DISCUSSION

A. 2011 Data

The year 2011 was characterized by substantially warmer than normal weather with average monthly temperatures from April through August at least 1.5°C above normal. There were 42 days with maximum temperatures above 32.2°C (90°F). Precipitation was well above normal in March and April, but well below normal in May, June, and July. Hurricane Isabel and Tropical Storm Lee passed through the area in late August and early September leaving 45 cm (over 18 in) of rain during a 2 week period. While local precipitation was low in May, enhanced mainstem discharge was observed in both April and May. Mainstem discharge was well below normal in late July and early August.

Water temperature tracked air temperature on a seasonal basis with river temperature warming more slowly than air temperature in the spring. Specific conductance and chloride were greatly reduced at the river site in April and early May due to the large volume of runoff. From May through August conductance and chloride both rose gradually owing to reduced freshwater inflow. In September both declined with the increased runoff from the tropical storms. Indicators of photosynthetic intensity--dissolved oxygen and pH--exhibited a general seasonal increase related to increased algal growth and were consistently higher at the cove station where the shallow depth allowed for more of the water column to support photosynthesis. Water clarity and light penetration were greatly reduced in the river in April owing to strong mainstem discharge, but recovered in May. The two sites had similar indicators of water clarity through the remainder of the year with values being somewhat less clear than in the last few years.

Ammonia nitrogen was quite low in the cove and somewhat higher in the river. Un-ionized ammonia nitrogen was well below toxic levels. Nitrate nitrogen was present at moderate levels at both sites through early June, but declined strongly in June and July remaining low through early September, probably related to algal uptake. This was reinforced by the increase in organic nitrogen in July and August, part of which is algal cells themselves. Total phosphorus was similar at the two sites and generally showed gradual seasonal increase through August followed by a steep decline in the fall. A noteworthy spike in TP in late April in the river was coincident with peaks in total suspended solids and ammonia nitrogen. This spike seems to be related to the high April flows in the river mainstem that was not observed in the local watersheds or the cove. SRP was generally higher in the river and very low in the cove due to greater algal uptake in the cove. An August spike in both TP and SRP was not related to other parameters. N to P ratio gradually declined at both sites approaching N limitation by August. Total suspended solids were generally somewhat higher in the river, while volatile suspended solids were higher in the cove. VSS showed a peak in August at both sites.

Algal populations as measured by chlorophyll *a* remained relatively low at both sites into early June being consistently somewhat higher in the cove. During late June and July chlorophyll levels rose markedly in both areas with river values actually exceeding cove values on many dates. Cove values declined markedly in early September while river values decreased strongly in late September. Phytoplankton cell density data indicated that levels increased markedly in July and further ramped up to very high levels in early August. The two sites exhibited remarkably similar values. Phytoplankton biovolume actually showed two peaks (early July and early August) at both sites. Cell density was dominated by smaller cyanobacterial cells which made up over 90% of total cells on most dates at both sites. *Microcystis* was the overwhelming dominant with *Oscillatoria* and *Anabaena* being consistent secondary taxa. *Melosira* was the strong dominant in cell density among the eukaryotic algae. In terms of biovolume, diatoms were generally the most abundant group with cyanobacteria being important mainly in July and August. Among the cyanobacteria *Oscillatoria*, *Anabaena*, *Raphidiopsis*, and *Microcystis* made the greatest contribution to biovolume. Among the eukaryotic algae *Melosira* was the overwhelming dominant. As these results indicate *Microcystis* was very abundant in late July and early August at both sites. This was part of a larger *Microcystis* bloom that was centered in the river mainstem near Indian Head. At all times, the bloom was actually more pronounced in the river mainstem than in Gunston Cove proper.

As in previous years, rotifers were consistently more abundant in the cove than in the river. A seasonal pattern was apparent at both sites with highest values in the summer. *Brachionus, Keratella,* and *Filinina* were the dominant genera. *Bosmina* was found at high densities in the cove in May, but in the river *Bosmina* reached two peaks in the summer. *Diaphanosoma* showed similar seasonal dynamics at both sites with a very strong peak in early June and a second, smaller peak in August. *Daphnia* had high springtime abundance especially in the cove in May. *Moina*, usually an insignificant taxon, reached high levels in early June in the cove. The predaceous cladoceran *Leptodora* was most common in early June at both sites. Copepod nauplii in the cover reached a strong peak in late May and then declined for the rest of the year. In the river the peak was in early July. *Eurytemora*, a large calanoid copepod, was very abundant in the cove in May, while in the river the peak was even higher, but delayed until early June. Cyclopoid copepods were present at very low levels in the cove, but attained higher levels in the summer in the river culminating in a very strong peak in mid August.

In 2011 ichthyoplankton was dominated by *Dorosoma* sp. (gizzard shad) and, to a lesser extent, alosids (herring and shad). Members of the genus *Morone* (white perch or striped bass) were significant as well. Other taxa were found in very low numbers, which makes 2011 less diverse than 2010.

In trawls, the overwhelming majority of the fish collected were represented by 2 taxa: white perch (*Morone Americana*) and spottail shiner (*Notropis hudsonius*). Other numerically abundant species included: sunfish (*Lepomis* sp.), blue catfish (*Ictalurus furcatus*), and channel catfish (*Ictalurus punctatus*). 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 early summer and in fall, and mainly in the river. Unlike 2010, *Alosa* sp. were not among the most abundant species in trawl collections.

In seines, the most abundant species by far was banded killifish (*Fundulus diaphonus*), followed by white perch. 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 and white perch were collected at all stations and throughout the year. The abundance peak of banded killifish was in June, while white perch had higher abundances in July and August. It will be interesting to investigate whether the abundance of banded killifish is indeed reduced in July and August, or whether they are more successful at finding refuge within the SAV beds, which have expanded in July and August. The inclusion of fyke nets in the sampling regime next season, which will be set up to sample the SAV beds, will make this study possible. The list of other species that occurred at high abundances (quillback, bluegill, blueback herring, gizzard shad, spottail shiner, mummichog, striped bass and tessellated darter) is also different than what was abundant in trawls. This indicates that different species use different habitats, and emphasizes the importance of sampling with different gear types to obtain a representative sample of the nekton community present at Gunston Cove.

Ponar samples indicated that as in most years oligochaetes were the most common invertebrates in the benthos and were found at about twice the density at Station 9 than at Station 7. In the cove diptera (chironomid/midge) larvae made up the bulk of the remaining organisms although they were present in lower numbers than in most years. A handful of amphipods were found in some of the cove samples. In the river, amphipods (crustaceans commonly known as scuds) were found in moderate numbers. *Corbicula* (Asiatic clam) was absent from the cove and rarer in the river than in recent years.. Diptera were rare in the river and *Corbicula* were absent in the cove.

B. Water Quality Trends: 1983-2011

To assess long-term trends in water quality, data from 1983 to 2011 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 11 and 12). This was similar to the analysis performed in previous reports.

Table 11
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1984-2011
GMU Water Quality Data
June-September

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Temperature	0.207	0.074	<0.001	0.125	0.040	0.064*
Conductivity, standardized to 25°C	0.194	3.02	0.002	0.030	----	NS
Dissolved oxygen, mg/L	0.023	----	NS	0.205	0.033	0.002
Dissolved oxygen, percent saturation	0.096	----	NS	0.227	0.462	<0.001
Secchi disk depth	0.689	1.55	<0.001	0.297	0.533	<0.001
Light extinction coefficient	0.611	0.104	<0.001	0.062	----	NS
pH, Field	-0.066	----	NS	0.212	0.013	0.005
Chlorophyll, depth-integrated	-0.511	-3.98	<0.001	-0.127	-0.429	0.067*
Chlorophyll, surface	-0.516	-4.23	<0.001	-0.128	-0.510	0.057*

*marginal significance
For Station 7, n=251-270 except pH, Field where n=204 and Light extinction coefficient where n=190.
For Station 9, n=209-223 except pH, Field where n=171 and Light extinction coefficient where n=158.

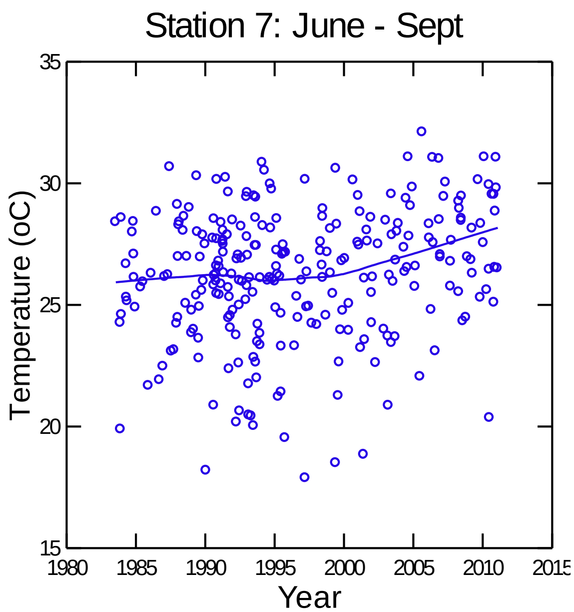
Significance column indicates the probability that a correlation coefficient this large could be due to chance alone. If this probability is greater than 0.05, then NS (not significant) is indicated.

Table 12
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1983-2011
Fairfax County Environmental Laboratory Data
June-September

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Chloride	+0.011	----	NS	+0.014	----	NS
Lab pH	-0.331	-0.026	<0.001	-0.245	-0.015	<0.001
Alkalinity	-0.072	----	NS	+0.183	0.289	<0.001
BOD	-0.603	-0.185	<0.001	-0.446	-0.058	<0.001
Total Suspended Solids	-0.283	-0.941	<0.001	-0.062	----	NS
Volatile Suspended Solids	-0.369	-0.720	<0.001	-0.310	-0.139	<0.001
Total Phosphorus	-0.488	-0.004	<0.001	-0.140	-0.0005	0.005
Soluble Reactive Phosphorus	-0.035	----	NS	0.172	0.0004	<0.001
Ammonia Nitrogen	-0.255	-0.018	<0.001	-0.256	-0.003	<0.001
Un-ionized Ammonia Nitrogen	-0.284	-0.005	<0.001	-0.318	-0.0004	<0.001
Nitrite Nitrogen	-0.361	-0.003	<0.001	-0.254	-0.002	<0.001
Nitrate Nitrogen	-0.504	-0.035	<0.001	-0.612	-0.044	<0.001
Organic Nitrogen	-0.493	-0.049	<0.001	-0.247	-0.010	<0.001
N to P Ratio	-0.259	-0.348	<0.001	-0.568	-0.744	<0.001

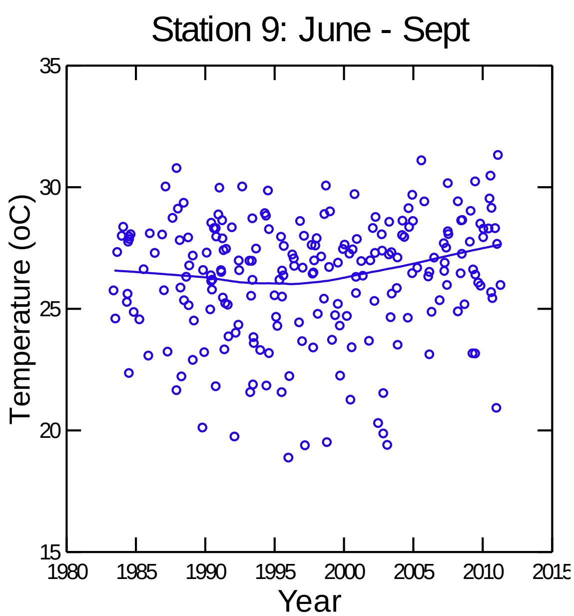
For Station 7, n=364-407 except Nitrite Nitrogen where n=329 and Chlorophyll a where n=141.
For Station 9, n=364-414 except Nitrite Nitrogen where n=328 and Chlorophyll a where n=141.

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.



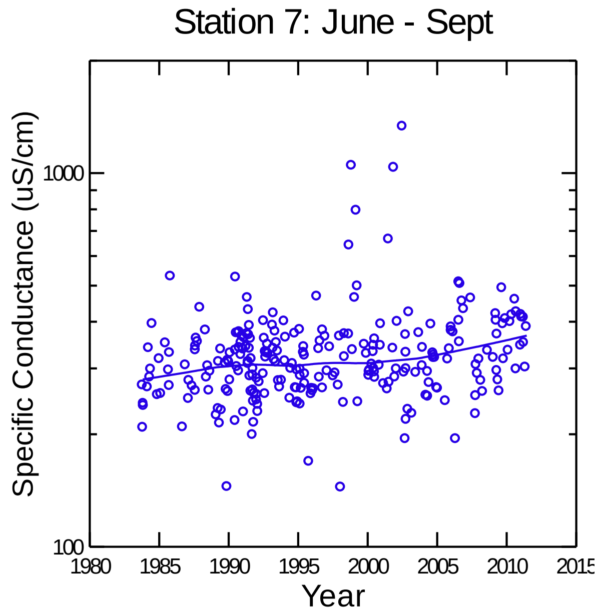
Water temperatures during the summer months generally varied between 20 and 30°C over the study period (Figure 63). The LOWESS curve indicated an average of about 26°C during the period 1984-2000 with a distinct upward trend in the last few years approaching 28ºC. Linear regression analysis indicated a significant linear trend in water temperature in the cove when the entire period of record is considered (Table 11). The slope of this relationship is 0.07°C/year.

Figure 63. Long term trend in Water Temperature (GMU Field Data). Station 7. Gunston Cove.



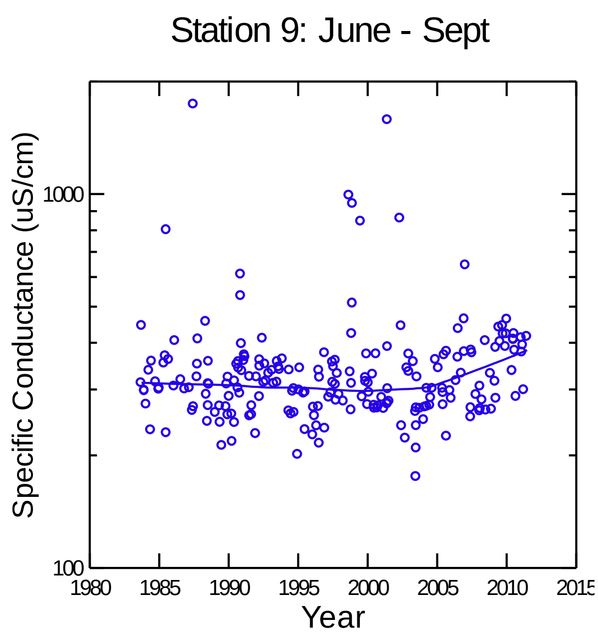
In the river summer temperatures have been slightly cooler than in the cove (Figure 64). The trend line again started out at about 26°C, but has increased less strongly. There appear to be somewhat fewer readings above 30° C in the river. Linear regression over the study period was marginally significant (Table 11).

Figure 64. Long term trend in Water Temperature (GMU Field Data). Station 9. Gunston Cove.



