower in 2012, but still higher than 2006-2010. *Alosa* sp. larvae abundances have increased since 2009 as well, and 2012 shows a 3-fold increase from 2011. *Morone* sp. larvae also show higher numbers than before in 2012; while the average of the last six years is 340 specimens, 2012 had abundances four time higher than that.

The peaks in abundance over the season reflect characteristic spawning times of each species. The earliest are yellow perch (Figure 147) and white perch (Figure 143), followed by gizzard shad and river herring (Figure 141), and inland silversides (Figure 145). Yellow perch tend to have a narrower spawning period – thus the larval density peaks at the beginning of the sampling season and tapers rapidly. However a small density peak is visible early June, which indicates the presence of some late spawners. White perch begin spawning early and larval abundances slowly taper off. 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. Silverside do not have a pronounced peak, and their density is evenly distributed from mid April to late August.

Table 17. The larval fishes collected in Gunston Cove and the Potomac River in 2006-12

Taxon	Common Name	2006	2007	2008	2009	2010	2011	2012	Total (%)
Alosa sp.	American shad, alewife, hickory shad, or blueback herring	63	109	15	224	1332	968	3118	5829 (14.6)
Dorosoma sp.	gizzard shad or threadfin shad	254	992	510	1768	5846	13110	7541	30021 (75.0)
Brevoortia tyrranus	menhaden	0	0	2	0	0	0	0	2 (<0.1)
Morone sp.	white perch or striped bass	52	233	427	414	504	413	1462	3505 (8.8)
Perca flavescens	yellow perch	136	70	6	2	86	3	3	306 (0.8)
Menidia beryllina	inland silverside	54	31	8	10	87	17	127	334 (0.8)
Strongylura marina	Atlantic needlefish	0	0	1	1	0	0	0	2 (<0.1)
Lepomis sp.	sunfish	0	0	0	0	1	5	20	26 (<0.1)
Unidentified		0	5	0	0	0	0	1	6 (<0.1)
Total		559	1440	969	2419	7856	14516	12272	

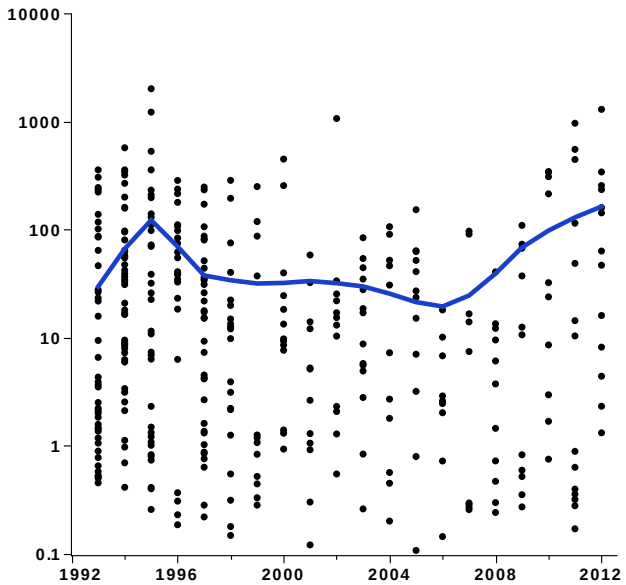


Figure 140. Long term trend in Clupeid Larvae (abundance 10 m^{-3}).

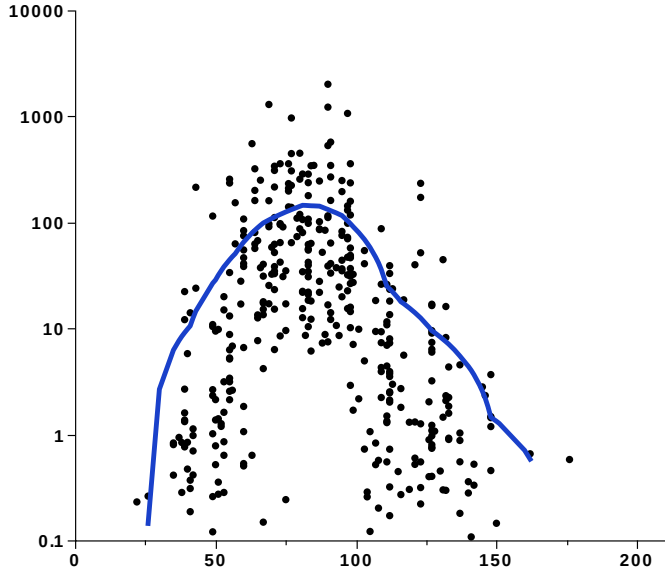


Figure 141. Seasonal pattern in Clupeid larvae (*Alosa* sp. and *Dorosoma* sp.; abundance 10 m^{-3}). The x-axis represents the number of days after March 1.

The seasonal pattern in clupeid larvae for 1993-2012 (Figure 141) shows that a peak in density occurs about 80 days after March 1, or mid-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.

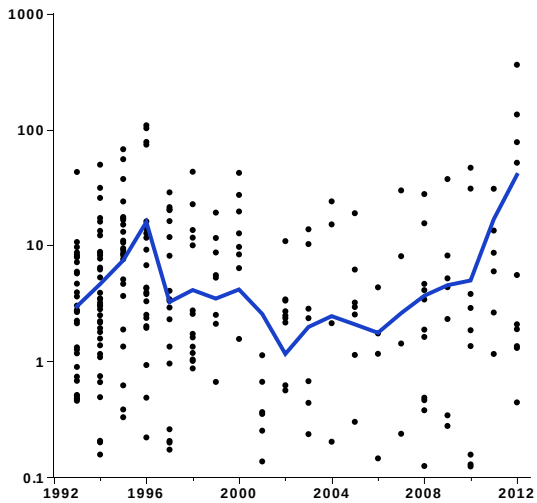
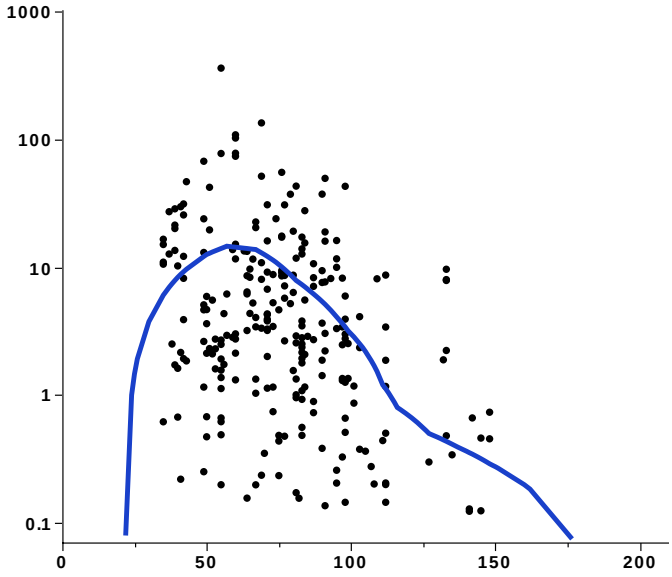


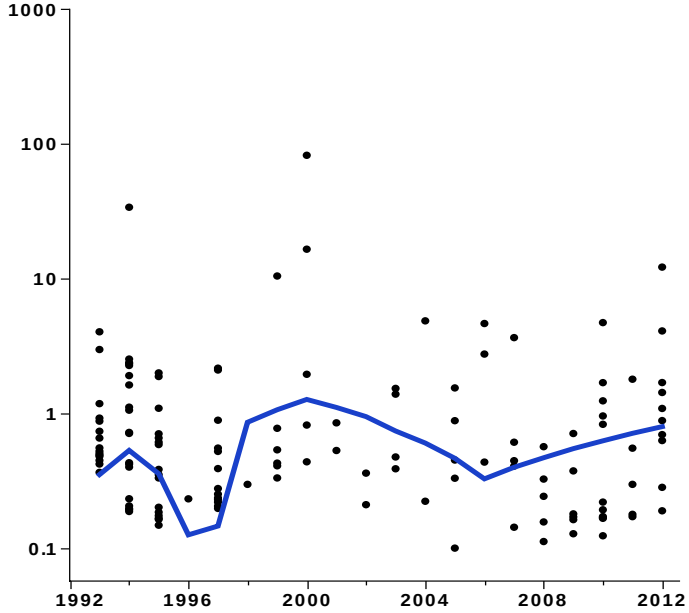
Figure 142. Long term trend in *Morone* Larvae (abundance 10 m^{-3}).

The trend in number of white perch and striped bass larvae per 10 m^3 since 1993 is depicted in the LOESS graph in Figure 142. A slow but steady increase from 2002 has changed into a sharp increase due to a 3-fold abundance increase from 2011 to 2012 .



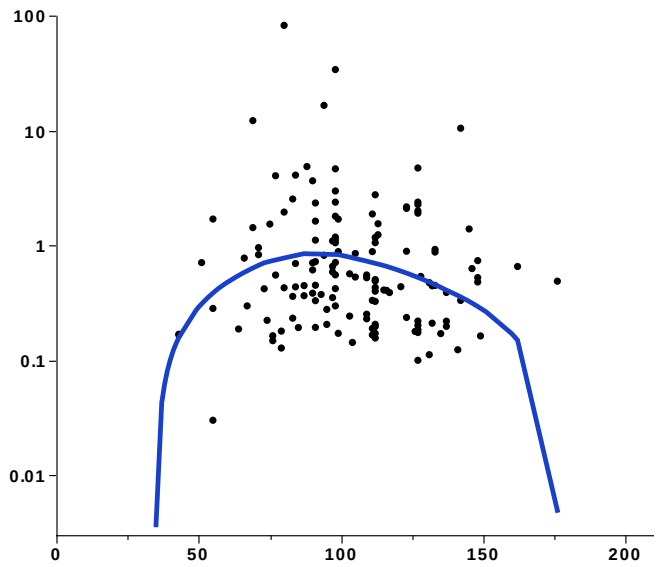
The seasonal occurrence of number of *Morone* sp. larvae per 10 m^3 is shown in Figure 143. The highest density of larvae occurs about 60 days after March 1 and declines thereafter. This peak occurs end of April.

Figure 143. Seasonal pattern in *Morone* sp. larvae (abundance 10 m^{-3}). The x-axis represents the number of days after March 1.



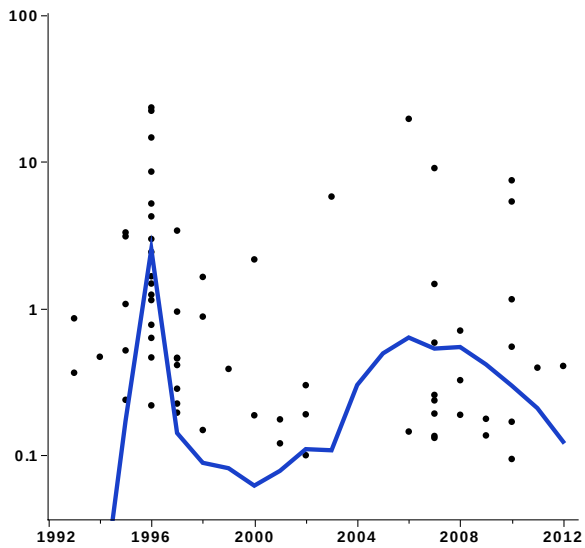
The long-term trend in density of Atherinid larvae (probably all inland silverside larvae) is presented in a LOESS graph in Figure 144. The number of Atherinid larvae per 10m^3 caught has remained low, although an increase is visible from 2006-2012.

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



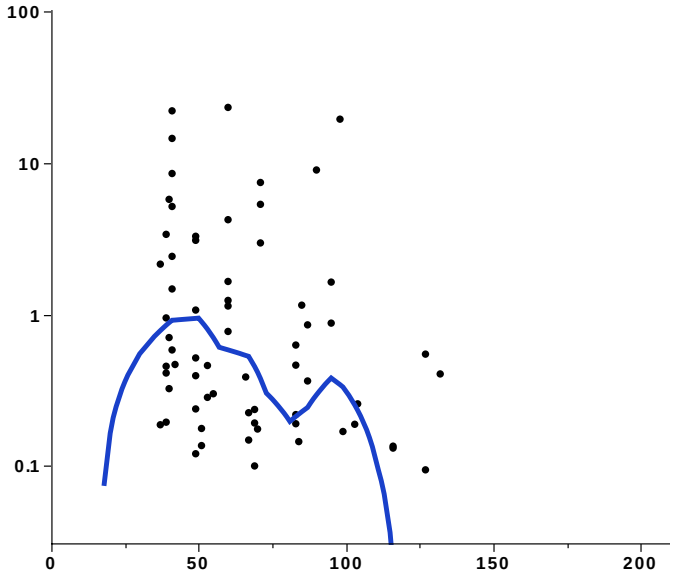
The seasonal occurrence of Atherinid larvae per $10m^3$ is shown in a LOESS graph in Figure 145. The pattern shows maximum density around 90 days after March 1, or around the first week of June. However, the peak is not pronounced, and the density persists at a slightly lower level into the fall.