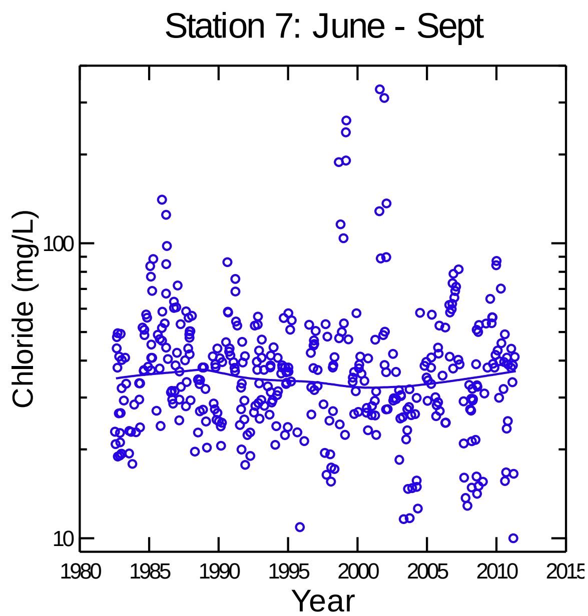
Specific conductance was generally in the range 200-500 µS/cm over the study period (Figure 65). Some significantly higher readings have been observed sporadically. A slight increase in specific conductance was suggested by the LOWESS line over the study period. This was confirmed by linear regression analysis which found a significant linear increase of 3.0 uS/cm per year over the long term study period (Table 11). The results for 2011 were centered around the trend line.

Figure 65. Long term trend in Specific Conductance (GMU Field Data). Station 7. Gunston Cove.



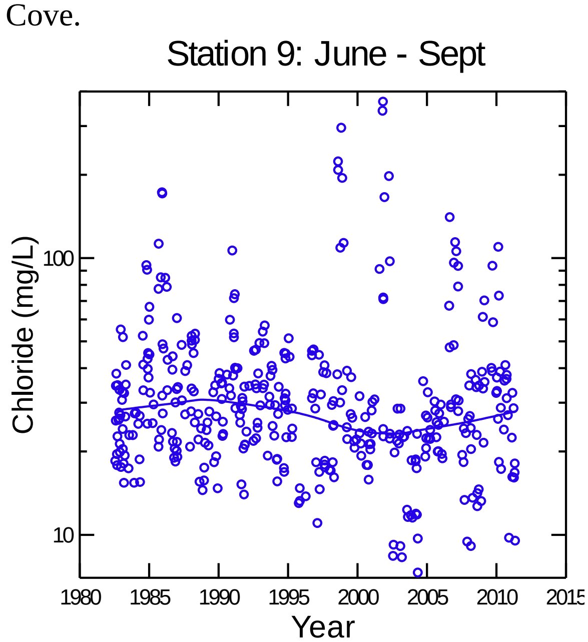
Conductivity values in the river were in the same general range as in the cove (Figure 66). Most values were between 200 and 500 uS/cm with a few much higher values. These higher values are probably attributable to intrusions of brackish water from downstream during years of low river flow. Linear regression did not reveal a significant trend in river conductivity (Table 11). However, the trend line has moved up in recent years from about 300 uS/cm to nearly 400 uS/cm. The 2011 results were generally above the long term trend line.

Figure 66. Long term trend in Specific Conductance (GMU Field Data). Station 9. River mainstem.



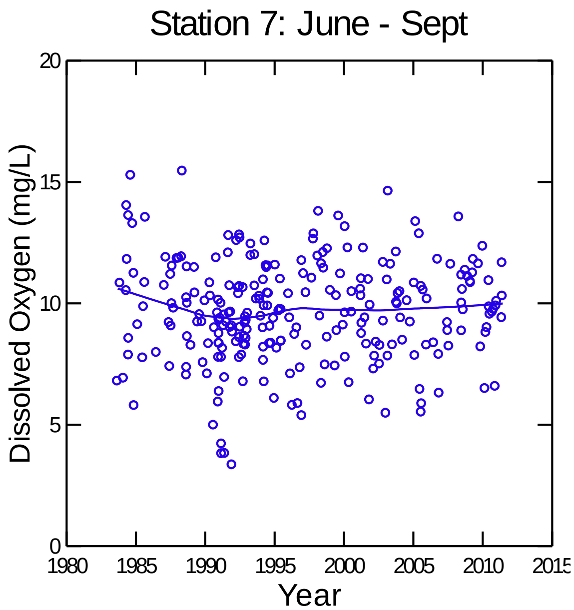
Chloride levels were clustered in a relatively narrow range of 20-60 mg/L for the entire study period (Figure 67). Higher values observed in some years were probably due to the estuarine water intrusions that occur in dry years. The trend is nearly flat and a linear regression was not statistically significant (Table 12). 2010 levels were above the trend line.

Figure 67. Long term trend in Chloride (Fairfax County Lab Data). Station 7. Gunston Cove.



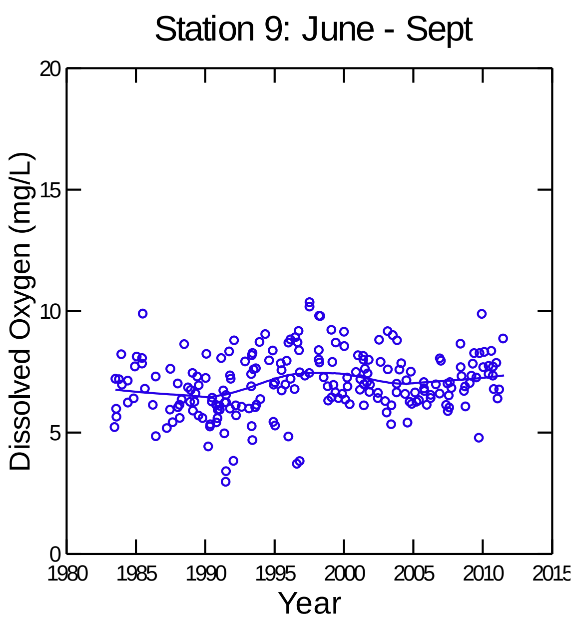
Chloride in the river has been slightly more variable than that in the cove, but in the same general range (Figure 68). The higher readings are again due to brackish water intrusions in dry years. A slight trend of increasing values in the 1980's followed by decreases in the 1990's and leveling in the 2000's was suggested by the LOWESS trend line. However, temporal regression analysis was not statistically significant (Table 12). The 2011 values clustered around the trend line with a few lower readings.

Figure 68. Long term trend in Chloride (Fairfax County Lab Data). Station 9. River mainstem.



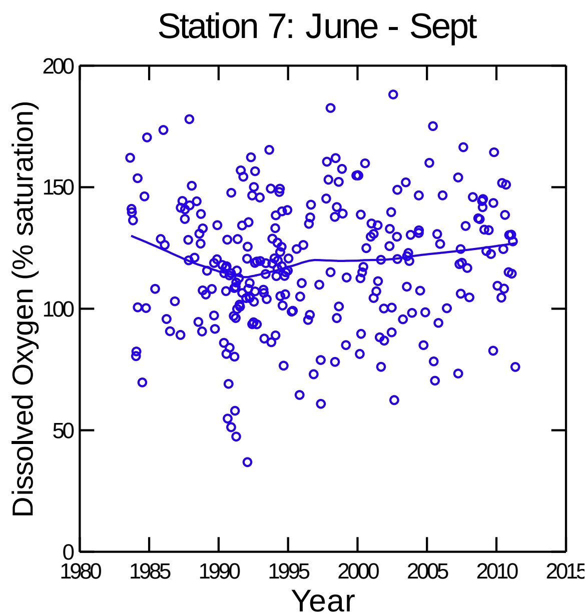
Dissolved oxygen in the cove has generally been in the range 7-12 mg/L during the summer months (Figure 69). A slight downward trend was observed through 1990, but since then the trend line has flattened, suggesting little consistent change and a mean of about 10 mg/L. In the cove dissolved oxygen (mg/L) did not exhibit a significant linear trend over the long term study period (Table 11).

Figure 69. Long term trend in Dissolved Oxygen, mg/L (GMU Data). Station 7. Gunston Cove.



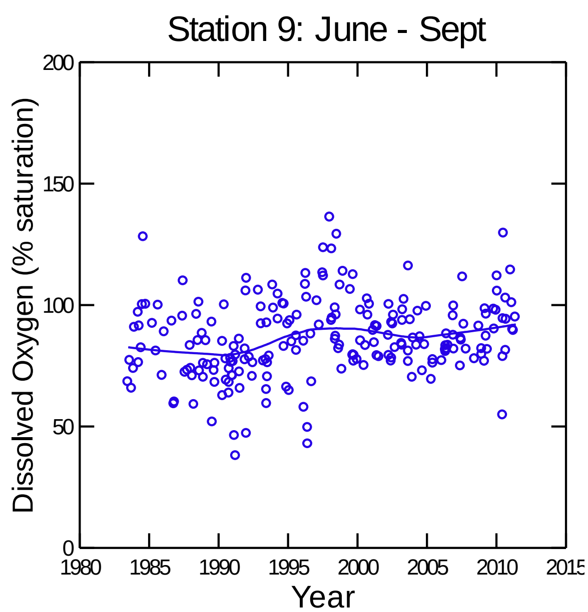
In the river dissolved oxygen values generally were in the range 5-9 mg/L over the long term study period (Figure 70). The LOWESS trend line suggested a decline in the 1980's, an increase in the early to mid 1990's and a decline in the 2000's. The linear regression analysis over the entire period indicated a significant positive trend with slope of 0.033 mg/L per year (Table 11). This implies an increase of 0.9 mg/L over the study period. 2011 readings were centered around the long term trend line.

Figure 70. Long term trend in Dissolved Oxygen, mg/L (GMU Data). Station 9. River mainstem.



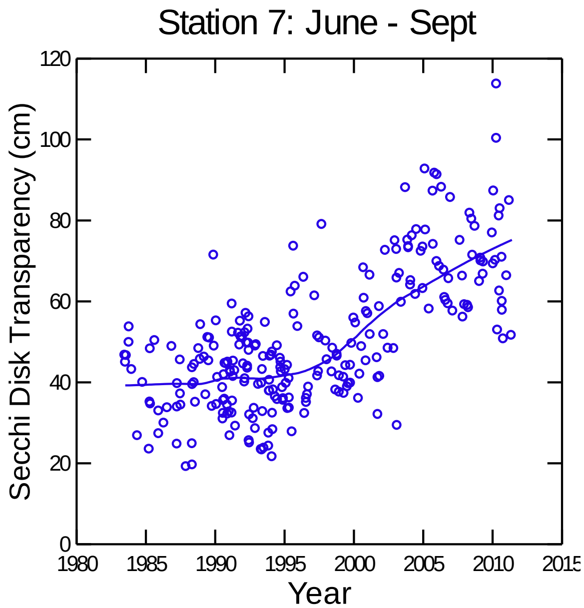
Dissolved oxygen was generally in the range 100-150% saturation in the cove over the long term study period indicating the importance of photosynthesis in the cove (Figure 71). A decline was indicated by the trend line through 1990 followed by a slight recovery in subsequent years. Percent saturation DO did not exhibit a significant linear trend over the long term study period (Table 11).

Figure 71. Long term trend in Dissolved Oxygen, % saturation (GMU Data). Station 7. Gunston Cove.



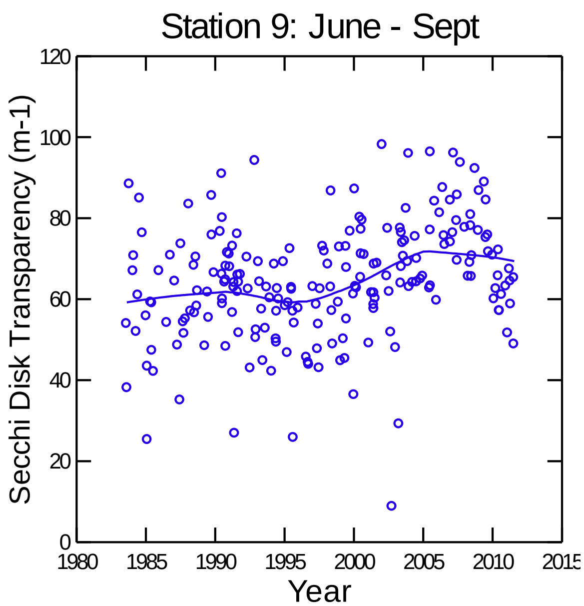
In the river dissolved oxygen was generally less than 100% indicating that photosynthesis was much less important in the river than in the cove (Figure 72). The temporal pattern showed a slight decline in the 1980's, an increase in the 1990's, and a subsequent slight decline in the 2000's. In the river a significant linear increase was indicated by regression analysis with a slope of 0.46% per year yielding about 13% increase over the study period (Table 11). 2011 readings were clearly above the long term trend line.

Figure 72. Long term trend in Dissolved Oxygen, % saturation (GMU Data). Station 9. Gunston Cove.



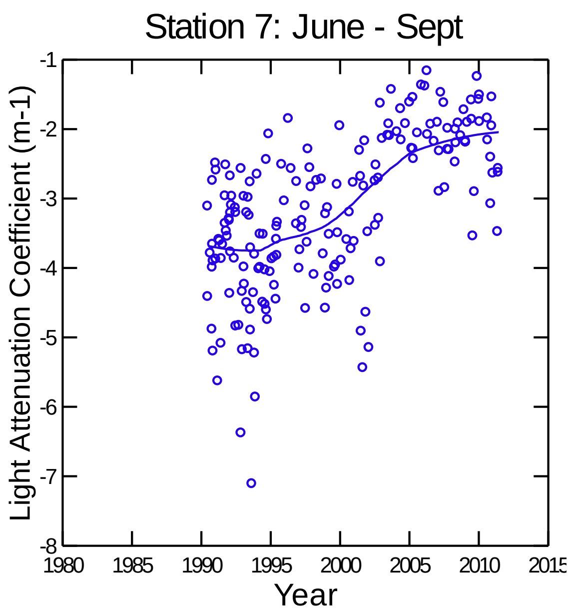
Secchi disk transparency is a measure of water clarity. Secchi disk was fairly constant from 1984 through 1995 with the trend line at about 40 cm (Figure 73). Since 1995 there has been a steady increase in the trend line from 40 cm to nearly 80 cm in 2011. Linear regression was highly significant with a predicted increase of 1.55 cm per year or a total of 43 cm over the study period (Table 11). In 2011 most readings were somewhat below the trend line.

Figure 73. Long term trend in Secchi Disk Transparency (GMU Data). Station 7. Gunston Cove.



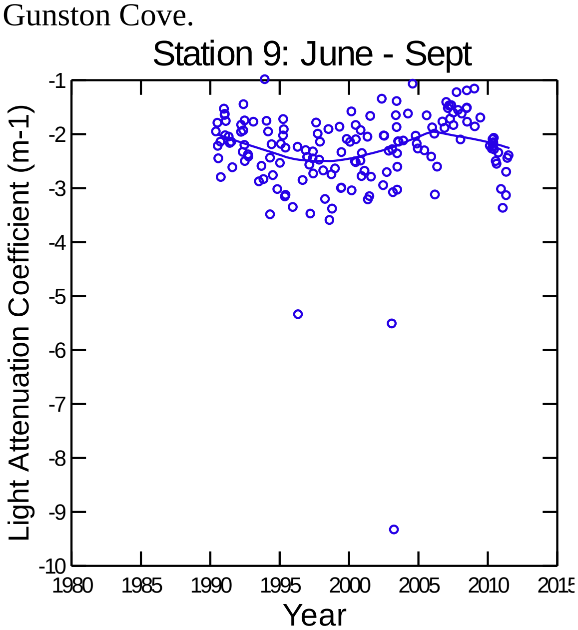
In the river Secchi depth was somewhat greater than in the cove initially (Figure 74). The trend line rose from 55 cm in 1984 to 62 cm in 1991. This was followed by a decline to about 58 cm in 1996 and then a steady increase to the 2006 level of about 80 cm. Most recently Secchi in the river has declined again. Linear regression revealed a significant increase of 0.53 cm per year with total increase of 15 cm predicted over of the study period (Table 11). 2010 and 2011 data were markedly below the trend line.

Figure 74. Long term trend in Secchi Disk Transparency (GMU Data). Station 9. River mainstem.



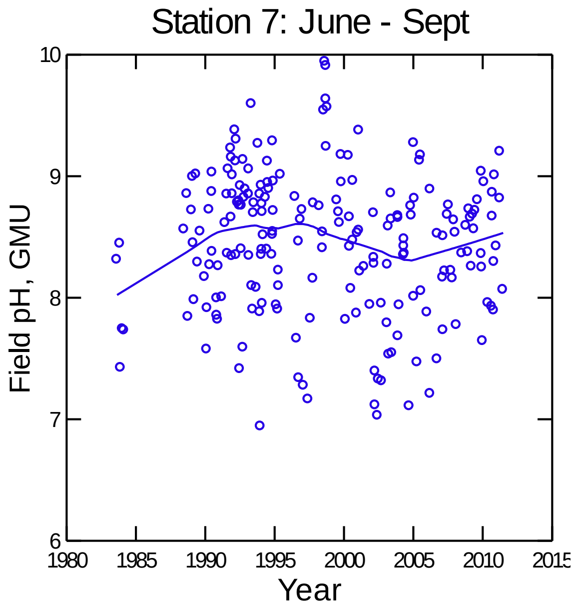
Light attenuation coefficient, another measure of water clarity, reinforces the conclusion that water clarity has been improving in the cove since 1995 (Figure 75). Trend line for the coefficient rose from about -4 to less than -2 m^{-1} during this time. Consistent with this was the regression analysis which revealed a significant linear increase in light attenuation coefficient over the period 1991-2011 with a slope of 0.1 per year yielding a prediction that light attenuation improved by about 2 units over this period (Table 11).

Figure 75. Long term trend in Light Attenuation Coefficient (GMU Data). Station 7. Gunston Cove.



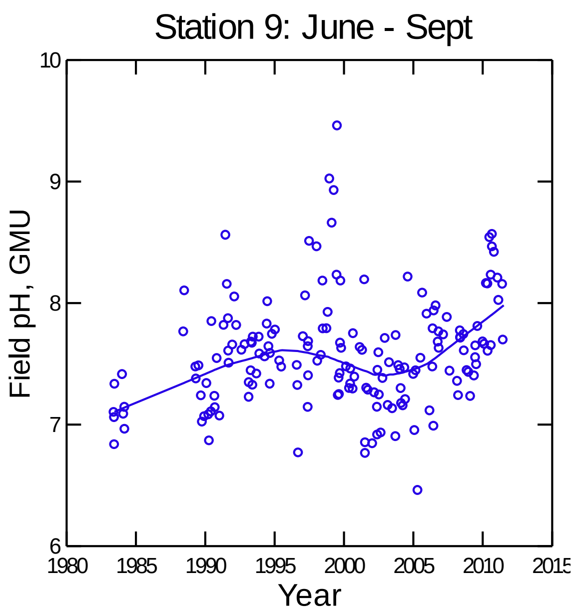
In the river light attenuation coefficient suggested a decline in light transparency between 1991 and 1997 followed by an increase through about 2008 (Figure 76). In recent years light transparency has decreased again in the river. Regression did not reveal a significant linear trend over the entire period (Table 11).

Figure 76. Long term trend in Light Attenuation Coefficient (GMU Data). Station 9. River mainstem.



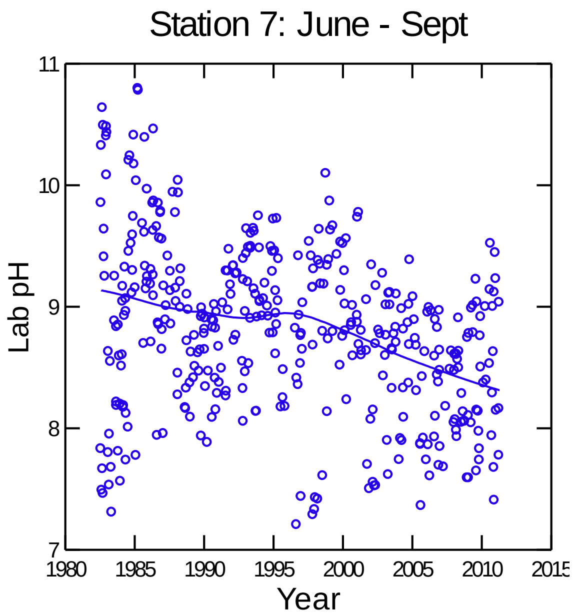
Field pH has not been measured as consistently over the entire study period as other parameters. There is little evidence for a consistent trend over the measurement period (Figure 77). Linear regression analysis did not provide evidence of a linear trend when the entire study period was (Table 11).

Figure 77. Long term trend in Field pH (GMU Data). Station 7. Gunston Cove.



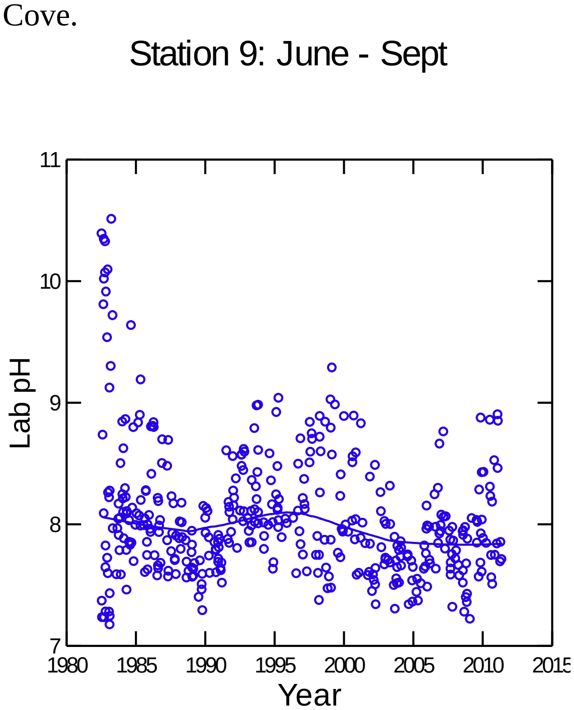
In the river a similar pattern has been observed over this period (Figure 78). pH in the river has been consistently lower by about 1 pH unit than in the cove. A gradual increase from 7.2 in 1989 to 7.7 in 1998 was followed by a decline to about 7.4. In recent years pH has again increased markedly with the trend line rising to 8.0. When all years were considered, field pH in the river shows a significant increase at a rate of 0.01 units per year (Table 11).

Figure 78. Long term trend in Field pH (GMU Data). Station 9. River mainstem.



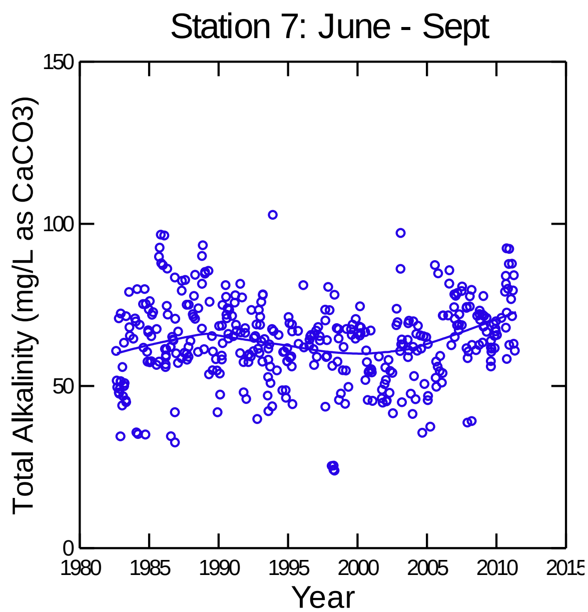
Lab pH as measured by Fairfax County personnel were generally in the range 7.5 to 9.5 over the long term study period (Figure 79). Since about 1996 a decline is very evident with the trend line decreasing from about 9 to about 8.2. Linear regression indicated a significant decline in lab pH over the study period at a rate of about 0.026 pH units per year or a total of 0.76 units over the study period (Table 12).

Figure 79. Long term trend in Lab pH (Fairfax County Lab Data). Station 7. Gunston Cove.



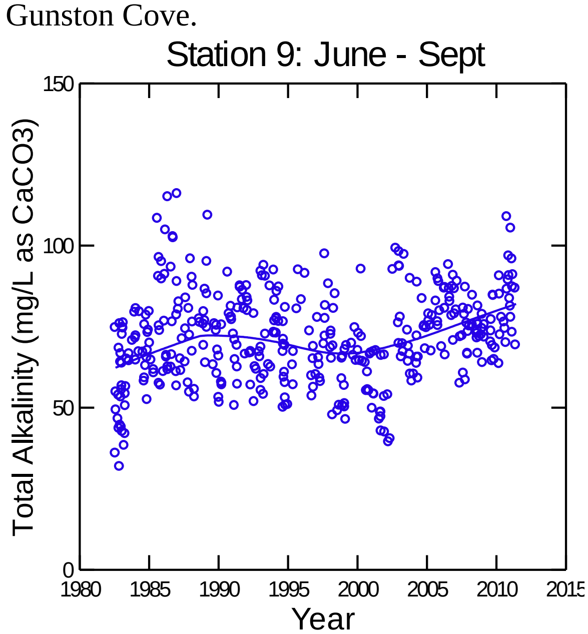
In the river, long term pH trends as measured by Fairfax County lab personnel indicate that most values fell between 7 and 9 (Figure 80). The trend line has increased and decreased slightly over the years with data since 1998 showing a slight decline. However, values have generally been above the trend line for the past 2-3 years. pH in the river showed a significant linear decline with a rate of 0.013 per year yielding a total decline of 0.38 units over the long term study period (Table 12).

Figure 80. Long term trend in Lab pH (Fairfax County Lab Data). Station 9. Potomac mainstem.



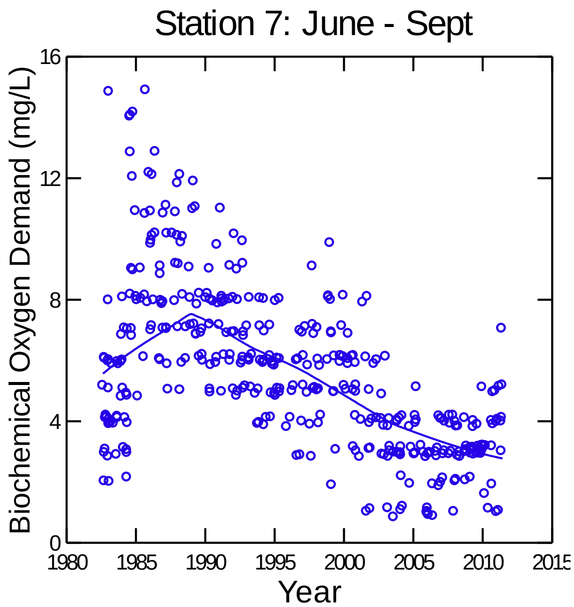
Total alkalinity as measured by Fairfax County personnel exhibited a rise from 1983 to 1990, a slow decline during the 1990's and a slow increase in the 2000's (Figure 81). The trend line at 2011 was slightly higher than it was in 1983. Overall, there has not been a statistically significant linear trend in total alkalinity in the cove over this period (Table 12).

Figure 81. Long term trend in Total Alkalinity (Fairfax County Lab Data). Station 7. Gunston Cove.



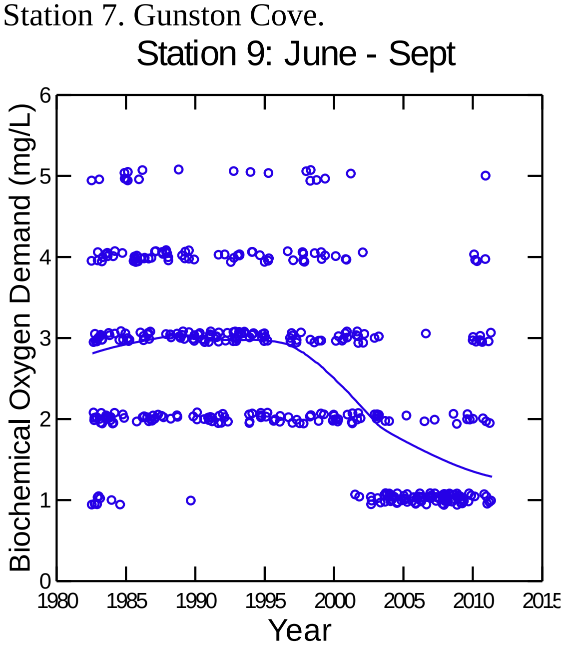
In the river a similar pattern has been observed over the three decadal intervals (Figure 82). However, there is a slightly significant linear trend over the period with a slope of 0.29 mg/L suggesting a modest increase of about 8 mg/L over the entire study period (Table 12).

Figure 82. Long term trend in Total Alkalinity (Fairfax County Lab Data). Station 9. Potomac mainstem.



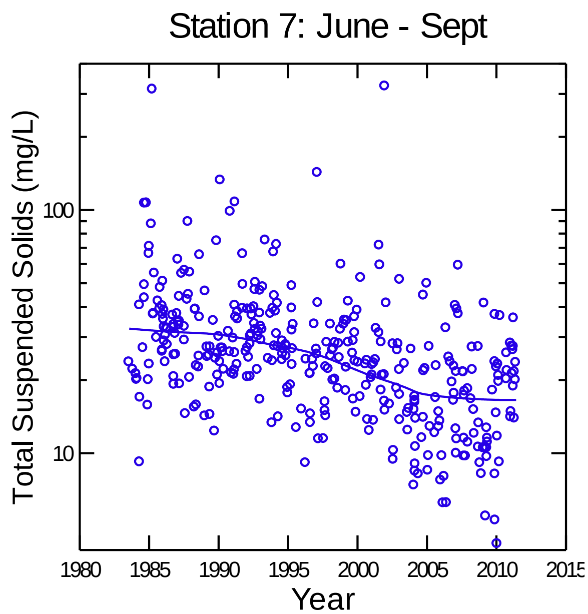
Biochemical oxygen demand has shown a distinct pattern over the long term study period in Gunston Cove (Figure 83). In the 1980's the trend line rose from about 5 mg/L to 8 mg/L by 1989. Since then there has been a steady decline such that the trend line has dropped back to about 2 mg/L. Recently, values of 5 or above have become more common. BOD has shown a significant linear decline over the entire study period at a rate of 0.19 mg/L per year yielding a net decline of about 5 mg/L over the entire period of record (Table 12).

Figure 83. Long term trend in Biochemical Oxygen Demand (Fairfax County Lab Data). Station 7. Gunston Cove.