Figure 145. Seasonal pattern in Atherinid larvae (abundance 10 m^{-3}).
The x-axis represents the number of days after March 1.



The long-term trend in density of yellow perch larvae since 1993 (Figure 146). Following unusually high densities in 1996, abundances decreased while the general trend remains highly variable.

Figure 146. Long-term trend in yellow perch larvae (abundance 10 m^{-3}).



The long term pattern of seasonal occurrence of yellow perch larval density is presented in a LOESS graph in Figure 147. The greatest densities occur in early to mid April, , while the density peak look bimodal with a smaller peak at 100 days since March 1, which falls in early to mid June.

Figure 147. Seasonal pattern in yellow perch larvae (abundance 10 m^{-3}).
The x-axis represents the number of days after March 1.

F. Adult and Juvenile Fish Trends: 1984-2012

Trawls

Overall patterns

Annual abundance of juvenile fishes inside Gunston Cove is indexed by mean catch per trawl in the inner cove (stations 7 and 10 combined; Table 18, Figure 148a). 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 148a). On average, catch rates of fishes within the cove are approximately the same over the time of the survey the survey (Figure 148b and c). The overall catch rate for the inner cove (stations 7 and 10) in 2012 was above the long-term mean (120) for the survey. A slow but steady increase is visible in the LOWESS algorithm after a decrease in abundance until 1996 (Figure 148b).

Table 18. Mean catch of adult and juvenile fishes per trawl for all months at Stations 7 and 10 combined.

Year	All Species	white perch	blueback herring	alewife	gizzard shad	bay anchovy	spottail shiner	brown bullhead	pumpkin-seed
2012*	159.3	127.7	0	0	0.5	0.4	11.8	0.6	2.1
2011**	95.2	43.6	1.0	0.1	0.2	0.0	20.0	0.1	2.0
2010*	310.7	206.8	0.2	5.4	1.8	0.3	5.0	0.4	1.2
2009	94.0	19.3	1.1	47.5	0.6	6.5	2.8	0.2	2.9
2008	70.7	16.2	0.0	0.1	4.0	0.3	2.6	0.6	7.0
2007	227.3	141.4	23.6	8.9	0.2	15.8	20.1	0.2	2.6
2006	23.5	8.7	1.5	0.6	0.2	2.1	2.7	0.4	1.6
2005	67.2	23.2	11.5	16.4	1.0	0.0	6.1	0.4	1.4
2004	340.3	19.5	281.3	27.6	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	81.4	15.6	9.8	28.5	0.1	15.8	0.7	0.9	1.7
2001	135.0	44.2	38.1	9.4	0.3	33.0	2.6	3.1	1.3
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	0.0	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	112.9	81.6	0.3	0.0	0.9	0.8	2.4	11.5	5.1
1991	123.7	90.9	1.0	0.5	8.1	2.6	2.9	12.4	1.7
1990	72.8	33.3	21.9	3.3	0.1	1.1	1.1	10.0	0.5
1989	78.4	14.9	16.1	0.3	42.4	0.3	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	16.1	3.5	5.6	8.8	0.7	15.1	1.4
1986	124.6	65.4	1.9	24.0	4.1	4.2	0.5	18.4	0.6
1985	134.4	43.2	13.5	12.4	2.9	48.1	0.9	9.6	0.0
1984	202.6	133.3	6.6	0.6	13.4	8.0	1.6	35.0	0.3

*Station 10 not sampled late July – Sept. **Station 10 not sampled in August

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. There was high variability between stations as well (Table 22). The presence and location of SAV beds is responsible for the variability as well. In 2012, trawling was already impeded at station 10 in July (Table 21), which resulted in a

much shorter trawling season at station 10 than usual. This is reflected in (and responsible for) the low total catch at station 10 in 2012 (Table 22). Sampling in the station 10 area was continued with fyke nets.

Table 19. Mean catch of selected 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
2012	60.5	20.1	0.0	31.7	0.7	0.0	0.3	0.0	0.1
2011	34.0	21.3	0.1	0.0	0.2	0.1	6.4	0.2	0.0
2010	38.6	10.7	0.0	7.9	0.0	0.1	0.0	0.0	0.1
2009	40.4	15.2	0.0	8.6	0.5	0.2	0.7	0.1	0.4
2008	95.0	10.0	0.0	80.0	0.1	0.0	0.0	0.0	0.0
2007	253.8	195.7	0.0	0.7	1.1	0.0	0.0	0.9	0.0
2006	68.1	31.0	0.2	3.0	0.2	8.0	4.6	0.0	0.2
2005	91.1	36.5	0.0	12.1	1.8	2.2	4.7	0.1	0.1
2004	41.9	20.4	0.0	0.0	1.1	2.2	6.6	0.3	0.9
2003	62.5	29.9	0.1	0.0	0.6	2.1	14.1	1.2	6.6
2002	52.9	27.2	0.1	0.5	0.0	2.3	10.3	0.8	1.9
2001	68.0	35.4	0.2	19.6	0.1	0.8	4.8	0.7	1.1
2000	52.4	43.4	0.1	0.0	0.1	2.2	3.9	0.0	2.2
1999	23.1	19.1	0.1	0.3	0.0	0.3	2.4	0.0	0.9
1998	22.1	12.8	0.1	0.4	0.1	0.3	6.2	2.0	0.2
1997	49.6	37.2	0.2	0.0	1.1	0.3	9.2	0.4	0.3
1996	14.0	7.0	0.1	0.0	0.1	0.1	6.0	0.8	0.0
1995	31.9	17.4	0.3	0.2	0.2	4.3	8.5	0.1	0.5
1994	31.9	13.4	3.1	0.1	0.0	2.4	6.3	3.5	2.4
1993	31.3	6.8	1.6	0.0	6.6	1.3	5.5	7.9	1.3
1992	27.5	14.3	2.6	0.0	0.0	1.3	1.6	0.8	6.6
1991	67.9	42.4	0.4	1.9	0.1	1.0	13.2	0.4	6.3
1990	101.5	50.6	1.0	0.0	0.1	5.3	39.9	0.1	4.0
1989	14.3	7.9	0.2	0.4	0.0	1.5	2.0	0.3	0.2
1988	19.3	5.3	0.0	11.5	0.0	0.0	0.8	0.0	0.5

Table 20. Mean catch of selected 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 catfish
2012*	119.8	84.6	0.0	0.2	0.3	13.0	7.4	0.4	0.2
2011**	73.5	35.6	0.6	0.1	0.1	0.0	12.9	0.1	2.3
2010*	220.0	141.5	0.1	3.6	1.2	2.9	3.3	0.3	0.0
2009	76.2	17.9	0.9	31.9	0.4	7.2	2.0	0.2	0.4
2008	78.8	14.1	0.0	0.1	2.7	26.8	1.7	0.4	0.0
2007	236.1	159.5	16.6	11.6	0.1	10.7	13.8	0.1	0.0
2006	38.3	16.1	1.0	0.4	0.1	2.4	1.9	2.9	1.5
2005	75.7	28.3	7.5	15.8	0.6	4.3	4.6	1.0	1.8
2004	240.9	19.8	187.6	19.5	0.5	0.3	4.8	0.8	2.2
2003	54.4	16.4	12.6	2.3	0.0	4.9	2.0	1.6	5.3
2002	71.7	19.6	6.6	19.0	0.1	10.6	0.4	1.3	4.6
2001	112.7	41.3	25.4	6.3	0.2	28.5	1.8	2.3	1.7
2000	64.1	51.1	2.4	1.3	1.7	1.1	0.9	2.1	1.4
1999	65.6	48.5	2.8	0.3	0.7	3.7	3.2	1.7	0.8
1998	62.8	46.9	1.5	0.4	0.4	2.6	4.5	0.7	2.1
1997	70.8	53.5	1.3	0.7	3.3	1.7	2.3	1.1	3.1
1996	36.7	25.9	1.6	1.1	0.3	0.1	1.7	0.4	2.0
1995	69.7	52.3	2.7	1.5	0.3	2.1	2.0	2.7	2.9
1994	73.2	50.1	0.5	0.0	0.1	0.4	4.3	2.9	2.2
1993	167.8	140.4	0.9	0.4	0.9	0.4	6.8	3.3	1.8
1992	88.5	62.3	0.2	0.0	0.6	0.6	1.7	8.6	0.5
1991	103.8	73.6	0.6	0.4	5.2	2.4	1.9	8.4	4.7
1990	82.4	39.1	14.6	2.2	0.1	0.8	0.8	8.4	13.3
1989	57.1	12.6	11.0	0.3	28.4	0.3	0.3	2.5	0.7
1988	85.7	39.8	9.7	7.6	11.0	8.7	1.6	4.6	0.3
1987	106.7	54.3	16.1	3.5	5.6	8.8	0.7	15.1	0.0
1986	124.6	65.4	1.9	24.0	4.1	4.2	0.5	18.4	0.0
1985	134.4	43.2	13.5	12.4	2.9	48.1	0.9	9.6	0.0
1984	202.6	133.3	6.6	0.6	13.4	8.0	1.6	35.0	0.1

*Station 10 not sampled late July – Sept. **Station 10 not sampled in August

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

Year	Stations	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2012	7 & 9	0	0	1	2	2	2	2	1	0	0	0
	10	0	0	1	2	2	0	0	0	0	0	0
2011	7 & 9	0	0	1	2	3	2	2	1	0	0	0
	10	0	0	1	2	3	2	0	1	0	0	0
2010	7 & 9	0	1	2	2	2	2	1	0	0	0	0
	10	0	0	1	2	2	1	0	0	0	0	0
2009		0	0	1	2	2	2	2	1	0	0	0
2008		0	0	1	2	2	2	2	1	0	0	0
2007		0	0	1	2	2	2	2	1	0	0	0
2006		0	0	1	2	2	2	2	1	0	0	0
2005	7 & 9	0	1	2	2	2	2	1	1	0	0	0
	10	0	0	1	2	2	2	2	0	0	0	0
2004		0	1	1	2	2	2	1	0	0	0	0
2003		0	1	2	2	2	2	1	1	1	1	1
2002	7 & 9	1	2	2	2	2	2	2	1	1	1	0
	10	0	0	2	2	2	2	2	2	1	1	1
2001	7	0	1	2	2	1	2	3	2	1	1	1
	9	0	1	2	1	1	2	3	2	1	1	1
	10	0	1	2	2	1	2	3	2	1	1	1
2000		0	1	2	2	2	2	2	2	2	1	1
1999		0	1	2	2	2	2	2	2	1	1	1
1998		0	1	2	2	2	2	2	2	1	1	1
1997		0	1	2	2	2	2	2	2	2	1	1
1996	7	0	1	2	2	1	2	1	2	1	1	1
	10	0	1	2	1	2	2	1	2	1	1	1
	9	0	1	2	2	1	2	1	2	1	1	1
1995		0	1	2	2	2	2	2	2	2	1	0
1994		0	1	1	1	2	2	0	2	2	1	0
1993		0	1	1	2	2	3	2	2	2	1	1
1992	7 & 10	1	1	1	1	1	1	1	1	1	1	0
	9	0	1	1	0	1	1	1	1	1	1	1
1991		0	1	1	1	1	1	1	1	1	1	0
1990		0	1	1	1	1	1	1	1	1	0	0
1989		0	1	1	1	1	1	1	2	2	1	1
1988	7 & 10	1	1	1	2	2	2	2	1	1	0	0
	9	0	0	0	0	0	0	0	2	1	1	0
1987	7 & 10	1	1	1	1	1	1	1	1	1	0	0
1986	7 & 10	1	1	1	1	1	1	1	1	1	0	0
1985	7 & 10	0	1	1	1	0	1	1	2	1	0	0
1984	7 & 10	1	2	3	2	3	2	3	3	2	1	0

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

Year	Station 7	Station 9	Station 10
2012*	217.7	60.5	42.4
2011**	114.0	34.0	72.2
2010*	615.6	38.6	5.8
2009	142.8	40.4	45.3
2008	50.1	95.0	91.3
2007	390.1	253.8	64.4
2006	40.7	68.1	6.2
2005	104.6	91.1	21.4
2004	658.2	41.9	22.4
2003	61.3	62.5	39.4
2002	91.2	52.9	70.9
2001	157.9	68.0	112.1
2000	95.1	52.4	44.8
1999	117.2	23.1	56.6
1998	88.3	22.1	78.1
1997	111.5	49.6	51.4
1996	64.5	14.0	31.5
1995	107.6	31.9	69.6
1994	122.3	31.9	62.1
1993	354.9	31.3	109.2
1992	155.5	27.5	70.2
1991	173.9	67.9	73.6
1990	77.3	101.5	68.4
1989	52.6	14.3	104.3
1988	95.8	19.3	96.2
1987	84.3	.	131.9
1986	95.8	.	153.4
1985	122.6	.	146.1
1984	197.4	.	207.7

*Station 10 not sampled July – Sept. **Station 10 not sampled in August

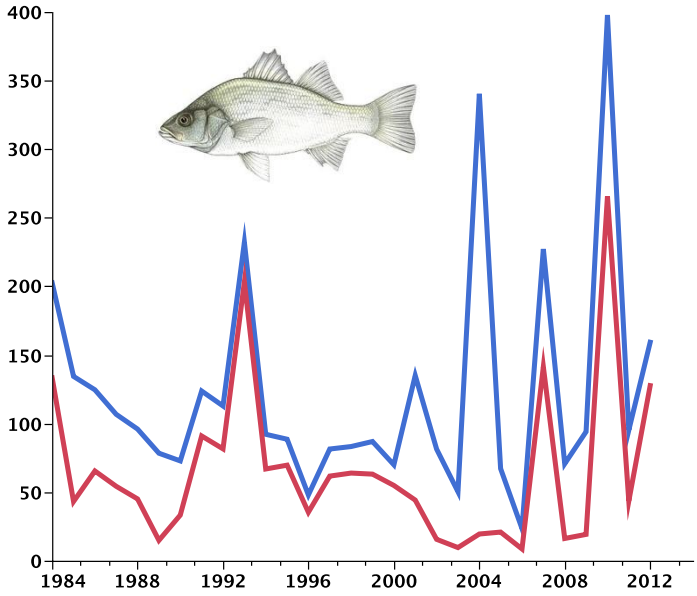


Figure 148a. Trawls. Annual Averages. All Species (blue) and white perch (red). Cove Stations 7 and 10.

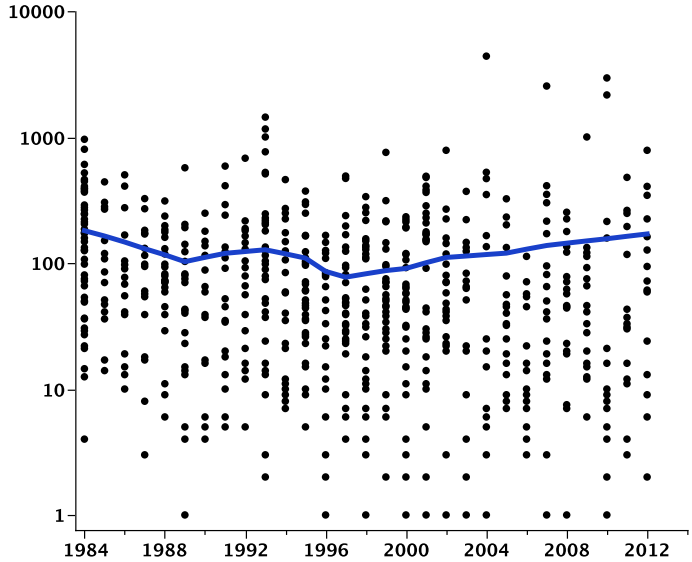


Figure 148b. Trawls. Long Term Trend in Total Catch. Cove Stations 7 and 10.

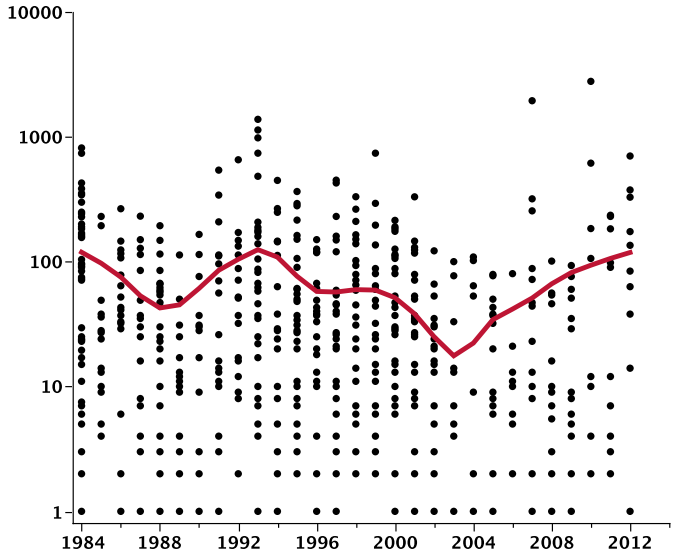


Figure 148c. Trawls. Long Term Trend in white perch (#/trawl). Stations 7 & 10.

Annual trends in other dominant species captured by the trawl survey are presented below. Note that LOWESS algorithms generated the smoothed trends. 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.

Mean total number of fish per trawl sample has remained steady over the course of the study (Table 20 and Figure 148b); the pattern is highly dominated by catches of white perch (Figure 148a). Strong cohorts punctuated white perch catch rates in 1993, 2007, and 2010,

which kept the overall trend from declining (Figure 148a, c). An overall increase in white perch can been seen starting in 2003 (Figure 148c). The remaining component of the total catch (species other than white perch) made up a moderate to large proportion of the catch until 1990; a relative small part of the catch between 1991 and 2000; and, excepting 2006, a moderate to large proportion of the catch from 2001 to 2012. There was a high peak in catches other than white perch in 2004, which was primarily due to exceptionally high catches of blueback herring (Figure 149a).

The high peak in blueback herring catches in 2004 stands out in otherwise low catches. The LOWESS trends recognize an increase in blueback herring from 1993 followed by a general decline since 2004, while a slower increase in alewife since 1994 has remained steady but has leveled off since 2004 (Figures 149 b & c).

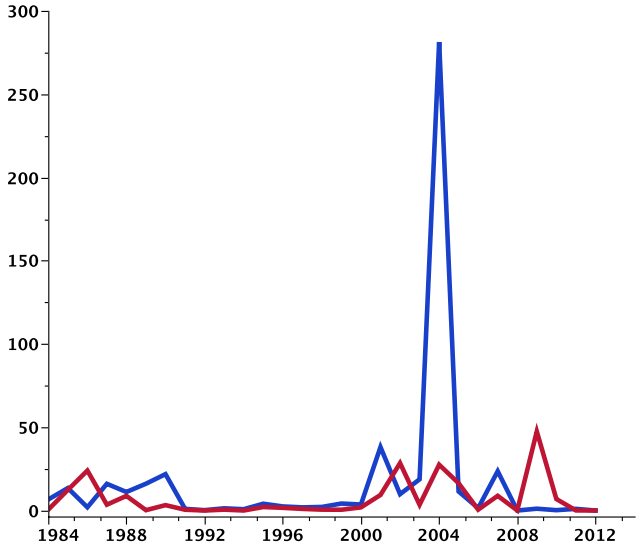


Figure 149a. Trawls. Annual Averages. Blueback herring (blue) and alewife (red). Cove Stations 7 and 10.

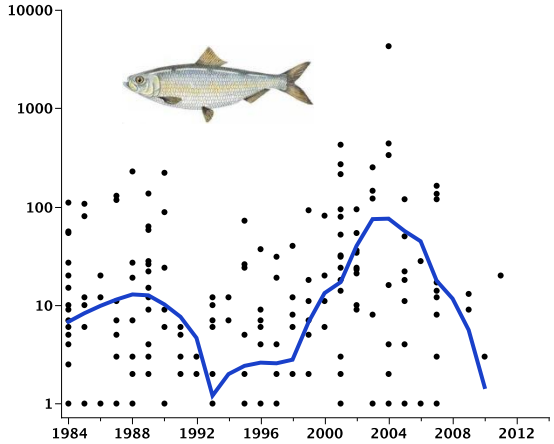


Figure 149b. Trawls. Long term trend in blueback herring (*Alosa aestivalis*; #/trawl). Cove Stations 7 and 10.

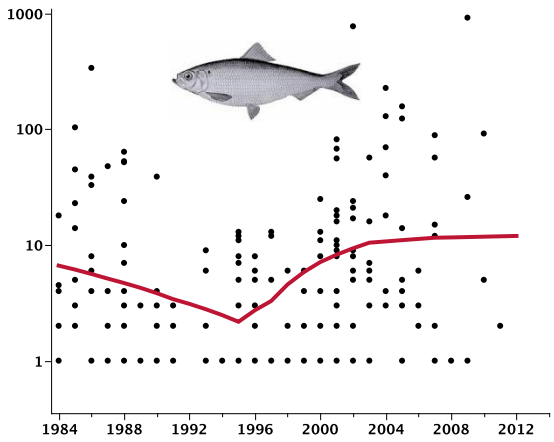


Figure 149c. Trawls. Long term trend in alewife (*Alosa pseudoharengus*; #/trawl). Cove Stations 7 and 10.

Gizzard shad catch rates in trawls in 2012 were low which contributes to a pattern of low and variable abundance since 1992 or earlier (Figure 150a,b). Trend analysis with LOWESS emphasized declining gizzard shad catch rates for stations 7 and 10 since 1989, with a variable trend around a lower mean since then. Bay anchovy catch rates were low at inner cove stations, and LOWESS trend analysis suggests a sinusoidal trend over the length of the survey. 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. As the abundance of bay anchovy is currently at a low, further years will determine whether the sinusoidal trend continues, or if the ecosystem of the inner cove has now shifted to a state (e.g. reduced open water/SAV bed ratio) that is less favorable for bay anchovy.

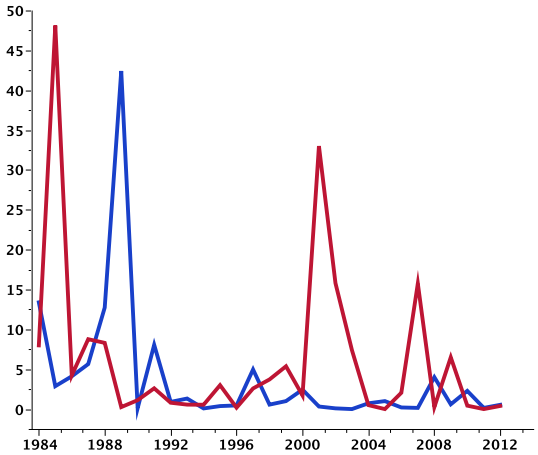


Figure 150a. Trawls. Annual Averages. Cove Stations 7 and 10. Gizzard shad (blue) and bay anchovy (red).

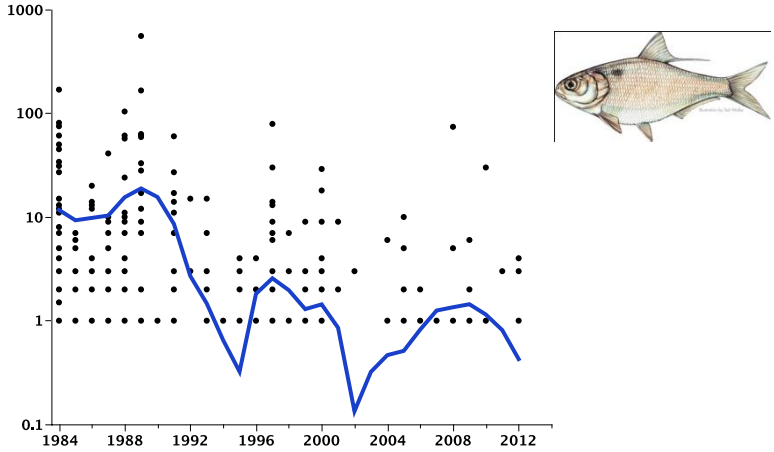


Figure 150b. Trawls. Long term trend in Gizzard Shad (*Dorosoma cepedianum*). Stations 7 and 10.