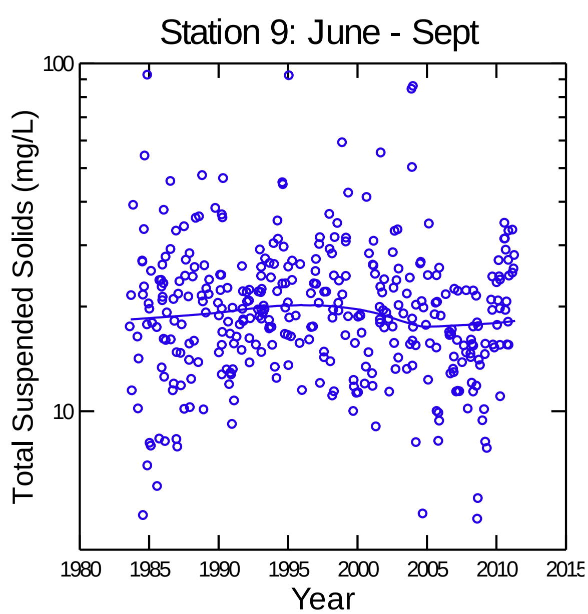
In the river biochemical oxygen demand exhibited a less distinct pattern through the mid 1990's (Figure 84). However, since that time it has decreased steadily to a median value of 1 mg/L. BOD in the river has exhibited a significant linear decrease at a rate of 0.06 units when the entire period of record was considered (Table 12). Recently, there has been a recurrence of BOD of 2 or greater.

Figure 84. Long term trend in Biochemical Oxygen Demand (Fairfax County Lab Data). Station 9. Potomac mainstem.



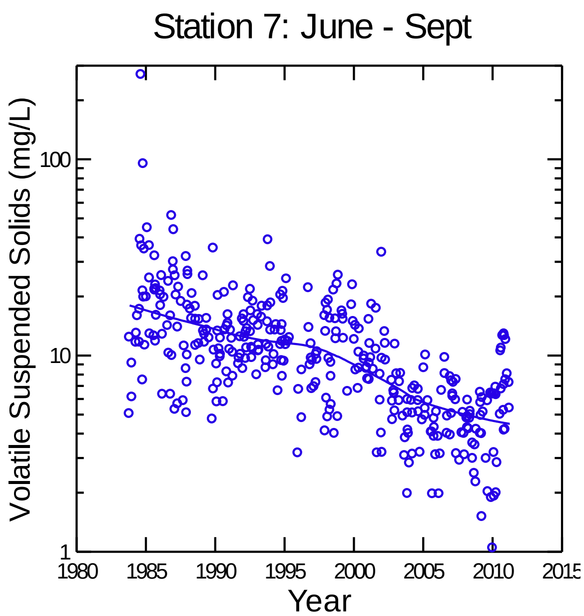
Total suspended solids (TSS) has shown a great deal of variability over the long term study period. Nonetheless, a decreasing trend has been detected in TSS in the cove with the trend line decreasing from about 30 mg/L in 1983 to about 15 mg/L in 2011 (Figure 85). Linear regression was significant indicating a decline of 0.9 mg/L per year yielding a total decline of 25 mg/L since 1984 (Table 12).

Figure 85. Long term trend in Total Suspended Solids (Fairfax County Lab Data). Station 7. Gunston Cove.



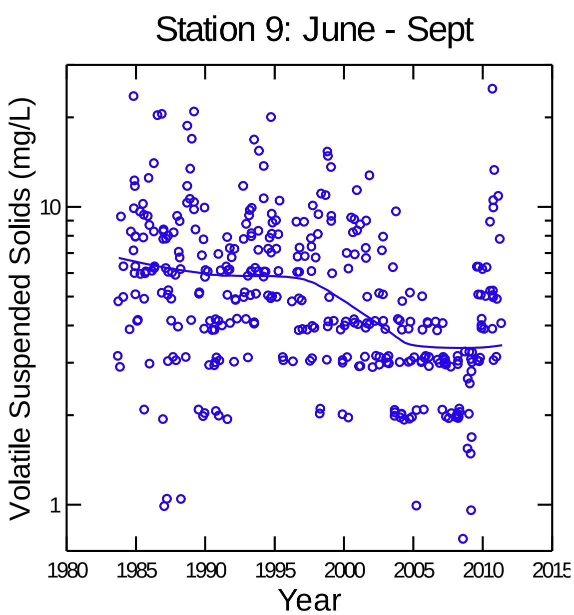
In the river TSS trends have not been as apparent (Figure 86). While much higher values have been observed sporadically, the LOWESS line remained steady at about 20 mg/L through 2000. Since then a slight decline is suggested. In the river TSS did not exhibit a significant linear trend over the period of record (Table 12). Most readings in 2010 and 2011 were above the trend line.

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



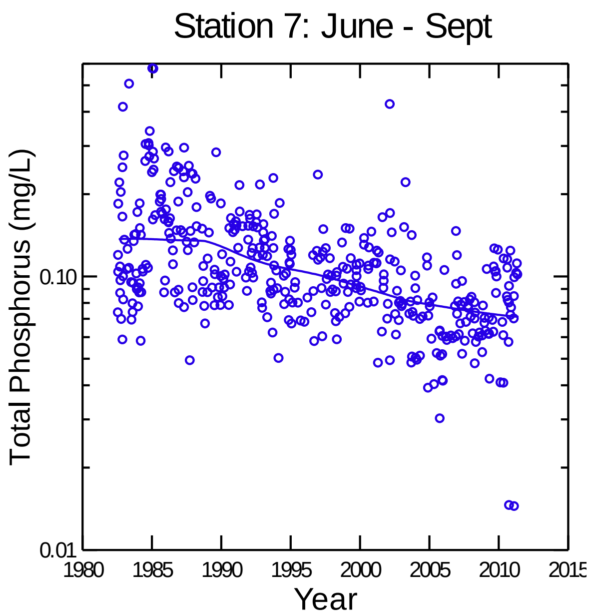
Volatile suspended solids have consistently declined over the study period, although there is evidence of an increase in the last 2-3 years (Figure 87). The LOWESS trend line has declined from 20 mg/L in 1984 to 5 mg/L in 2011. VSS has demonstrated a significant linear decline at a rate of 0.72 mg/L per year or a total of 20 mg/L over the study period (Table 12).

Figure 87. Long term trend in Volatile Suspended Solids (Fairfax County Lab Data). Station 7. Gunston Cove.



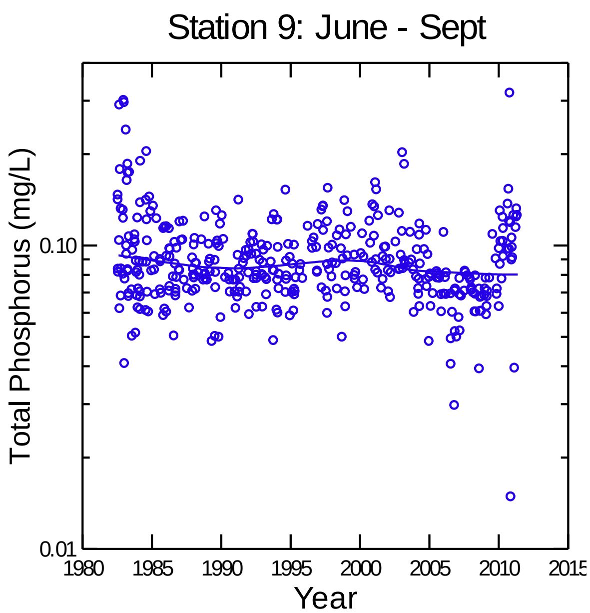
In the river the trend line for volatile suspended solids (VSS) was steady from 1984 through the mid 1990's, but has decreased consistently since then. Trend line values of about 7 mg/L in 1984 dropped to about 3 mg/L by 2005 (Figure 88). In the last 2-3 years, VSS has been higher. VSS in the river demonstrated a significant linear decline at a rate of 0.14 mg/L per year or 4 mg/L since 1984 (Table 12). Note that almost all VSS readings in 2011 were above the trend line.

Figure 88. Long term trend in Volatile Suspended Solids (Fairfax County Lab Data). Station 9. Potomac mainstem.



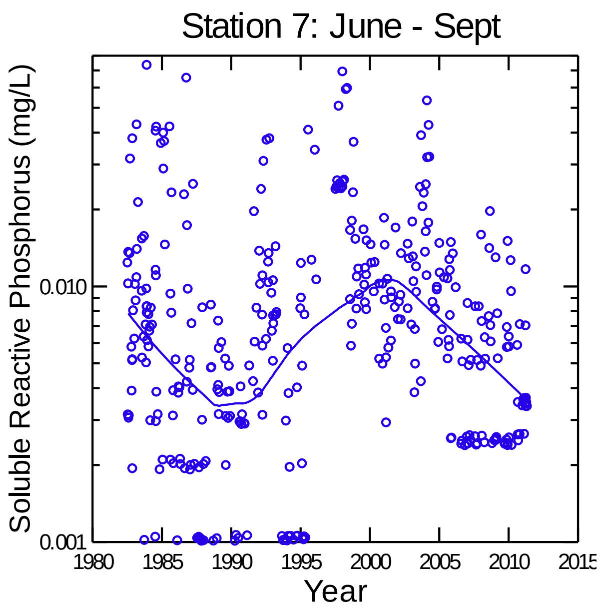
In the cove, total phosphorus (TP) has undergone a consistent steady decline since the late 1980's in the cove (Figure 89). By 2011 the trend line had dropped to 0.07 mg/L. However, in 2010 and 2011, values were generally elevated above the trend line. Linear regression over the entire period of record indicated a significant linear decline of 0.004 mg/L per year or 0.1 mg/L over the entire study period (Table 12).

Figure 89. Long term trend in Total Phosphorus (Fairfax County Lab Data). Station 7. Gunston Cove.



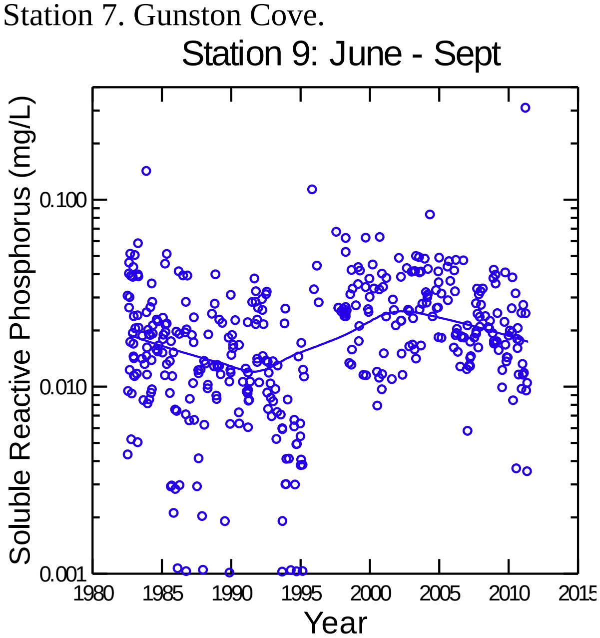
Total phosphorus (TP) values in the river have shown less of a trend over time (Figure 90). Values were steady through about 2000, then declined and have recently shown in increase. TP exhibited a slight, but significant linear decrease in the river over the long term study period with a very modest slope of 0.0005 mg/L per year (Table 12).

Figure 90. Long term trend in Total Phosphorus (Fairfax County Lab Data). Station 9. Potomac mainstem.



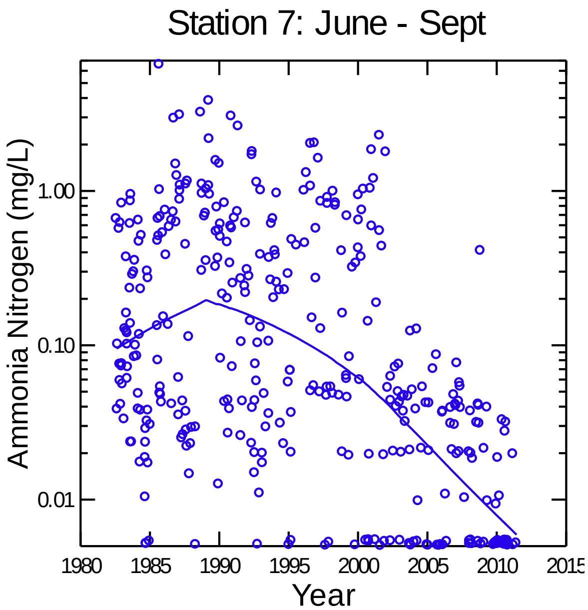
Soluble reactive phosphorus (SRP) declined in the cove during the first few years of the long term data set, but demonstrated an increase to near its initial level by 2000 (Figure 91). Since then a decline has ensued. The pattern through 2000 was consistent with the concept that SRP is negatively correlated 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 12). One possibility is that less SRP is entering the cove water; another is that increased SAV is taking more up.

Figure 91. Long term trend in Soluble Reactive Phosphorus (Fairfax County Lab Data). Station 7. Gunston Cove.



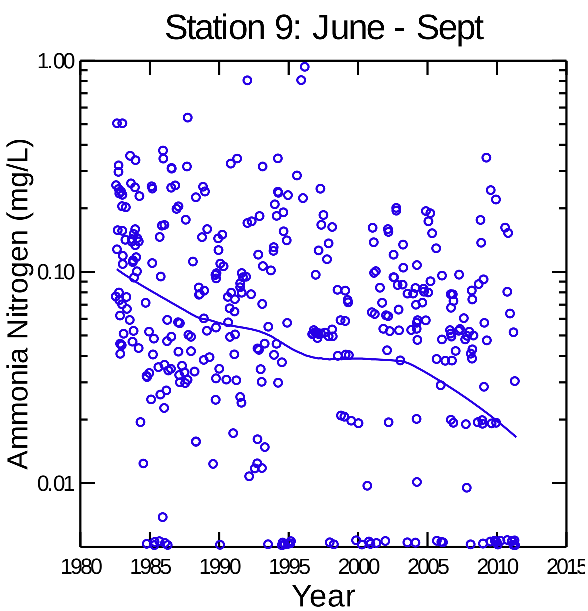
Soluble reactive phosphorus (SRP) in the river has generally been present at higher levels than in the cove, but has undergone a similar decline and resurgence (Figure 92). By 2011 the trend line in the river was at 0.02 mg/L compared to less than 0.01 mg/L in the cove. Again, this may reflect less demand for P in the river; algae in the river may be more light-limited. Values in the river in 2011 were similar to those in the early 1980’s. In the river SRP showed a positive linear trend over the study period (Table 12).

Figure 92. Long term trend in Soluble Reactive Phosphorus (Fairfax County Lab Data). Station 9. Potomac mainstem.



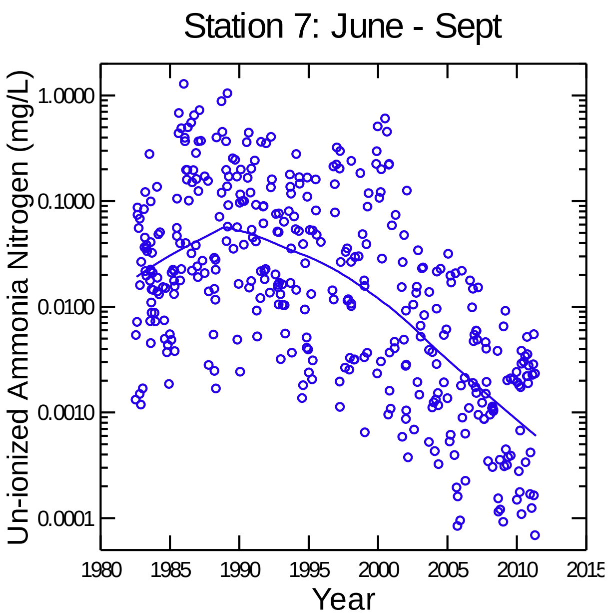
Ammonia nitrogen levels were very variable over the long term study period in the cove, but a trend of decreasing values is evident from the LOWESS trend line (Figure 93). Since 1989 the trend line has decreased from about 0.2 mg/L to less 0.01 mg/L. Linear regression has revealed a significant decline over the entire period of record with a rate of 0.018 mg/L per year yielding a total decline of 0.52 mg/L (Table 12).