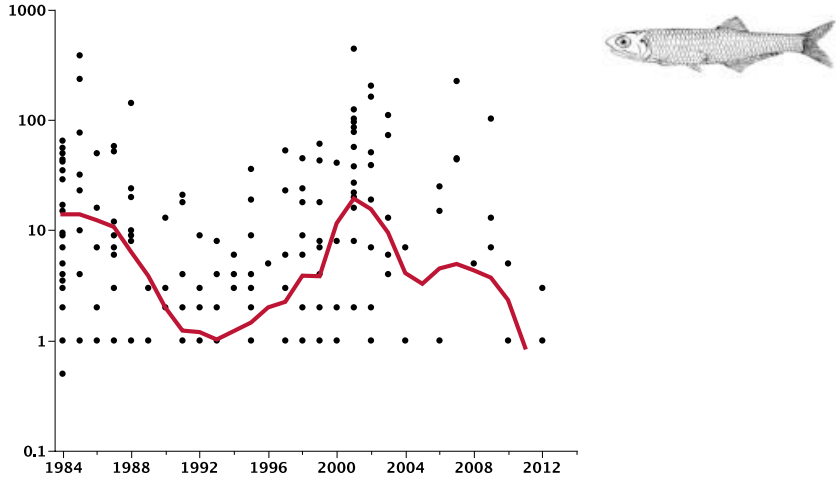


Figure 150c. Trawls. Long term trend in Bay Anchovy (*Anchoa mitchilli*). Stations 7 and 10.

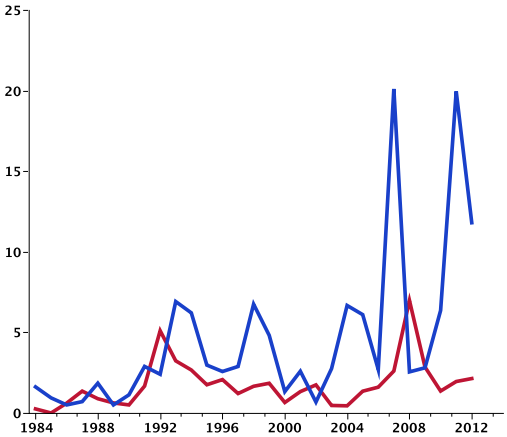


Figure 151a. Trawls. Annual Averages. Spottail shiner (blue) and pumpkinseed (red). Cove Stations 7 and 10.

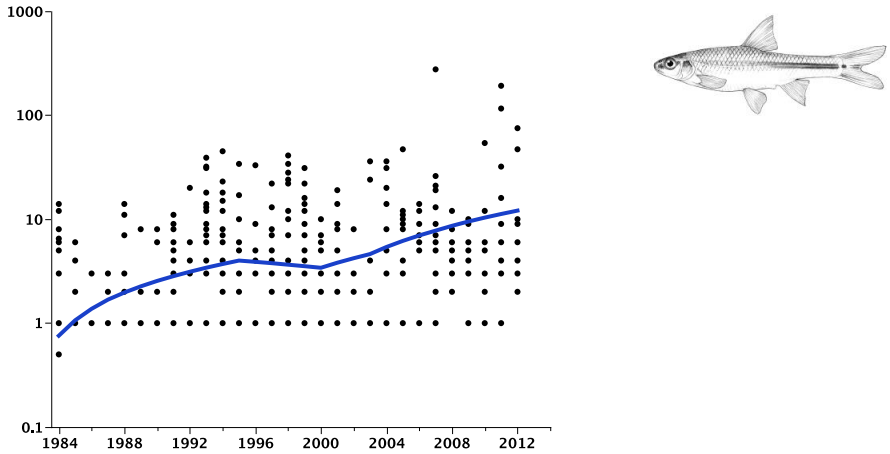


Figure 151b. Trawls. Long-term Trends in Spottail Shiner (*Notropis hudsonius*). Cove Stations 7 and 10.

Spottail shiner and sunfish (bluegill and pumpkinseed) have been consistently collected in the majority of all trawl and seine samples (Figure 151 a,b,c,d). An increasing trend has been observed for spottail shiner 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, with high numbers in 2007 and 2011. These individuals were mostly juveniles, indicating relatively high reproductive success as measured by this survey. The trends for sunfish are more variable, but also indicate a potential increase over time.

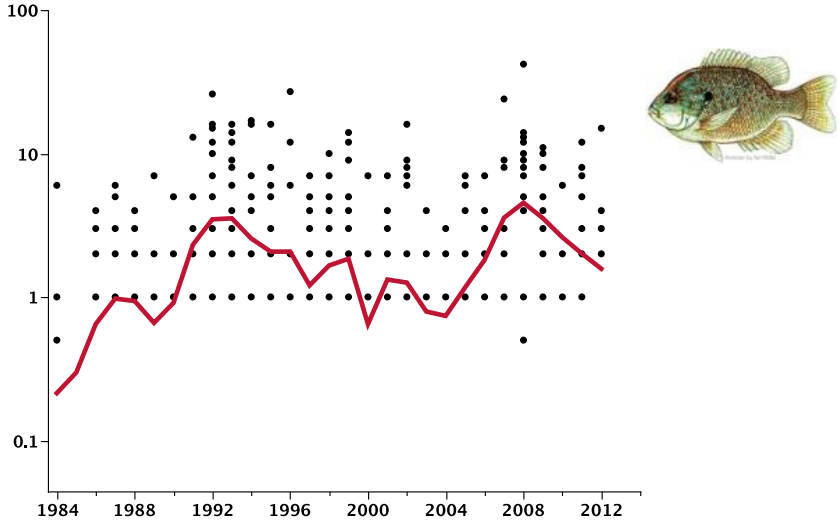


Figure 151c. Trawls. Long term trend in Pumpkinseed (*Lepomis gibbosus*). Cove stations 7 and 10.
10.

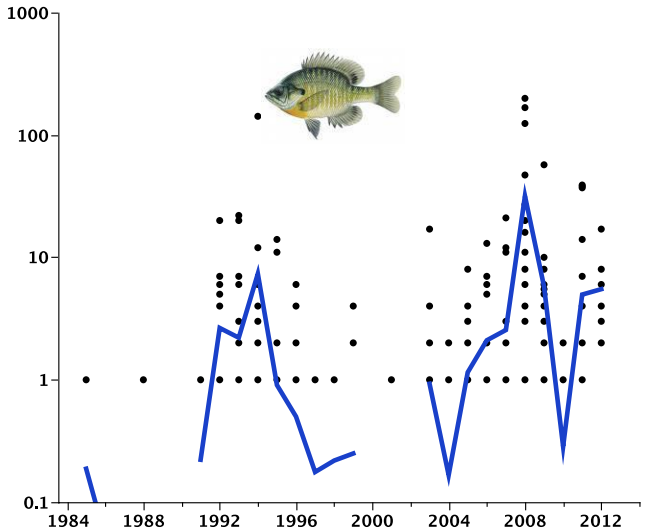


Figure 151d. Trawls. Long term trend in Bluegill (*Lepomis macrochirus*). Cove stations 7 and 10.

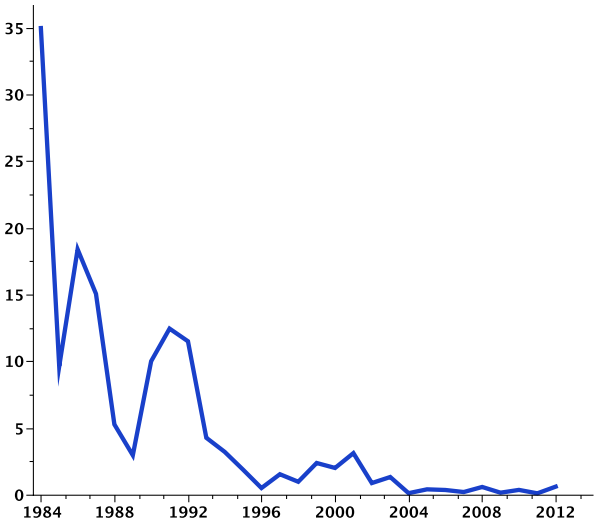
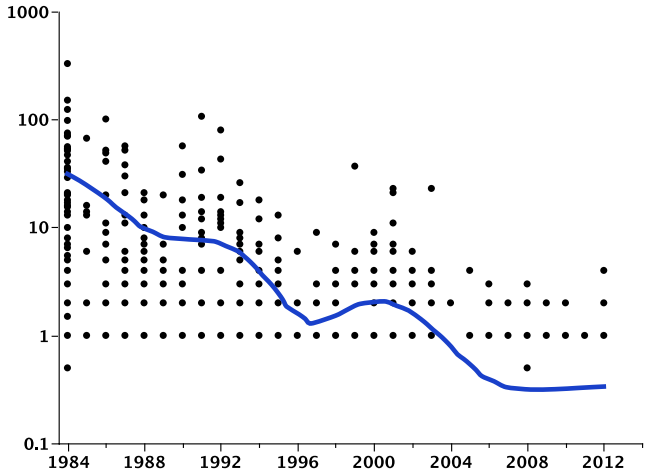


Figure 152a. Annual Averages. Brown Bullhead. Cove Stations 7 and 10.

Very few brown bullhead were captured during 2012, 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 LOWESS trend (Figure 152a,b).



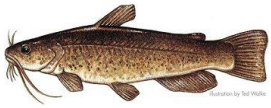


Figure 152b. Trawls. Long term trend in Brown Bullhead (*Ameirus nebulosus*; #/trawl). Cove stations 7 and 10.

Tessellated darter was 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 152c).

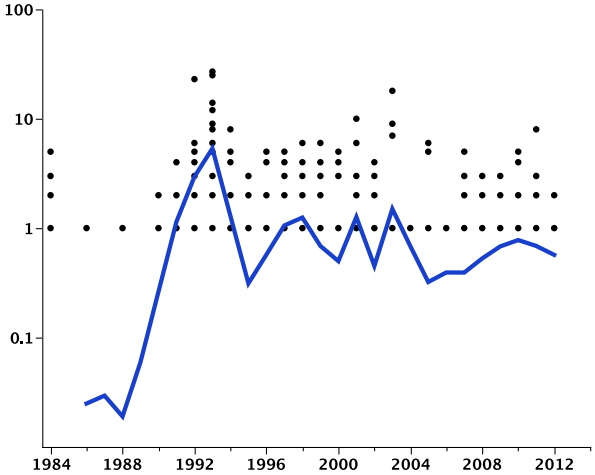


Figure 152c. Trawls. Long term trend in Tessellated Darter (*Etheostoma olmstedi*). Cove stations 7 and 10.

At the river channel station (station 9), catches were low to average in 2012 (Figure 153a). As in the inner cove, 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 also evident in the LOWESS algoritms, both for total catch and white perch (Figures 153b,c). The LOWESS trends indicate a decline after 2007, which for total catch could be merely reflecting the lower catches compared to a record abundance in 2007, while white perch seem to vary around a new low mean since 2007.

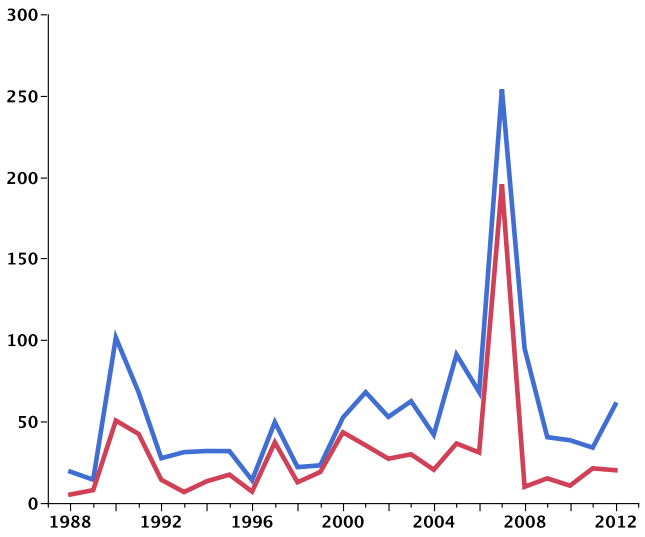


Figure 153a. Trawls. Annual averages. River Station (9). Total catch (blue), white perch (red)

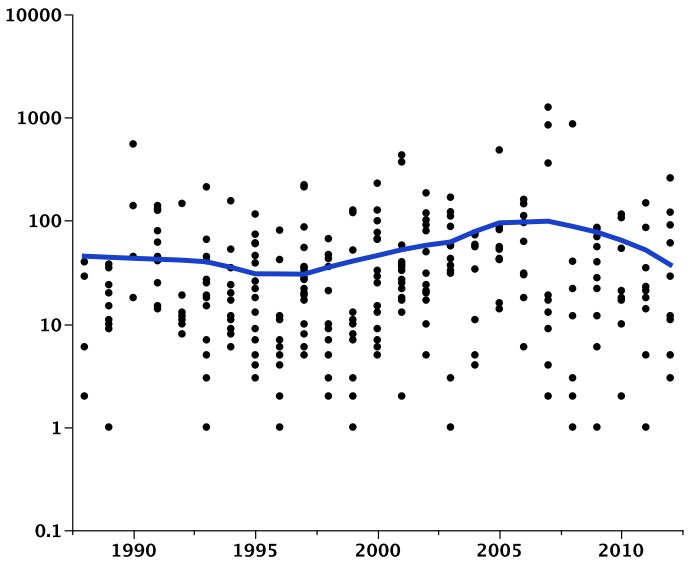
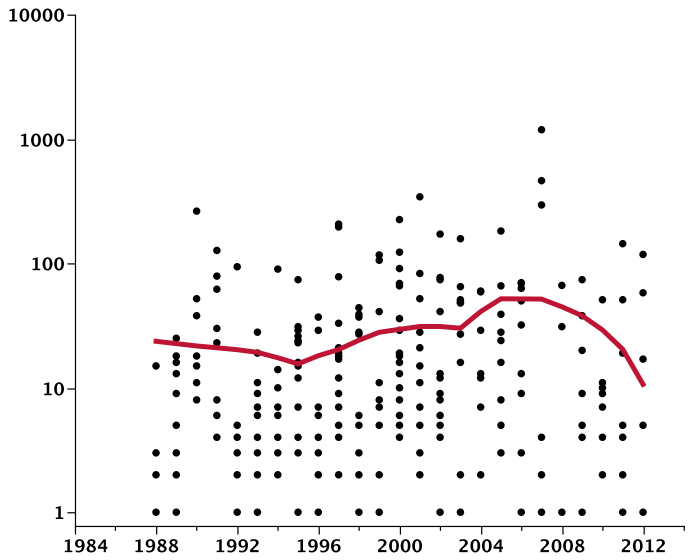


Figure 153b. Trawls. Long-term trend in total catch. River Station (9).



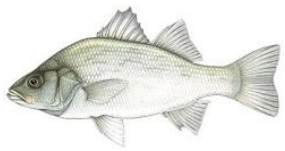


Figure 153c. Trawls. Long-term trend in white perch (*Morone americana*). River Station (9).

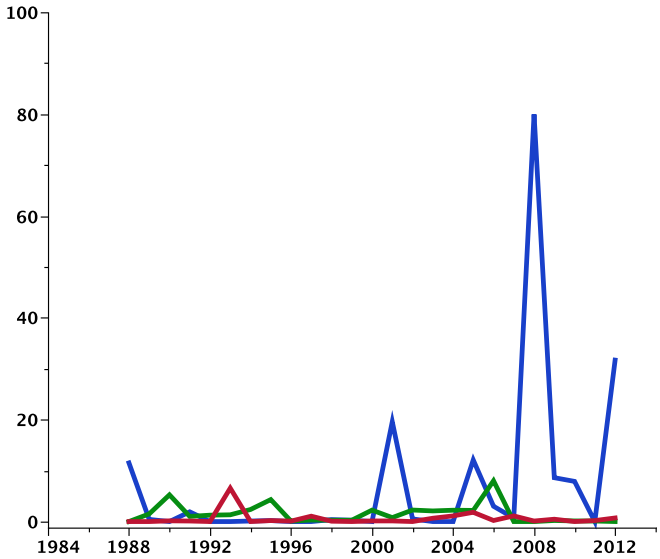


Figure 154a. Trawls. Annual Averages. River Station (9). Bay anchovy (Blue) Spottail shiner (red) Americal eel (green)

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 154a,b,c). A record catch of bay anchovy in September of 2008 was the highest on record and indicates strong reproductive success and/or upstream transport. Catches were high again in 2012, overall there is an increasing trend in bay anchovy abundances (154b).

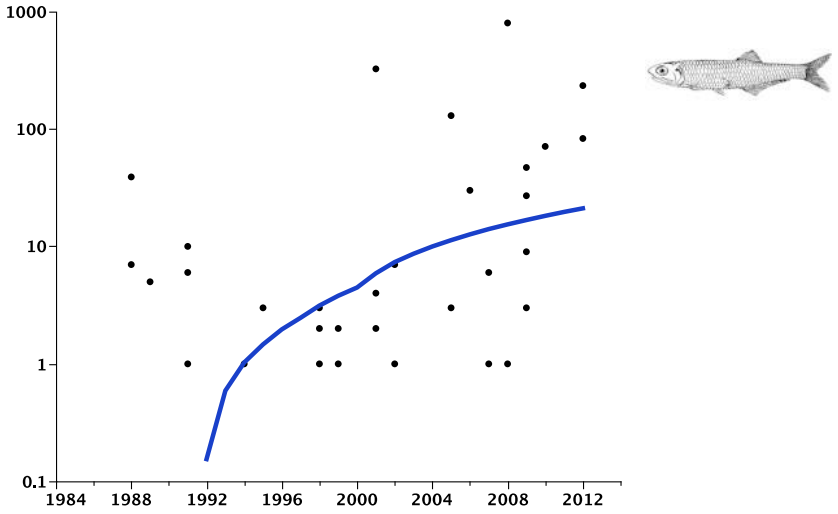


Figure 154b. Trawls. Long term trend in bay anchovy (*Anchoa mitchilli*). River station (9).

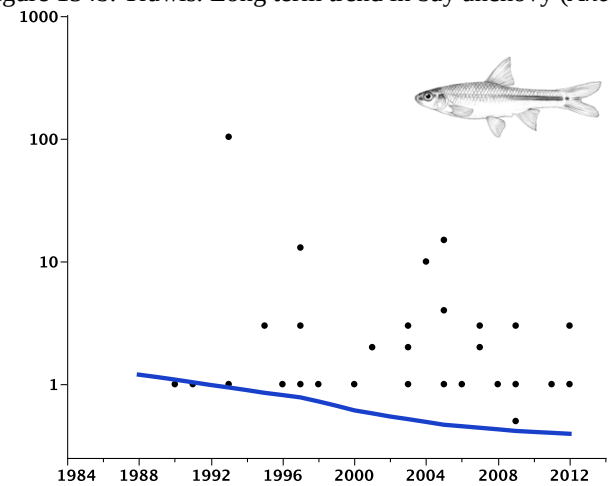


Figure 154c. Trawls. Long term trend in spottail shiner (*Notropis hudsonius*). River station (9).

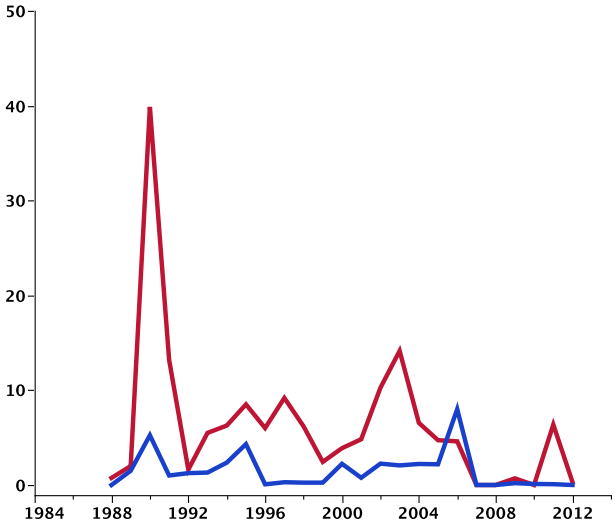


Figure 155a. Trawls. Annual Averages. River Station (9). Brown bullhead (blue) and channel catfish (red).

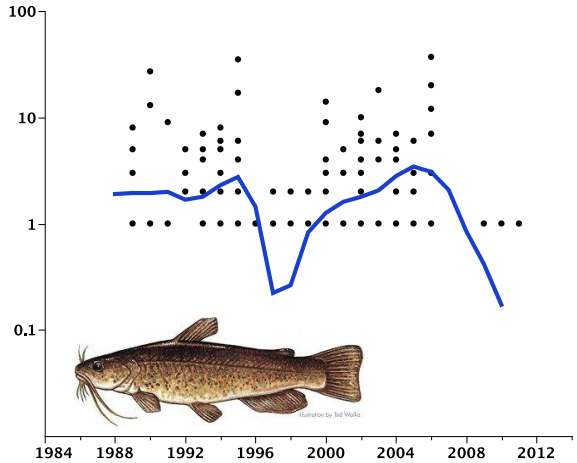


Figure 155b. Trawls. Long term trend in brown bullhead (*Ameiurus nebulosus*). River Station (9).

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 155a, b, c, d). Low catches were observed for brown bullhead again in 2012, and channel catfish catches were equally low. Long-term mean trends identify a decline in both brown bullhead and channel catfish (Figures 155b and c). One species that warrants close attention is the invasive blue catfish, which was positively identified on the survey in 2001 and has been captured in high numbers relative to channel catfish and brown bullhead ever since (Figure 155d). Since blue catfish occupy the same niche, but can grow to larger sizes, it generally outcompetes the native catfish population (Schloesser et al., 2011). The LOWESS algorithm shows that blue catfish established itself in 2001 with relatively high numbers, but those numbers have remained stable since then (Figure 155d). The system may have reached a new stable state that includes blue catfish in relative high numbers, and channel catfish and brown bullhead in low numbers. There is no further increasing trend in blue catfish abundances visible, though continued monitoring in the growth of this population is warranted.

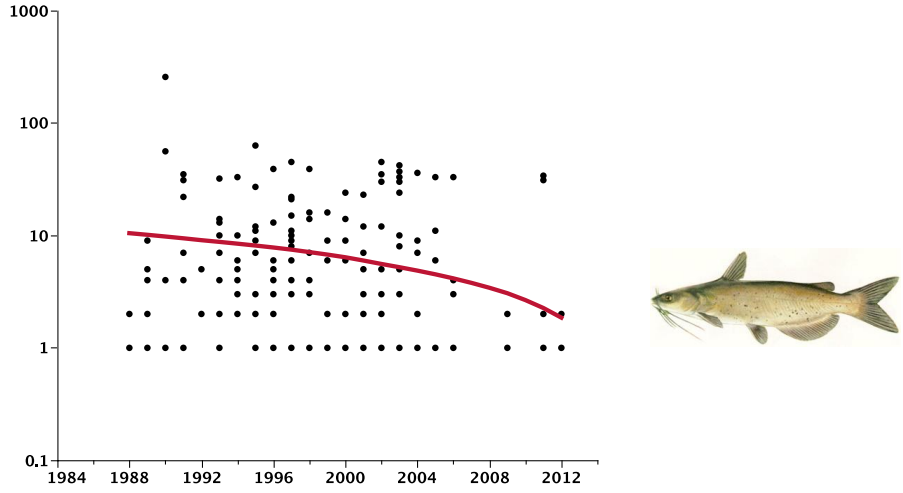


Figure 155c. Trawls. Long term trend in Channel Catfish (*Ictalurus punctatus*). River Station (9).