Figure 93. Long term trend in Ammonia Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



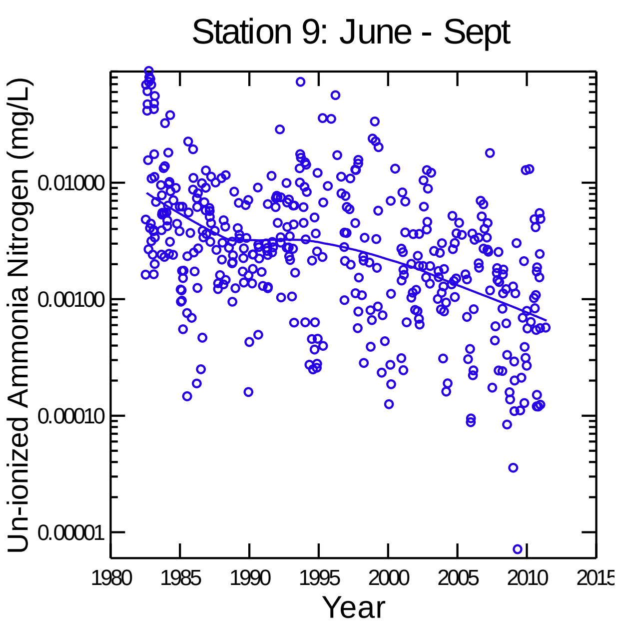
In the river a decreasing trend in ammonia nitrogen has also been observed over most of the study period (Figure 94). Between 1983 and 1999 the trend line dropped from 0.1 mg/L to 0.04 mg/L. Since 1999 it has continued to decline and is now less than 0.02 mg/L. Overall, in the river ammonia nitrogen has demonstrated a significant decline over the study period at a rate of 0.003 mg/L per year or a total of 0.087 over the study period (Table 12).

Figure 94. Long term trend in Ammonia Nitrogen (Fairfax County Lab Data). Station 9. Potomac mainstem.



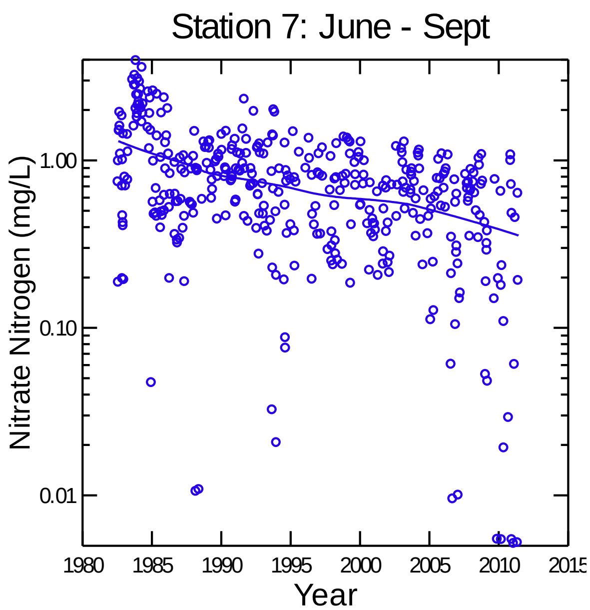
Un-ionized ammonia nitrogen in the cove demonstrated a clear increase in the 1980's with a continuous decline since that time (Figure 95). The LOWESS trend peaked at about 0.07 mg/L and is now less than 0.001 mg/L. When considered over the entire time period, there was a significant decline at a rate of 0.005 mg/L per year or a total of 0.14 mg/L over the 29 years (Table 12).

Figure 95. Long term trend in Un-ionized Ammonia Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



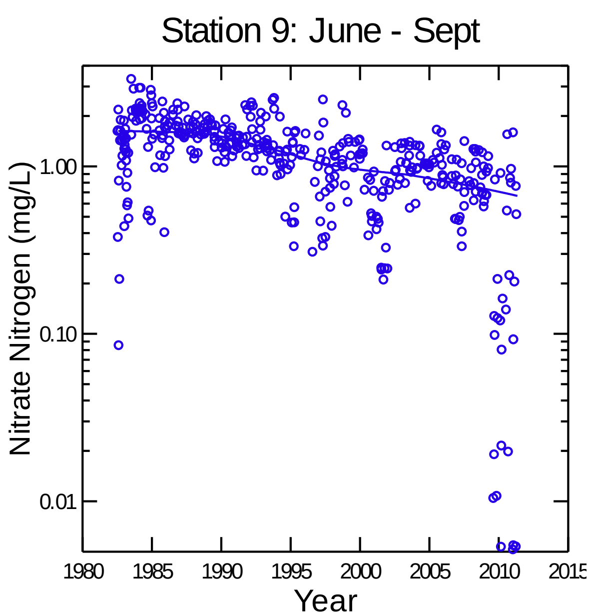
Un-ionized ammonia nitrogen in the river declined during the 1980's, was stable in the early 1990's and has declined since (Figure 96). LOWESS values have dropped from about 0.009 mg/L to less than 0.001 mg/L. Linear regression analysis over the entire period of record suggested a significant decline at a rate of 0.0004 units per year (Table 12).

Figure 96. Long term trend in Un-ionized Ammonia Nitrogen (Fairfax County Lab Data). Station 9. Potomac mainstem.



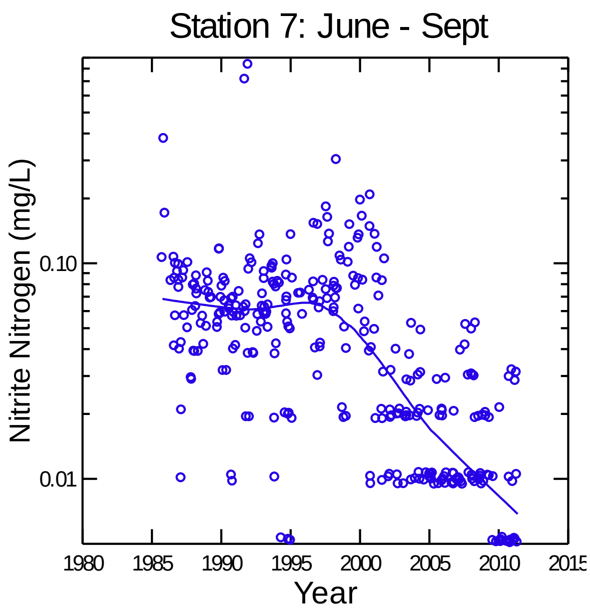
Nitrate nitrogen has demonstrated a steady decline in the cove over the entire period of record (Figure 97). The trend line was at 1.3 mg/L in 1983 and by 2011 was at 0.4 mg/L. Linear regression suggested a decline rate of 0.035 mg/L per year yielding a total decline of 1.0 mg/L over the long term study period (Table 12).

Figure 97. Long term trend in Nitrate Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



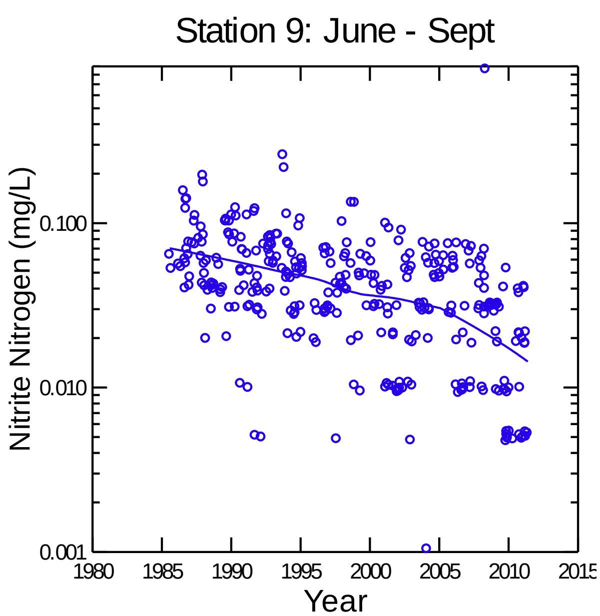
In the river nitrate nitrogen has declined steadily since about 1990 (Figure 98). The trend line dropped from 1.5 mg/L in the mid 1980's to 0.7 mg/L in 2011. Linear regression indicated a rate of decline which would have yielded a 1.3 mg/L decrease in nitrate nitrogen over the study period (Table 12). 2011 values were generally well below the trend line.

Figure 98. Long term trend in Nitrate Nitrogen (Fairfax County Lab Data). Station 9. River mainstem.



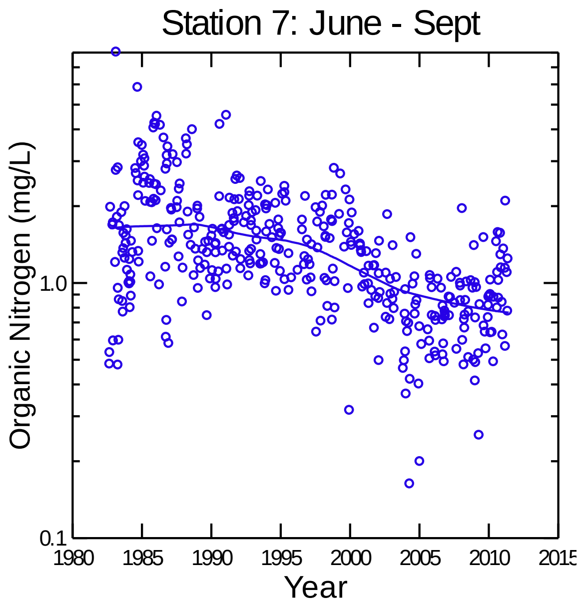
The trend line for nitrite nitrogen indicated steady values at about 0.06-0.07 mg/L through 1999 (Figure 99). Since then there is clear evidence for a decline with the LOWESS line reaching below 0.01 in 2011. Linear regression revealed a significant decline with a slope of 0.003 mg/L per year when the entire period of record was considered (Table 12).

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



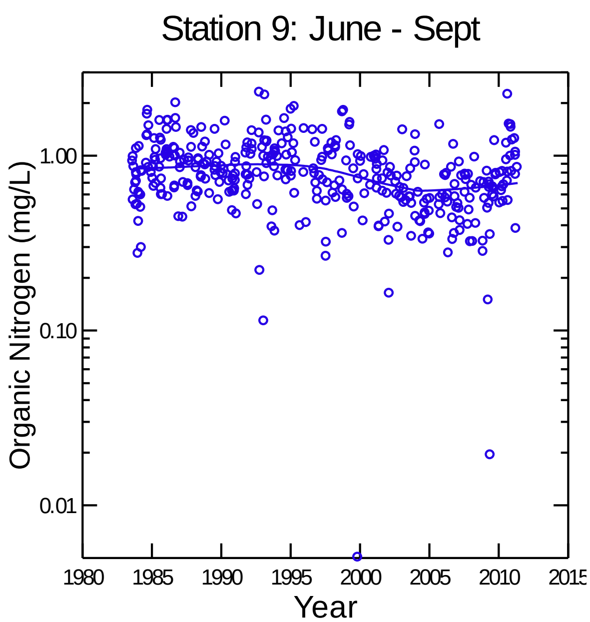
Nitrite nitrogen in the river demonstrated a pattern of decrease during the long term study period (Figure 100). The LOWESS line dropped from 0.07 mg/L in 1986 to 0.015 mg/L in 2011. Linear regression indicated a significant linear decline at a rate of 0.002 mg/L per year or 0.05 mg/L over the study period (Table 12).

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



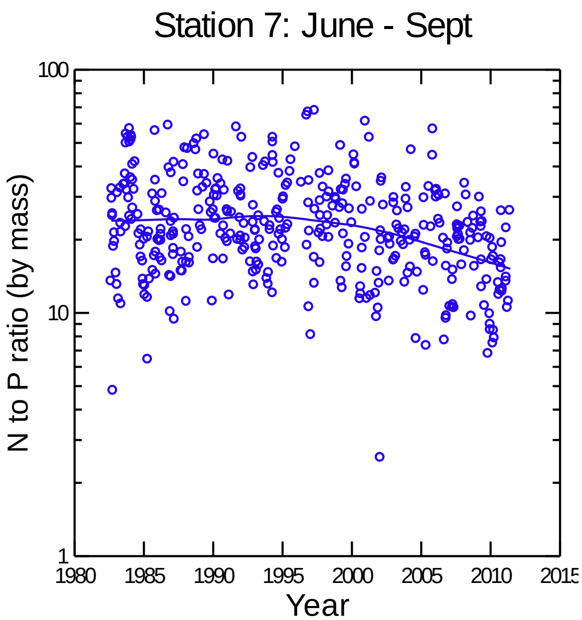
Organic nitrogen in the cove was fairly high in the 1980's and has since undergone a consistent decline through 2011 (Figure 101). In 1983 the trend line was at 1.5 mg/L and dropped below 0.8 mg/L in 2011. Regression analysis indicated a significant decline over the study period at a rate of about 0.049 mg/L per year or a total of 1.4 mg/L over the whole study period (Table 12).

Figure 101. Long term trend in Organic Nitrogen (Fairfax County Lab Data). Station 7. Gunston Cove.



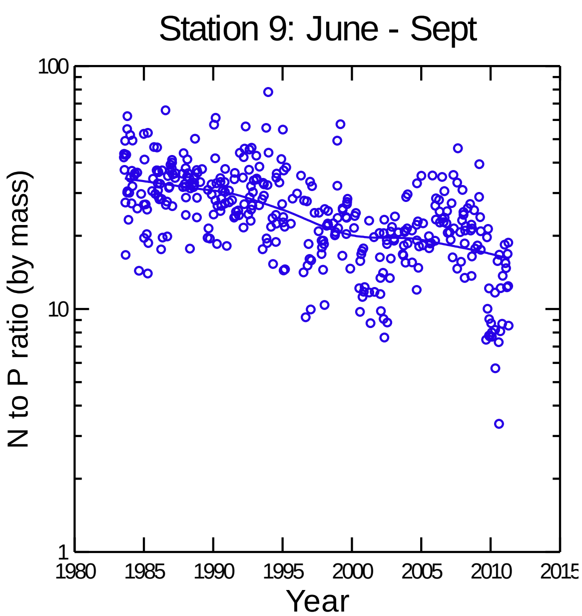
In the river organic nitrogen was steady from 1984 through 1995 and since then has shown a modest decline (Figure 102). The LOWESS line peaked at about 0.9 mg/L and has dropped to about 0.6 mg/L. Regression analysis indicated a significant linear decline at a rate of 0.01 mg/L when the entire period of record was considered for a total decline of 0.3 mg/L (Table 12).

Figure 102. 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 14 by 2011 (Figure 103). Regression analysis over the period of record indicates a statistically significant decline at a rate of 0.35 per year or about 10.2 units over the entire period (Table 12).