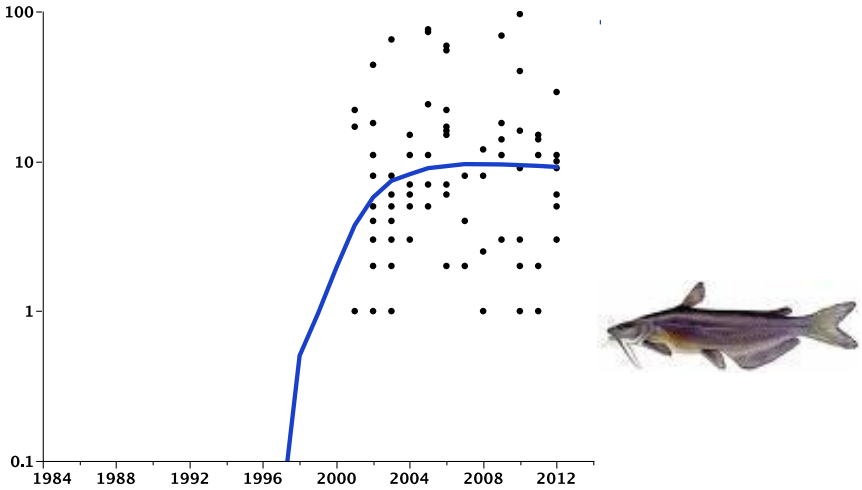


Figure 155d. Trawls. Long term trend in Blue Catfish (*Ictalurus furcatus*). River Station (9).

Station 9 represented low catch rates for the demersal species tessellated darter and hogchoker (Figure 156a, b, and c). On rare occasions, catches exceeded 50 individuals per trawl, but high catches have not occurred since 2004 (Figure 156a). The mean annual trend seems to indicate a general decline in catch rates for each of these species over the time-span of the survey (Figure 156b and c).

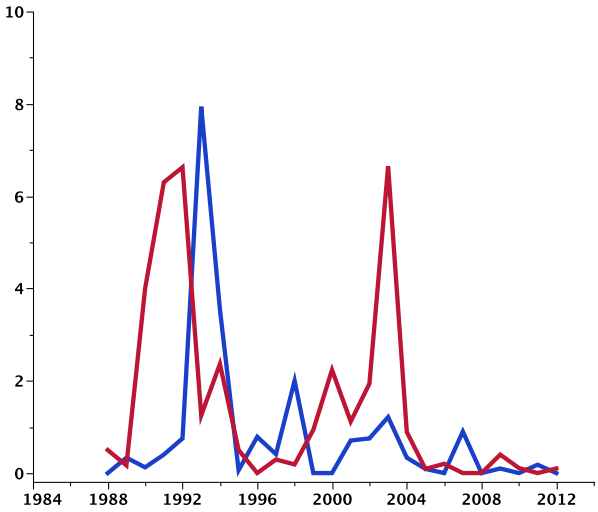


Figure 156a. Trawls. Annual Averages. Tessellated darter (blue) hogchoker (red). River Station (9).

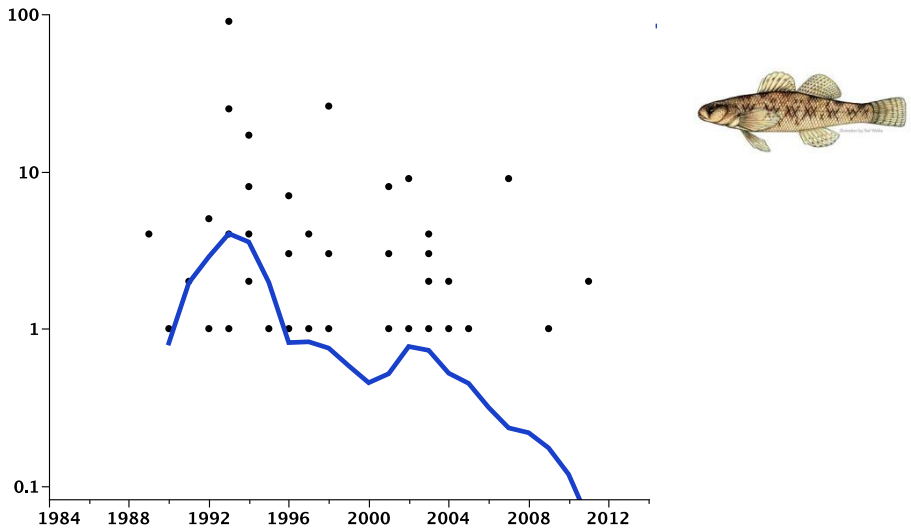


Figure 156b. Trawls. Long term trend in Tessellated darter (*Etheostoma olmstedi*). River Station (9).

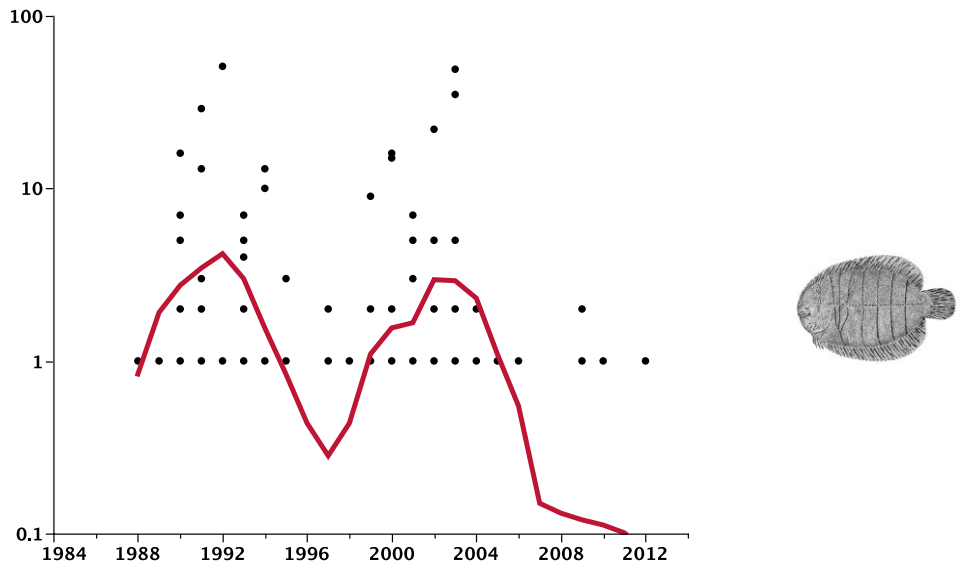


Figure 156c. Trawls. Long term trend in Hogchoker (*Trinectes maculatus*). River Station (9).

Seines

Overall Patterns

Mean annual seine catch rates were generally less variable than trawl catch rates. The long-term trend of seine catches shows a period of lower catch rates during the mid-1990s followed by variable increases in catches (Figures 157). This was reflected by only a slight drop in the moving average (LOWESS trend; figure 158) of catch rates during the middle of the series, which rebounded in 1998 and has increased since. Together, the overall pattern shows a very slight increase in catches over the course of the survey (Figure 158). 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 23; Figure 157). Overall, white perch and banded killifish have been the dominant species in seine samples throughout the survey; in 2012 white perch catches were low and were surpassed by inland silverside catches, while banded killifish was the most abundant by far. This is likely an indication of the shifted ecosystem state to an SAV dominated system, since banded killifish prefers SAV habitat, while white perch prefers open water.

Table 23. Mean catch of adult and juvenile fishes per seine at all stations and all months

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

2007-2010 averages do not include Station 4A

Table 24. The number of seines in each month at Station 4, 4A, 6, and 11 in each year

Year	Stations	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2012	4A	0	0	1	2	2	2	2	1	0	0	0
	4	0	0	1	2	2	1*	0*	0*	0	0	0
	6	0	0	1	2	2	2	2	1	0	0	0
	11	0	0	1	2	2	2	2	1	0	0	0
2011	4A	0	0	1	2	3	2	2	1	0	0	0
	4	0	0	1	2	3	2	2	1	0	0	0
	6	0	0	1	2	3	2	2	0	1	0	0
	11	0	0	1	3	3	2	2	1	0	0	0
2010		0	0	1	1	2*	2*	2*	1*	0	0	0
2009	4, 6, & 11	0	1	2	2*	2*	2*	1*	0	0	0	0
	4A	0	0	1	2	2	2	2	1	0	0	0
2008	4, 6, & 11	0	1	2	2*	2*	2*	1*	0	0	0	0
	4A	0	0	1	2	2	2	2	1	0	0	0
2007	4, 6, & 11	0	1	2	1*	2*	2*	1*	0	0	0	0
	4A	0	0	0	0	0	2	2	1	0	0	0
2006	4	0	0	1	2	1*	1*	2**	1**	0	0	0
	6	0	0	1	2	2	0*	0*	0	0	0	0
	11	0	0	1	2	2	2	2	1	0	0	0
2005	4 & 6	0	1	2	2	2	0*	0*	0	0	0	0
	11	0	0	1	2	2	2	2	1	1	0	0
2004	4	0	0	1	1	2	1	0*	0*	0	0	0
	6	0	0	1	1	2	0*	0*	0*	0	0	0
	11	0	0	0	0	2	2	2	1	0	0	0
2003		0	1	2	2	2	2	1	1	1	1	1
2002		0	1	2	2	2	2	2	2	1	1	1
2001		0	1	1	2	1	2	3	2	1	1	1
2000		0	1	2	2	3	2	2	2	1	1	1
1999		0	1	2	2	2	2	2	2	1	1	1
1998		0	1	2	2	2	2	2	2	1	1	1
1997		0	1	2	2	2	2	2	2	2	1	1
1996	4 & 11	1	2	2	2	2	1	2	1	1	1	0
	6	0	1	2	2	2	2	1	2	1	1	0
1995		0	1	2	2	2	2	2	2	2	1	0
1994		0	1	0	1	1	0	0	1	1	0	0
1993		0	1	2	2	1	3	2	0	1	1	1
1992		0	1	1	1	1	1	1	1	1	1	1
1991		0	1	1	1	1	1	1	1	1	1	0
1990		0	1	1	1	1	1	1	1	0	0	0
1989		0	1	1	1	1	1	1	1	1	1	0
1988	4	0	1	1	0	2	2	1	1	1	1	0
	6 & 11	1	1	1	2	2	2	1	1	1	0	0
1987	4 & 11	1	1	1	1	0	0	0	1	1	0	0
	6	0	1	1	1	1	0	0	0	1	0	0
1986	4	0	1	0	1	0	1	0	0	1	1	0
	6 & 11	1	1	0	1	1	1	0	1	1	1	0
1985		0	0	0	0	0	0	1	1	1	2	0

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

Table 25. Mean catch of adult and juvenile fishes per seine in all months at each station

Year	Station 4	Station 6	Station 11
2012	305.3	111.1	78.9
2011	161.3	159.3	134.5
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

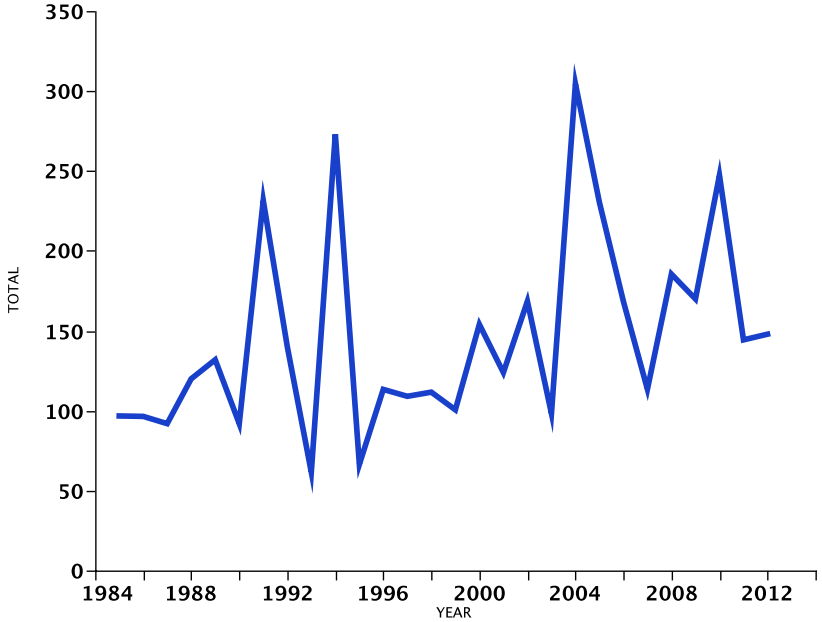


Figure 157. Seines. Annual Average over Stations 4, 6, and 11. All Species.