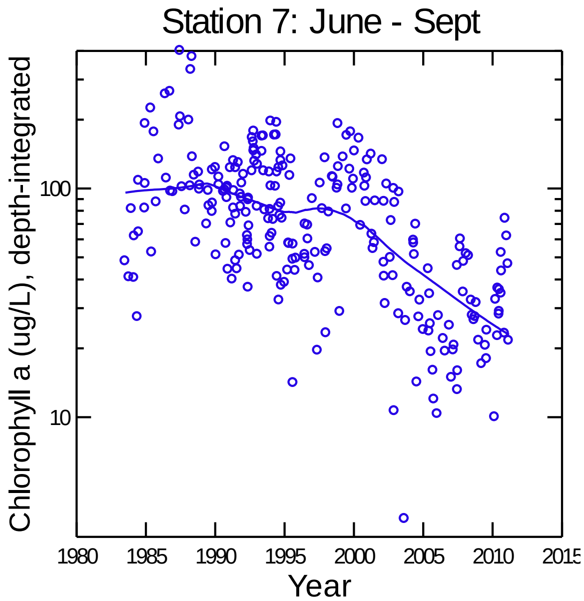
Figure 103. Long term trend in N to P Ratio (Fairfax County Lab Data). Station 7. Gunston Cove.



Nitrogen to phosphorus ratio in the river exhibited a strong continuous decline through about 2000 and has declined more slowly since then (Figure 104). The LOWESS trend line declined from about 35 in 1984 to 15 in 2011. 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 12). 2011 data were substantially below the trend line falling to values indicative of N limitation.

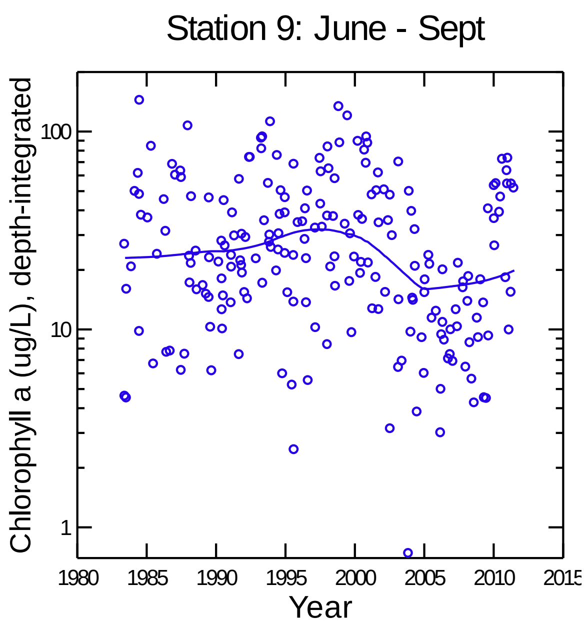
Figure 104. Long term trend in N to P Ratio (Fairfax County Lab Data). Station 9. River mainstem.

C. Phytoplankton Trends: 1984-2011



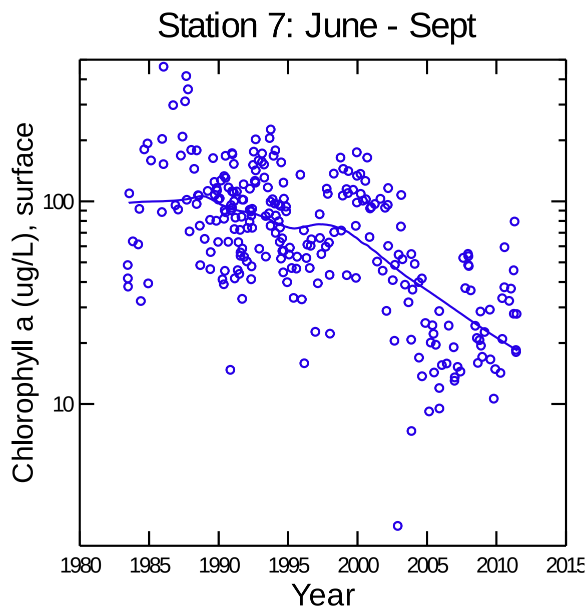
After increasing through much of the 1980's, depth-integrated chlorophyll *a* in the cove demonstrated a gradual decline from 1988 to 2000 and a much stronger decrease since then (Figure 105). The LOWESS line has declined from about 100 ug/L to a level of about 25 ug/L in 2011. The observed decrease 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 4.0 µg/L per year or 112 µg/L over the 28 year long term data set (Table 11).

Figure 105. Long term trend in Depth-integrated Chlorophyll *a* (GMU Lab Data). Station 7. Gunston Cove.



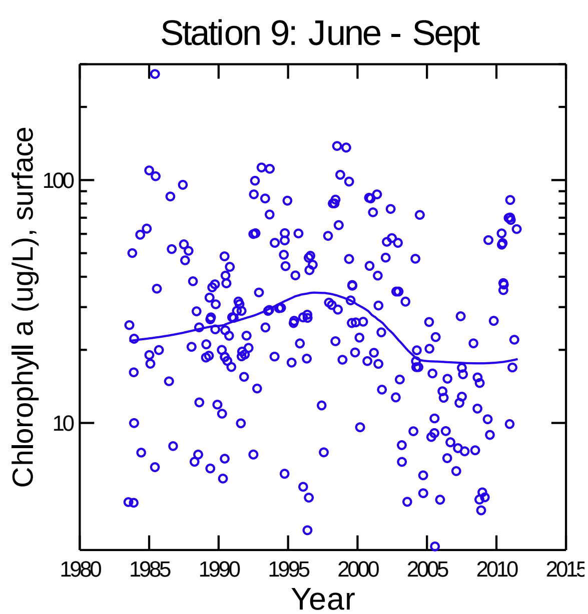
In the river depth-integrated chlorophyll *a* was fairly consistent through 2000 with the trend line varying between 20 and 30 ug/L (Figure 106). This was followed by a strong decline through about 2005, but a recent upswing has now been observed with trend line values now at about 20 µg/L. Note that in 2010 river chlorophylls were well above this trend line. Regression analysis revealed a marginally significant linear decline at a rate of 0.43 µg/L/yr when the entire period is considered (Table 11).

Figure 106. Long term trend in Depth-integrated Chlorophyll *a* (GMU Lab Data). Station 9. River mainstem.



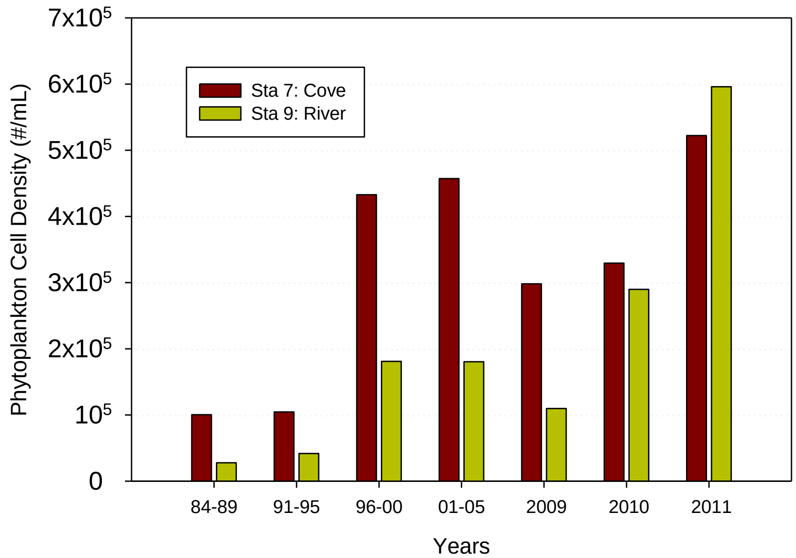
Surface chlorophyll *a* in the cove exhibited a clear decline over the long term study period, especially since 2000 (Figure 107). Trend line values of just over 100 µg/L in 1988 dropped to about 20 µg/L in 2011. The observed decrease has brought chlorophyll values into the range of water clarity criteria 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 4.2 µg/L per year or 118 µg/L over the entire study (Table 11).

Figure 107. Long term trend in Surface Chlorophyll *a* (GMU Data). Station 7. Gunston Cove.



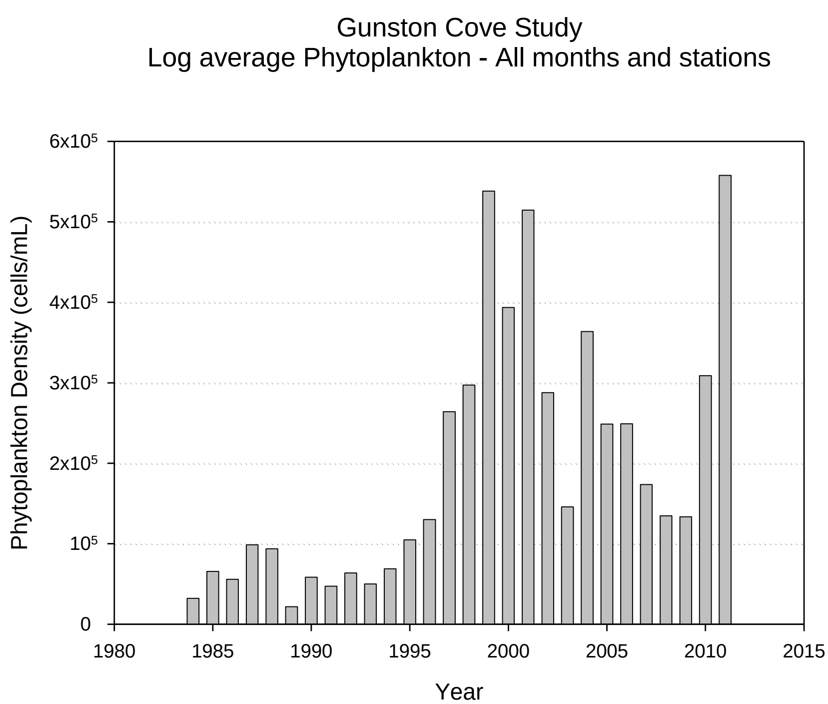
In the river the LOWESS line for surface chlorophyll *a* increased slowly from 1983 to 2000 and then declined markedly (Figure 108). Linear regression revealed a marginally significant decline in surface chlorophyll across this period with a rate of 0.5 µg/L/yr or about 14 µg/L over the whole period (Table 11).

Figure 108. Long term trend in Surface Chlorophyll *a* (GMU Data). Station 9. River mainstem.



Phytoplankton cell density in the cove in 2011 was higher than in 2009 and 2010 and about equal to the averages for 1996-2000 and 2001-2005 (Figure 117). In the river phytoplankton cell density was substantially higher than observed in previous years and can be ascribed mainly to the high densities of cyanobacteria. Most of the cells are relatively small so the relatively high number of cells does not necessarily mean an increase in phytoplankton biomass.

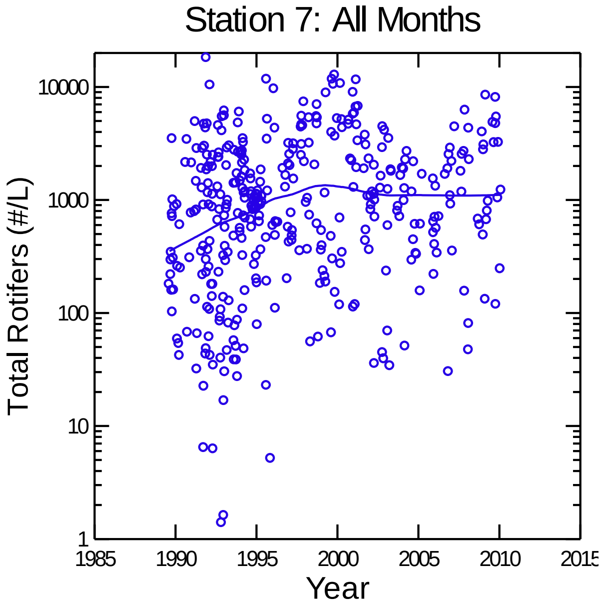
Figure 109. Interannual Comparison of Phytoplankton Density by Region.



By looking at individual years (Figure 118), we see that phytoplankton densities in the 2011 averaged over both stations were about equal to the peak years of 1999-2001, but higher than most years since then. Again, this was due to high values at both stations.

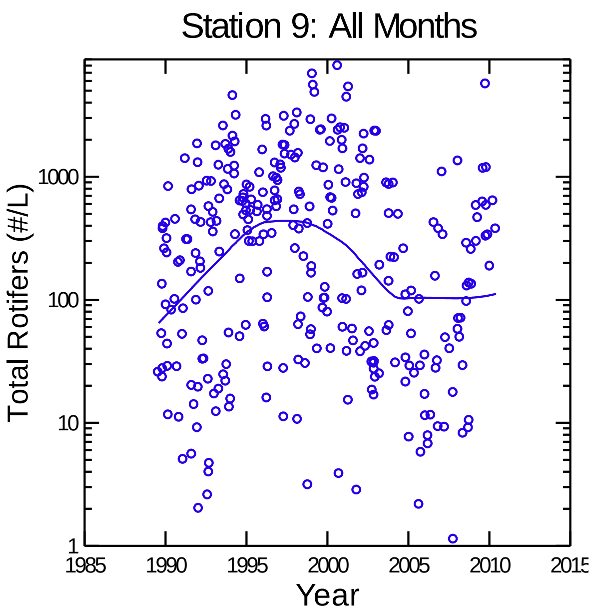
Figure 110. Interannual Trend in Average Phytoplankton Density.

D. Zooplankton Trends: 1990-2011



In the Cove total rotifers continued to show a leveling off after an initial decade (1990-2000) of steady increase (Figure 111). The LOWESS fit line indicated about 1000/L in 2011, 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 13).

Figure 111. Long term trend in Total Rotifers. Station 7. Gunston Cove.



In the Potomac mainstem, rotifers exhibited an initial increase, but then a marked decline in abundance which has leveled off. In the last two years values have been well above the trend line suggesting another increase (Figure 112). The LOWESS line has dropped to about 100/L whereas it had been at about 500/L in 1996-1999 period. When the entire 1990-2003 period was considered, total rotifers did not exhibit a significant linear trend in the river (Table 12).

Figure 112. Long term trend in Total Rotifers. Station 9. River mainstem.

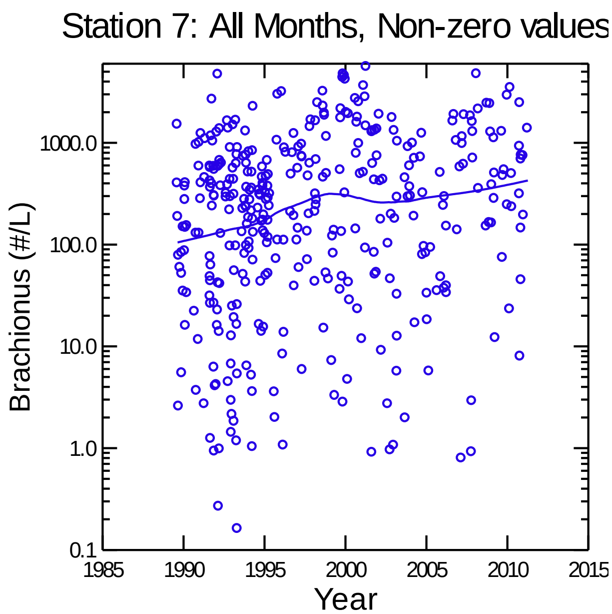
Table 11
Correlation and Linear Regression Coefficients
Zooplankton Parameters vs. Year for 1990-2011
All Nonzero Values Used, All Values Logged to Base 10

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Brachionus (m)	0.175 (375)	0.026	0.001	0.046 (299)	---	NS
Conochilidae (m)	0.226 (336)	0.025	<0.001	0.044 (255)	---	NS
Filinia (m)	0.222 (321)	0.032	<0.001	0.039 (206)	---	NS
Keratella (m)	0.318 (384)	0.041	<0.001	0.050 (309)	---	NS
Polyarthra (m)	0.255 (371)	0.032	<0.001	0.079 (291)	---	NS
Total Rotifers (m)	0.211 (401)	0.024	<0.001	0.031 (321)	---	NS
Bosmina (m)	0.109 (219)	---	NS	0.138 (256)	0.017	0.027
Diaphanosoma (M)	0.032 (310)	---	NS	0.063 (213)	---	NS
Daphnia (M)	0.192 (254)	0.035	0.002	0.146 (161)	0.021	0.064*
Chydorid cladocera (M)	0.283 (216)	0.039	<0.001	0.396 (133)	0.046	<0.001
Leptodora (M)	0.052 (155)	---	NS	0.037 (111)	---	NS
Copepod nauplii (m)	0.415 (369)	0.044	<0.001	0.253 (317)	0.030	<0.001
Adult and copepodid copepods (M)	0.079 (497)	---	NS	0.115 (362)	0.015	0.028

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

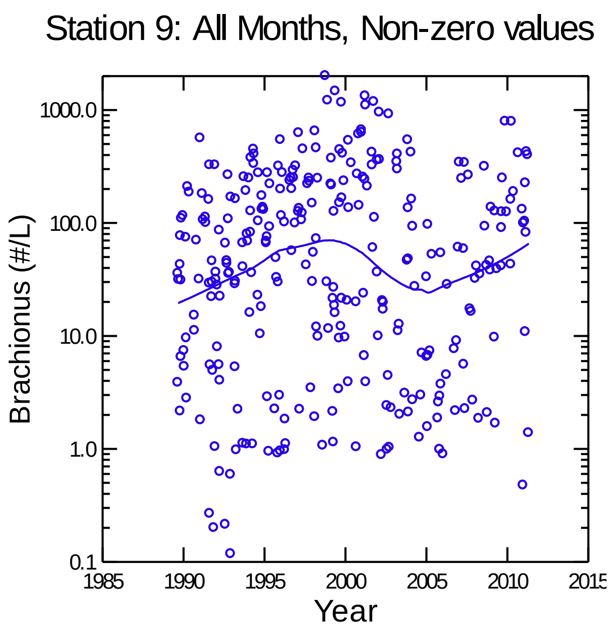
Significance column indicates the probability that a correlation coefficient this large could be due to chance alone. If this probability is greater than 0.05, then NS (not significant) is indicated. * = marginally significant.

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



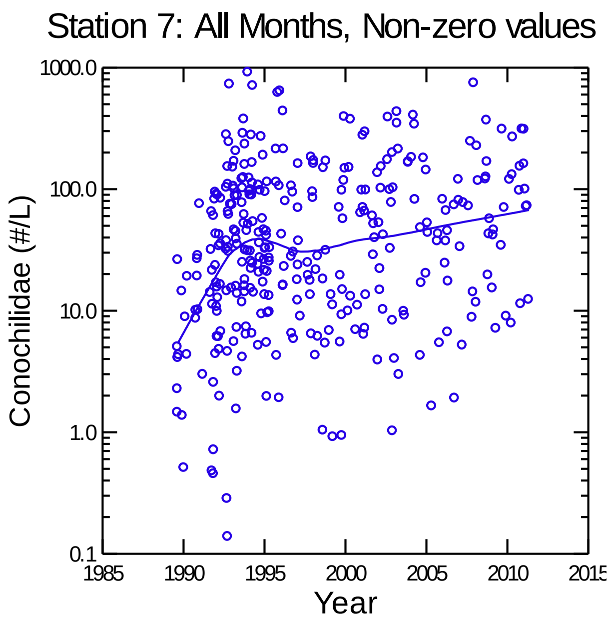
Brachionus is the dominant rotifer in Gunston Cove and the trends in total rotifers are generally mirrored in those in *Brachionus* (Figure 113). The LOWESS line for *Brachionus* suggested about 450/L in 2011, greater than the 100/L found in 1990. A statistically significant linear increase was found over the study period (Table 13).

Figure 113. Long term trend in *Brachionus*. Station 7. Gunston Cove.



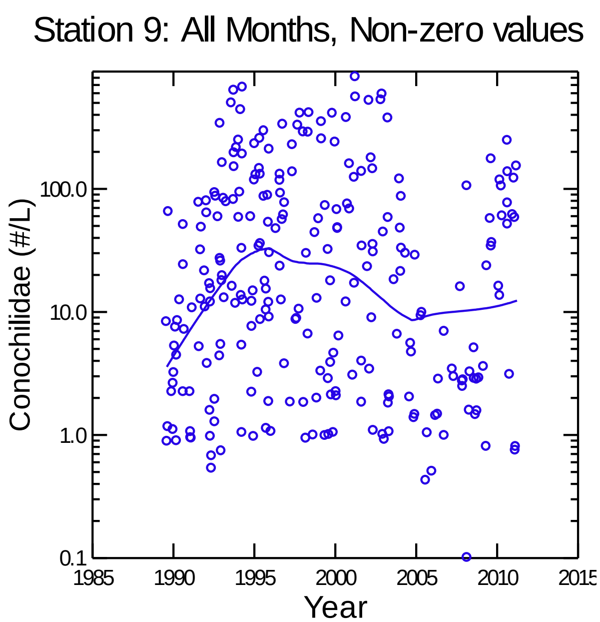
Brachionus was found at lower densities in the river. In the river the LOWESS line for *Brachionus* increased through 2000, but dropped markedly from 2000-2005.Since 2005 an increase has been noted, particularly in the last 3 years. The LOWESS value in 2011 was about 70/L, near the peak of 80/L in 1999 (Figure 114). No linear trend was indicated when the entire study period was considered (Table 13).

Figure 114. Long term trend in *Brachionus*. Station 9. River mainstem.



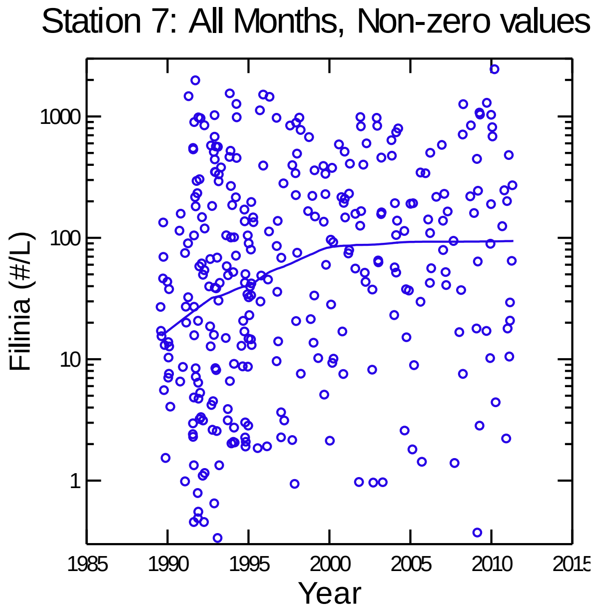
Conochilidae increased strongly from 1990-1995, leveled off, and is now showing a gradual increase. In 2011 the LOWESS trend line stood at about 70/L (Figure 115). This was well above levels of about 5/L in 1990. Over the entire period of record, a significant linear increase was found (Table 13).

Figure 115. Long term trend in Conochilidae. Station 7. Gunston Cove.



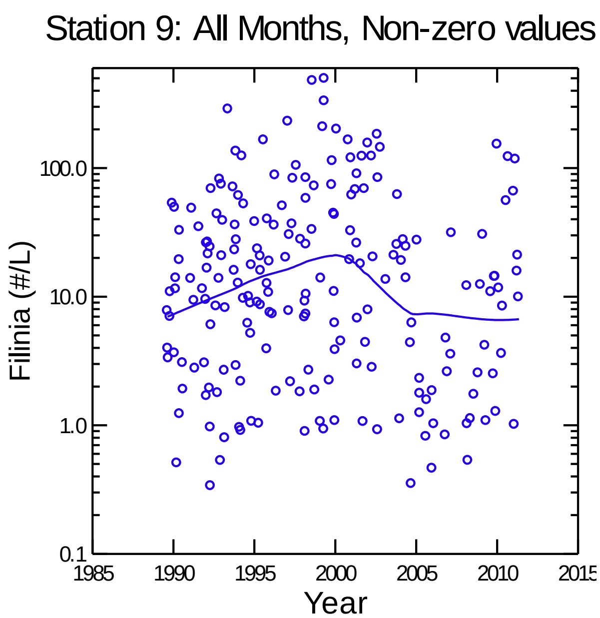
In the river, Conochilidae exhibited a strong increase in the early 1990's similar to that observed in the cove (Figure 116). This was followed by a period of decline and recently a renewed increase. The trend line has gone from 3/L in 1990 to 35/L in 1995 to 15/L in 2011. Most values in the last 2 years were above the trend line. When the entire period of record was examined, there was not a significant linear trend (Table 13).

Figure 116. Long term trend in Conochilidae. Station 9. Gunston Cove.



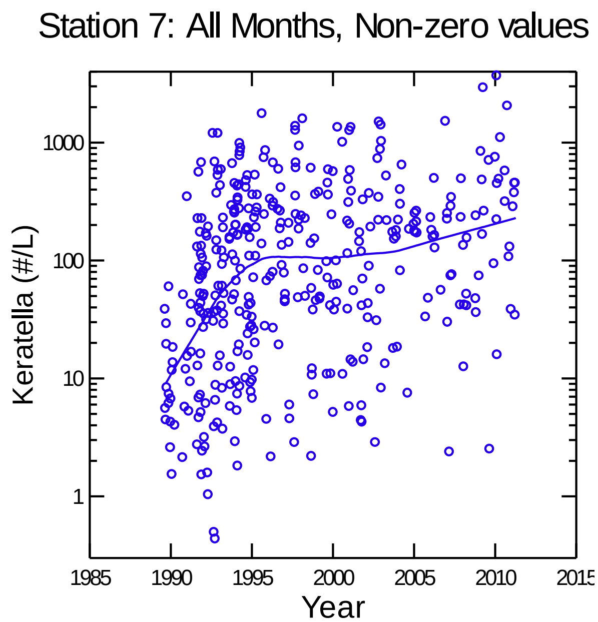
In the cove *Filinia* exhibited a steady increase from 1990 through 2000 rising from about 20/L to nearly 100/L (Figure 117). It has now leveled off at about 100/L. When the entire period of record was considered, there is strong evidence for a linear increase in the cove (Table 13).

Figure 117. Long term trend in *Filinia*. Station 7. Gunston Cove.



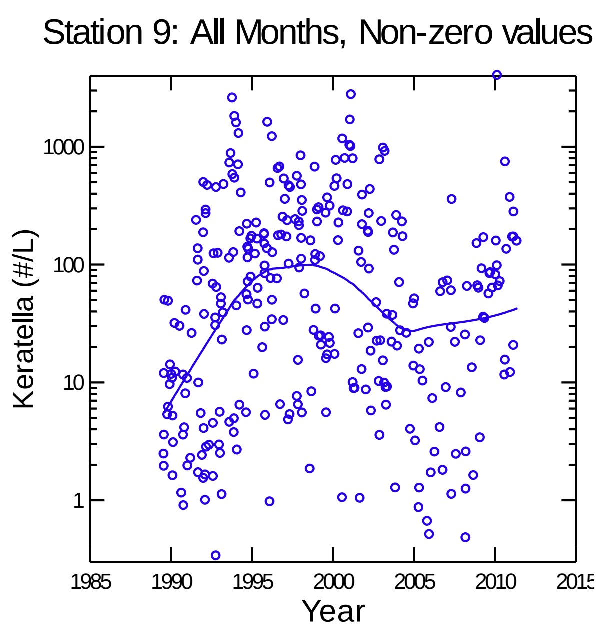
In the river *Filinia* demonstrated an increase through about 2001, but has declined strongly since. The trend line indicates about 7/L in 2011, about equal to the 7/L in 1990, but well below the peak of 20/L in 2000 (Figure 118). When the entire period of record was examined, there was not a significant linear trend (Table 12).

Figure 118. Long term trend in *Filinia*. Station 9. River mainstem.



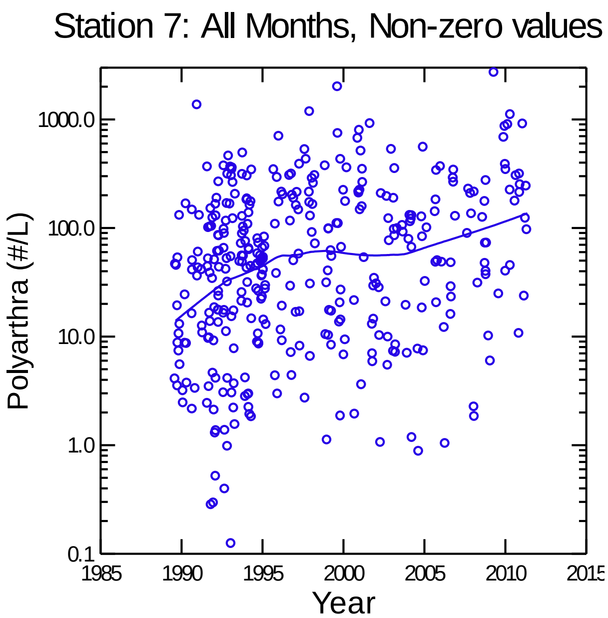
Keratella increased strongly from 1990 to 1995 and has shown only a mild increase since then with the trend line reaching about 200/L in 2011 (Figure 119). When the entire period of record was examined, there was a significant linear increase (Table 12).

Figure 119. Long term trend in *Keratella*. Station 7. Gunston Cove.



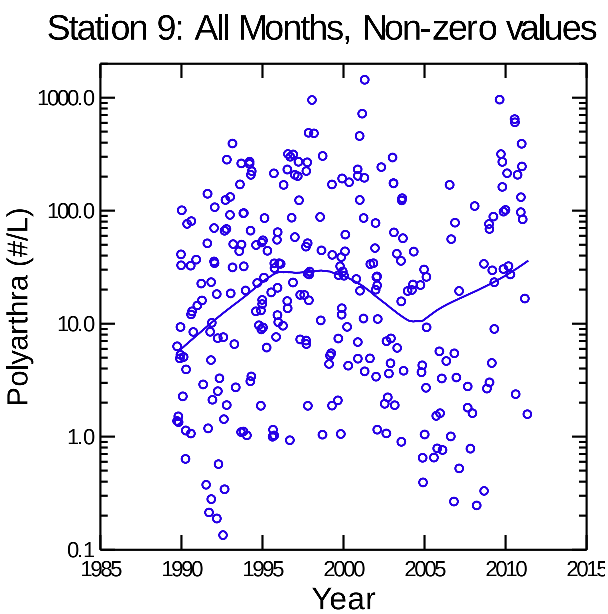
In the river *Keratella* increased from less than 10/L in 1990 to peak values of about 100/L in the mid to late 1990’s (Figure 128). The trend line then declined to about 25/L, but since 2005 it has increased to 45/L. Linear regression showed no significant trend when the entire study period was considered (Table 12).