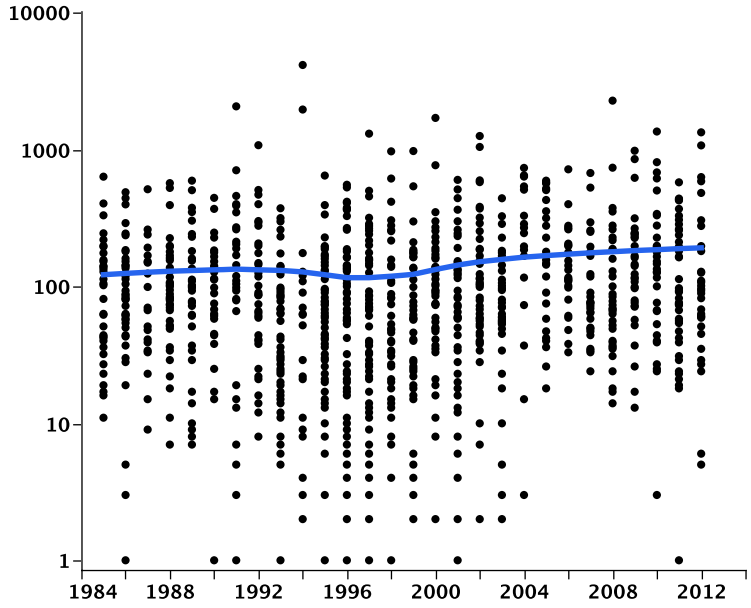


Figure 158. Seines, all stations Long-term trend in total seine catch.

Over the course of the survey mean annual seine catch rates of white perch have exhibited a gradual decline (Figures 159a), and the LOWESS algorithm indeed shows a decline over this period (Figure 159b). As this declining pattern is also reflected in the trawl data of station 9 it may be the case that white perch abundance at a larger spatial scale has declined. An 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 were necessary to understand the relative importance of these factors. In 2012, fyke nets were added to the sampling gear that sampled station 4 (seine station where SAV interferes halfway during the sampling season) and station 10 (trawl station where SAV interferes with sampling halfway during the sampling season) for part of the sampling season. In fyke nets, white perch was not among the dominant species, and catches in fyke nets did not make up for the reduced catches in seines and trawls. Fyke nets did efficiently sample the SAV beds, and were dominated by SAV-associated species like sunfishes and banded killifish (Figure 63a and b). The state shift of the ecosystem to a SAV dominated system seems to have resulted in a shift in the nekton community from open-water species to SAV-associated species. Further analysis in community composition changes through time are detailed after the seine discussion.

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, as mentioned above, prominent increases in mean catch rates of banded killifish are associated with development of SAV in the cove since 2000. The SAV provides refuge for banded killifish adults and juveniles and may enhance feeding opportunities with epifaunal prey items.

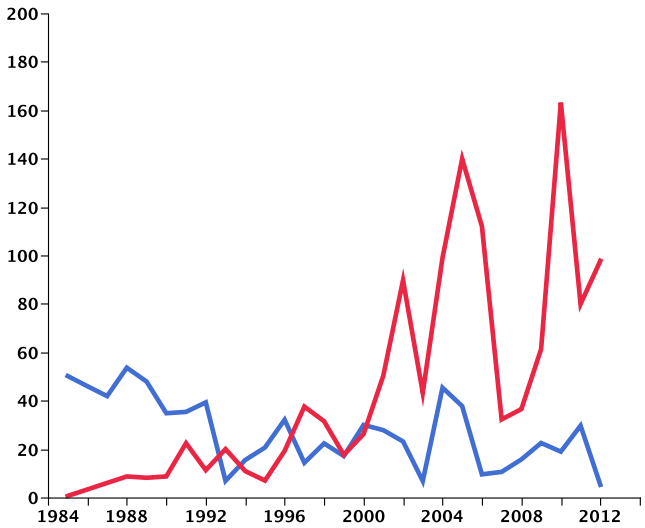
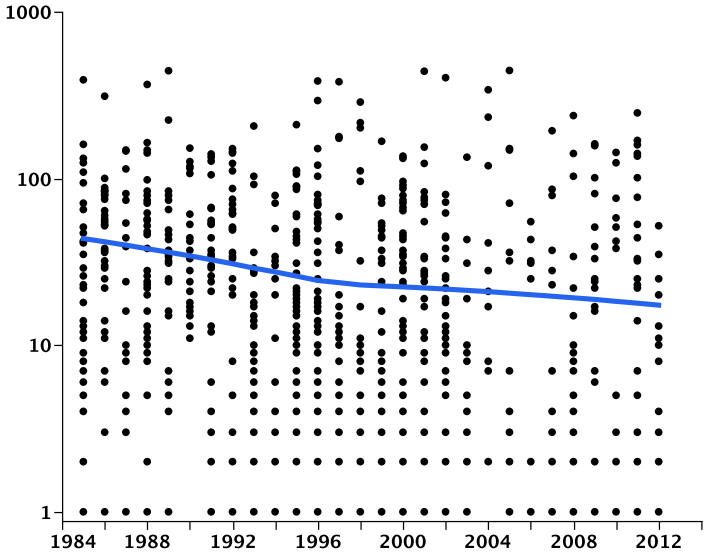


Figure 159a. Seines. Annual Average Stations 4, 6, and 11. White perch (blue) and banded killifish (red).

Long-term trends in mean annual catch rates (Figure 159a) and long-term LOWESS trends (Figures 159b,c) for the two dominant species in seine hauls have exhibited a negative association (r=-0.33) over the course of the survey (Figure 159a). White perch mean catches have declined steadily since the beginning of the survey, while banded killifish numbers have increased since the start of the survey, and experienced a prominent increase since 1999 (Figure 159c).



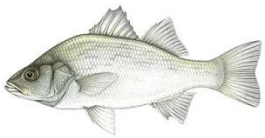


Figure 159b. Seines. Long-term trend in white perch (*Morone americana*). All Stations.

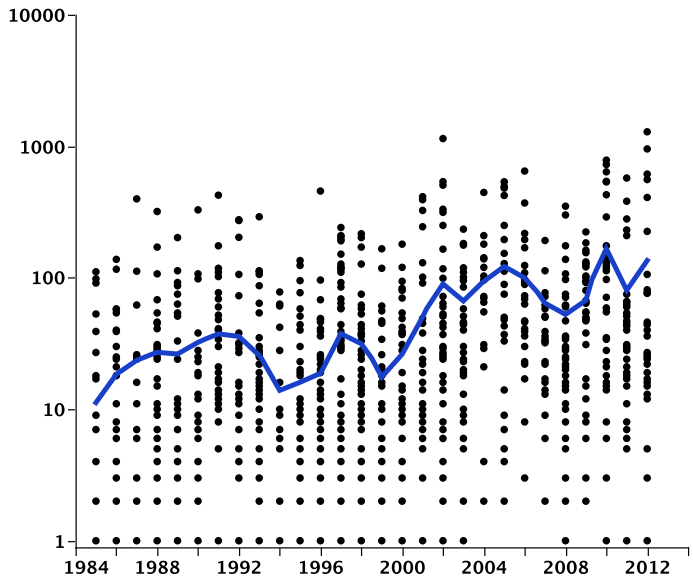


Figure 159c. Seines. Long term trend in banded killifish (*Fundulus diaphanus*). All Stations.

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 160a). Typically, less than 10 of either species were captured in a single sample (Figures 160b,c). Though very variable, long-term trends may indicate a decline in overall catches of alewife and blueback herring. The moratorium on river herring since January 2012 is an indication that a widespread decline in river herring has been observed. If successful, the moratorium (on fishing) may results in an increase in river herring over time in future years. Continued monitoring will be key in determining the success of the moratorium.

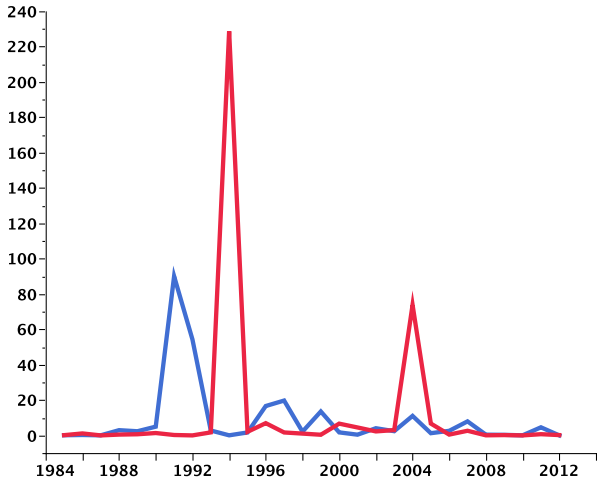


Figure 160a. Seines. Annual Average over 4, 6, and 11 Stations. Blueback herring (blue) and alewife (red).

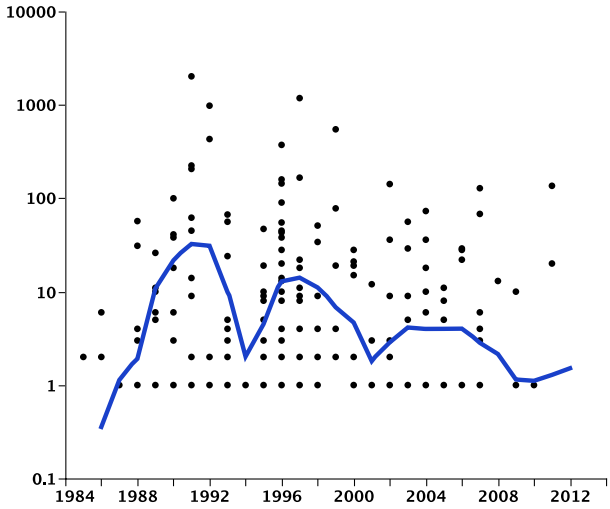


Figure 160b. Seines. Long term trend in blueback herring (*Alosa aestivalis*). All Stations.

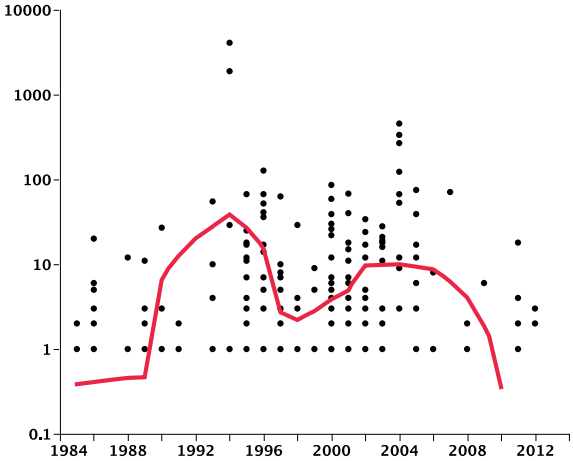


Figure 160c. Seines. Long term trend in alewife (*Alosa pseudoharengus*). All Stations.

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 161a). Although a few high abundance years (1991, 2000, and 2004) have occurred, a general declining trend in catches since 2000 was present (Figure 161c, b). The fyke nets did not capture high proportions of these two species either, so instead of a spatial shift towards SAV beds, an actual decline in abundance of these two species is most likely as part of the species composition changes in the inner cove.

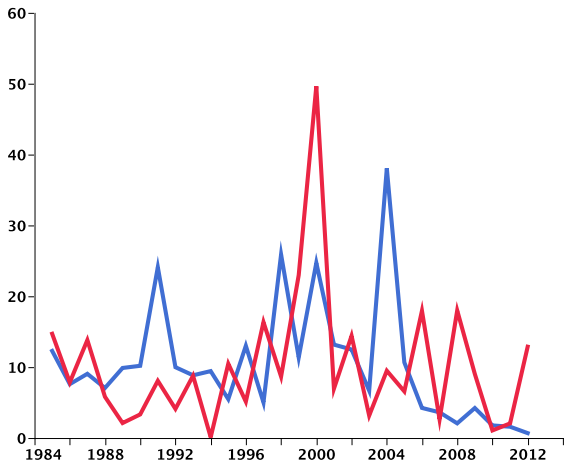
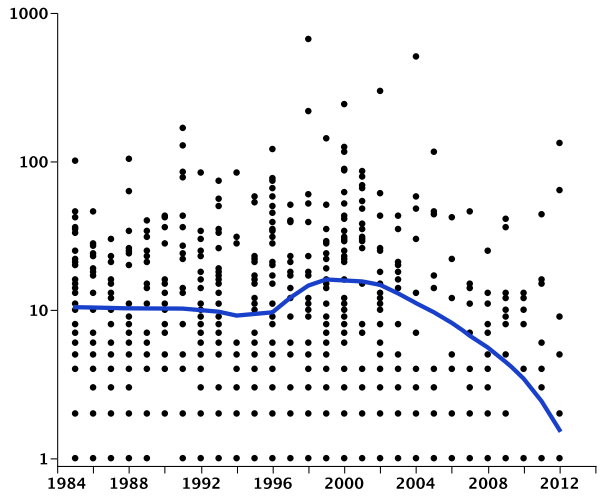


Figure 161a. Seines. Annual Average over 4, 6, and 11 Stations. Spottail Shiner (blue) and Inland Silverside (red).



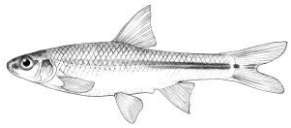
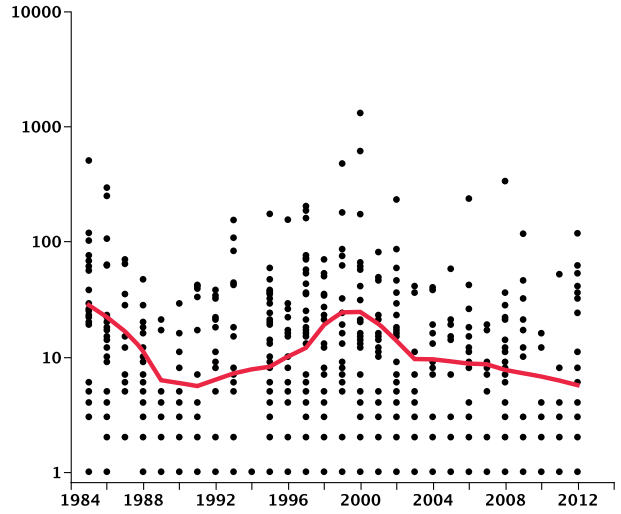


Figure 161b. Seines. Long term trend in spottail shiner (*Notropis hudsonius*). All Stations.



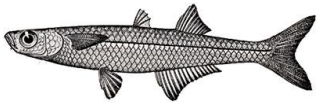


Figure 161c. Seines. Long term trend in inland silverside. (*Menidia beryllina*). All Stations.

Long-term Species Composition Analysis

The species composition and community structure is changing throughout the time of the survey as indicated by trawl and seine catches. The expansion of SAV beds in the inner cove seems to be driving this change. To analyze how community structure is related to SAV habitat we divided the survey years in three groups strictly based on SAV cover: 1984-1992 had no SAV; 1993-2004 had sparse SAV; and 2005-2011 had expansive SAV. Performing an analysis to compare the similarity in nekton community structure between these three time periods (an analysis of similarity in PRIMER; Clarke and Warwick, 2001) revealed that the communities of each of these time periods were significantly different from each other, and the timing of the shifts in community structure was the same as the shift in SAV cover. The community of 1984-1992 was characterized by the dominance of white perch, the community of 1993-2004 distinguished itself by the high abundance of bay anchovy and other open water species, while the community of the latest period is dominated by banded killifish, largemouth bass, and other centrarchids (Figure 162).

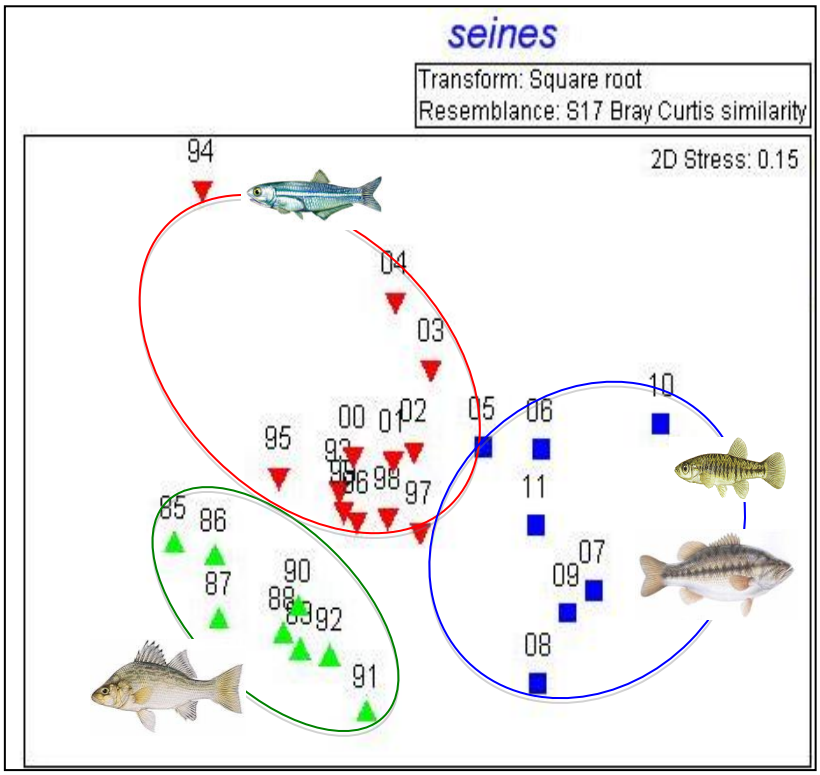


Figure 162. Non-metric Multi-Dimensional Scaling Plot of the fish community structure of seine catches in each year from 1985-2011.

Summary

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 years is providing more favorable conditions for banded killifish, several species of sunfish (bluegill and pumpkinseed) and largemouth bass among other species. Indeed, seine and trawl sampling has indicated a coincident and relative increase in some of these species. The abundance of some species such as white perch are beginning to show a decline. This is likely due to a shift in nekton community structure as a result of the state shift of Gunston Cove to a SAV-dominated system. The shift in fish community structure was clearly linked to the shift in SAV cover with a community structure analysis.

The SAV expansion has called for an addition to the sampling gear used in the survey, since both seines and trawls cannot be deployed where SAV beds are very dense. While drop ring sampling has been successfully used in Gunston Cove in previous years (Krauss and Jones 2011), this was done in an additional study and is too labor-intensive to add to our semi-monthly sampling routine. In 2012, fyke nets were deployed to sample the SAV beds. The fyke nets proved to be an effective tool to sample the fish community within the vegetation. When set for 5 hours, this gear can be included in our sampling routine with minimal extra cost. While fyke-nets do not provide a quantitative assessment of the density of species, it effectively provided a qualitative assessment of the species that reside in the SAV beds. The two fyke nets collected 1500 specimens, while only deployed for part of the season. The fyke nets collected mostly several species of sunfish and banded killifish, which are indeed species know to be associated with SAV. In 2013, fyke nets will be set twice a month in the same locations from May to September. Setting fyke nets both during times when trawls are deployed and when they are not will allow for gear comparison.

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). We saw declines in river herring in our 2012 survey, which is in concordance with other surveys around the Potomac and Chesapeake watersheds. In January 2012, a moratorium on river herring was put in effect to alleviate fishing pressure in an effort to help river herring stocks rebound. The continued monitoring of Gunston Cove since the complete closure of this fishery will help determine if this moratorium results in a recovery of blueback herring and alewife.

G. Submersed Aquatic Vegetation (SAV) Trends: 1994-2012

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 1994-2012 except for 2001 and 2011. Data was not available in 2011 due to severe weather and poor imagery issues. But data availability resumed in 2012 and a plot of SAV vs. Chlorophyll a and Secchi Disk Depth revealed that SAV is maintaining its gains in coverage made in the mid 2000's. Chlorophyll values remained lower and Secchi depth continued to be well above pre-2005 values. These values reflect the sustained partial recovery of Gunston Cove from eutrophication.

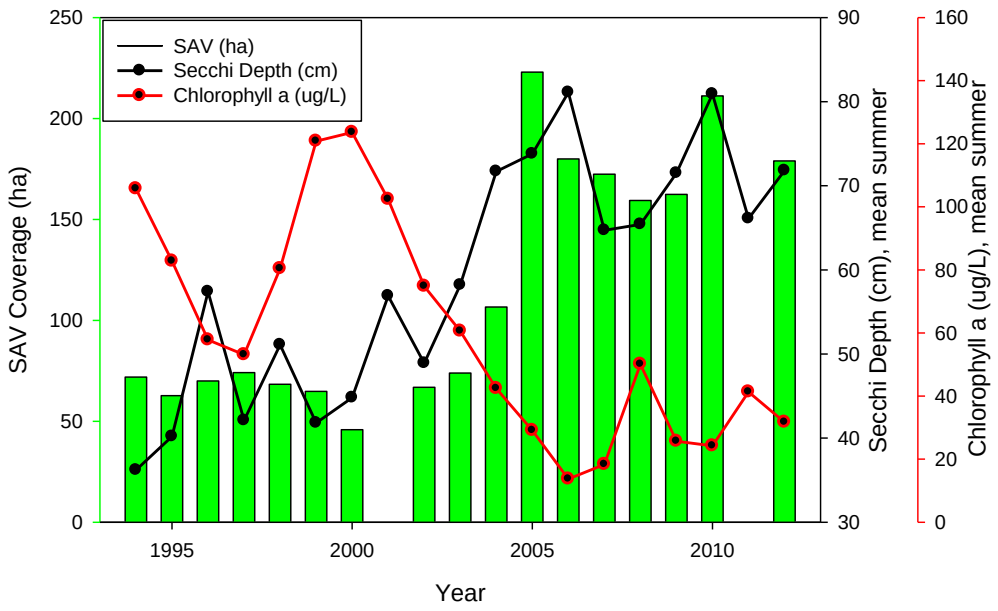


Figure 163. Inner Cove SAV Coverage. Graphed with average summer (June-September) Depth-integrated Chlorophyll a (ug/L) and Secchi Depth (cm) measured at Station 7 in Gunston Cove.

H. Benthic macroinvertebrates

Benthic invertebrates have been monitored in a consistent fashion for the last 4 years. Those data are assembled below (Table 26) and general trends are generally consistent among years. Oligochaetes are the most abundant taxon in the river. In the cove oligochaetes have been dominant in all years except 2012 . Chironomids (midge larvae) are second in abundance in the cove whereas amphipods are second most common in the river. *Corbicula* (the only bivalve common in the area) and gastropods (an assemblage of several snail species) are mostly found in the river. Unionid mussels are a native bivalve group which was more common in 2012 than in previous years. Isopods were found in 2010 and were even more abundant in 2012. A few maylies were found in the river in 2012. Turbellaria (flatworms) and Hirundinea (leeches) are found in low numbers sporadically at both sites.

The observed differences between sites are probably related to sediment characteristics (very fine in cove; coarser in the river). The consistent finding of small numbers of taxa other than chironomids and oligochaetes in the cove is encouraging and could be the result of improved water quality conditions in the cove.

Table 26. Benthic macroinvertebrates: annual averages (#/petite ponar)

Taxon	Station 7 (#/petite ponar)				Station 9 (#/petite ponar)			
	2009	2010	2011	2012	2009	2010	2011	2012
Oligochaeta	72.5	21.1	18.3	72.5	35.9	42.7	51.6	142.3
Amphipoda	1.9	0.7	2.0	1.3	22.8	17.5	30.7	27.1
Chironomidae	16.8	7.0	5.6	121.4	0.9	0.0	1.4	3.7
Corbicula	0.0	0.0	0.2	0.2	27.5	3.2	0.4	8.4
Gastropoda	0.0	0.3	1.3	0.1	13.7	0.0	2.0	3.2
Isopoda	0.0	0.1	0.0	0.0	0.0	1.3	0.0	4.8
Turbellaria	0.0	0.6	0.0	0.0	1.2	0.9	0.0	1.6
Hirundinea	0.0	0.0	0.1	1.8	0.0	0.0	0.0	1.1
Total	91.8	29.7	27.6	198.5	102.8	65.5	86.3	192.4

For 2009-10, n=8 per station; for 2011-12, n=6 per station.

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