Figure 120. Long term trend in *Keratella*. Station 9. Gunston Cove.



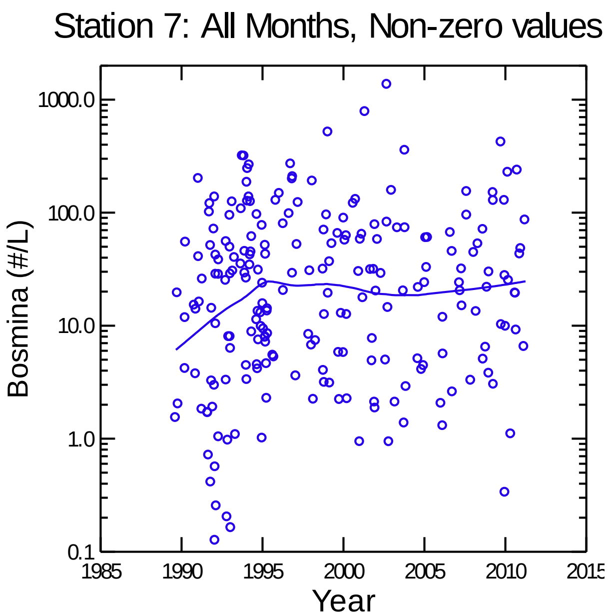
The trend line for *Polyarthra* in the cove increased steadily from 1990 to about 2000 rising from 15/L to about 60/L (Figure 121). Since 2000 densities have increased more slowly with the trend line reaching about 120/L by 2011. Regression analysis indicated a significant linear increase when the entire period of record was examined (Table 13).

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



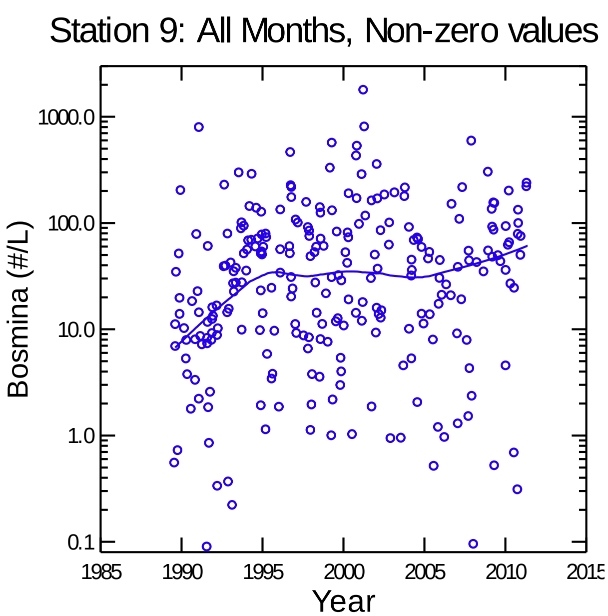
In the river *Polyarthra* showed a marked increase from 1990 to 2000 and then a decline to 2005. Recently values have increased again and by 2011 the trend line reached 40/L (Figure 122). Linear regression analysis did not indicate a significant trend over the period of record (Table 13).

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



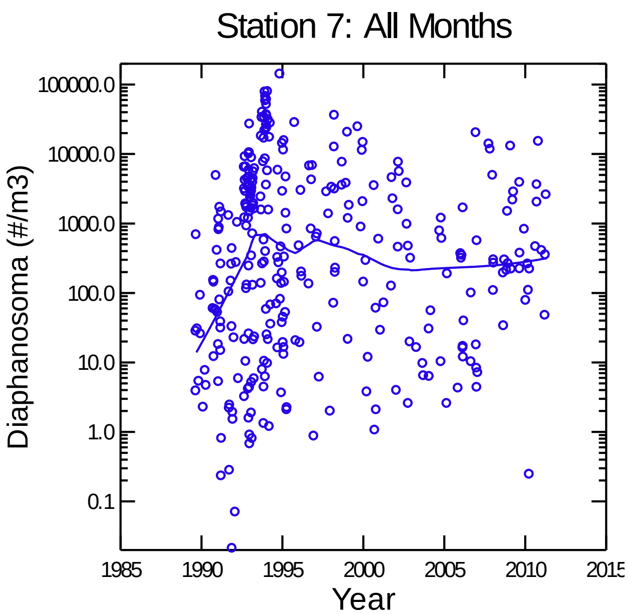
The trend line for *Bosmina* in the cove showed an increase from 7/L in 1990 to about 25/L in 2000 (Figure 123). Since 2000 densities have not changed much. Linear regression did not indicate a significant trend in the cove over the entire period of record (Table 13).

Figure 123. Long term trend in *Bosmina*. Station 7. Gunston Cove.



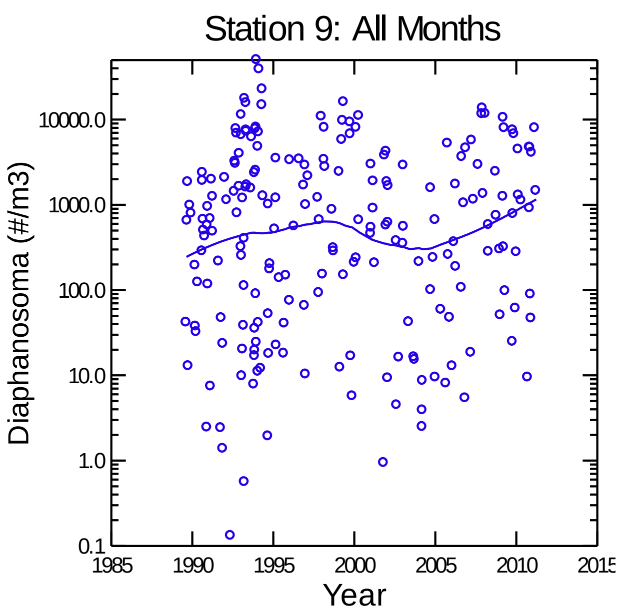
In the river mainstem the LOWESS curve for *Bosmina* increased from 1990 to 1995, and remained rather constant from 1995 to 2005 before increasing to about 60/L in 2011 (Figure 124). Regression analysis indicated a significant linear increase over the entire period of record (Table 13).

Figure 124. Long term trend in *Bosmina*. Station 9. River mainstem.



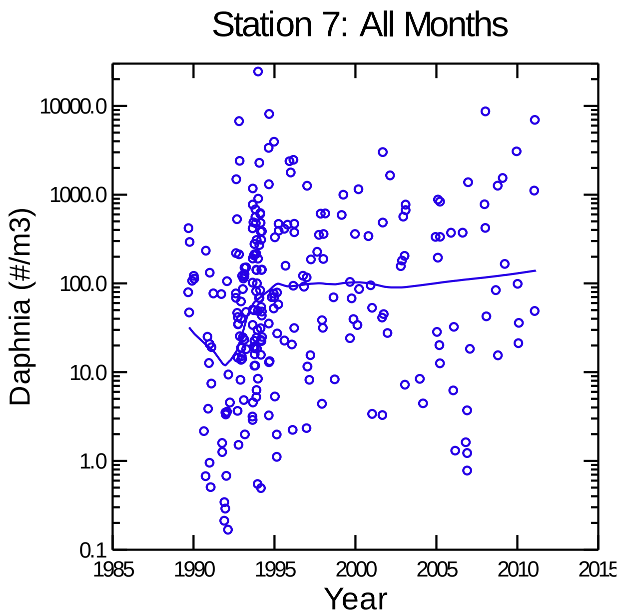
Diaphanosoma increased strongly in the early 1990s from about 15/m^3 nearly 1000/m^3. It gradually declined through 2005 to about 300/m^3 (Figure 125). Recent years have increased slightly. Linear regression analysis of the entire period of record indicated a no significant linear trend (Table 13).

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



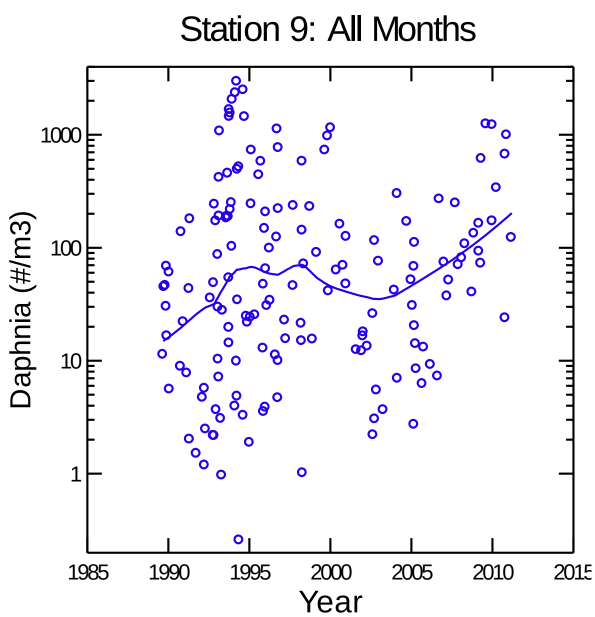
In the river the LOWESS line suggested a generally stable pattern in *Diaphanosoma* (Figure 126). The trend line value of 1000/m^3 found in 2011 compared with values as high as 800/m^3 in 1999 and 1993 and as low as the 200/m^3 in 1990. Regression analysis indicated no significant linear trend over the period of record (Table 13).

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



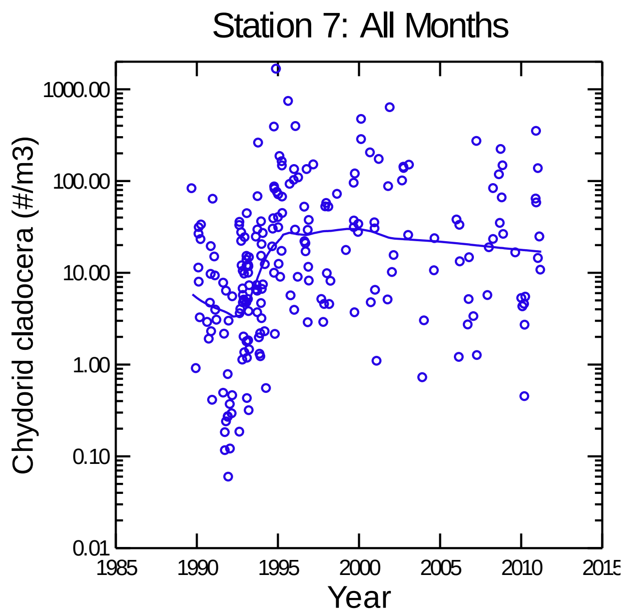
Daphnia in the cove has been relatively stable since 1995 at about 100/m^3 (Figure 127). This is up from the low of about 10/m^3 in 1992 and the starting value of 40/m^3 in 1990. Regression analysis examining the entire period of record gave clear support for a linear increase (Table 13).

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



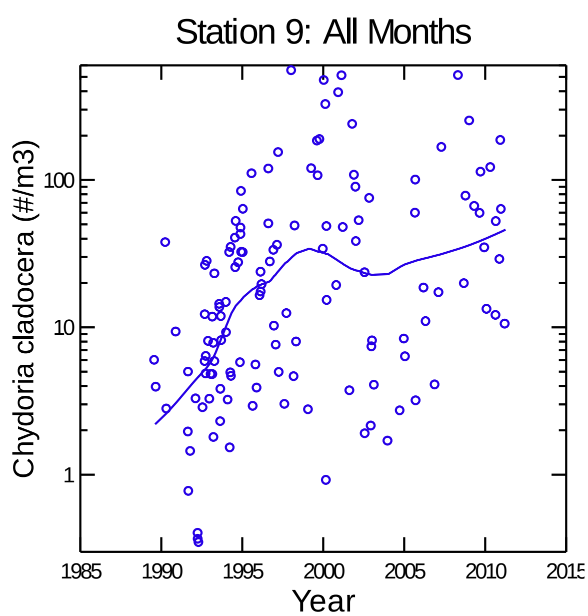
Daphnia in the river has shown a lot of variability over time, but little consistent trend (Figure 128). The trend line in 2011 reached about 200/m^3, substantially higher than the level observed at the beginning of the record in 1990. Regression analysis indicated a marginally significant positive trend over the study period (Table 13).

Figure 128. Long term trend in *Daphnia*. Station 9. River mainstem.



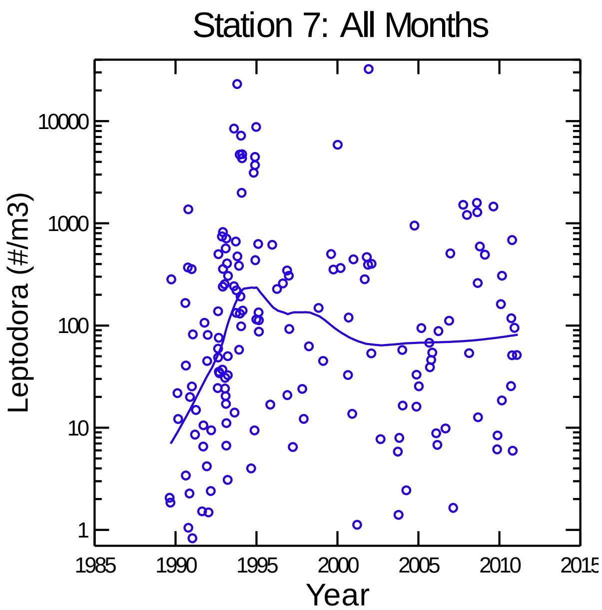
Chydorid cladocera in the cove continued a slow decline observed in recent years to about 20/m^3, substantially higher than the low of 3/m^3 in 1992 and the initial value of 8/m^3 in 1990, but below trend line values of 30/m^3 observed between 1995 and 2000 (Figure 129). Regression analysis gave evidence for a linear increase over the study period (Table 13).

Figure 129. Long term trend in Chydorid Cladocera. Station 7. Gunston Cove.



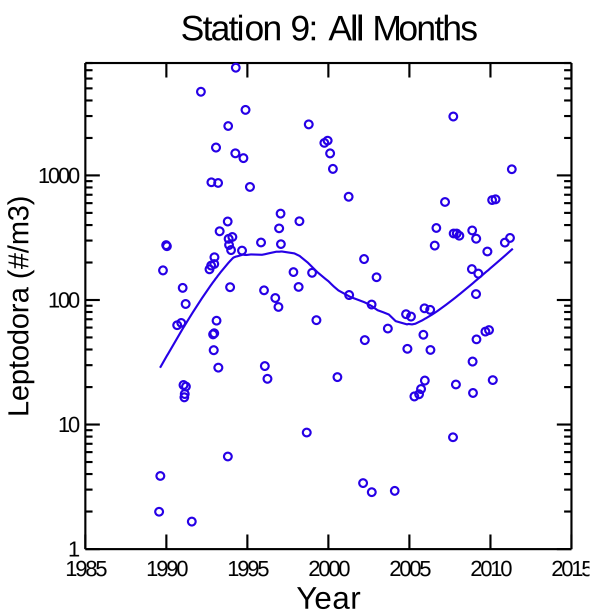
In the river chydorids continued a gradual increase to about 45/m^3, well above the low of about 4/m^3 in the early 1990's (Figure 130). There was evidence for a linear increase in chydorids over the entire study period as indicated by linear regression analysis (Table 13).

Figure 130. Long term trend in Chydorid Cladocera. Station 9. River mainstem.



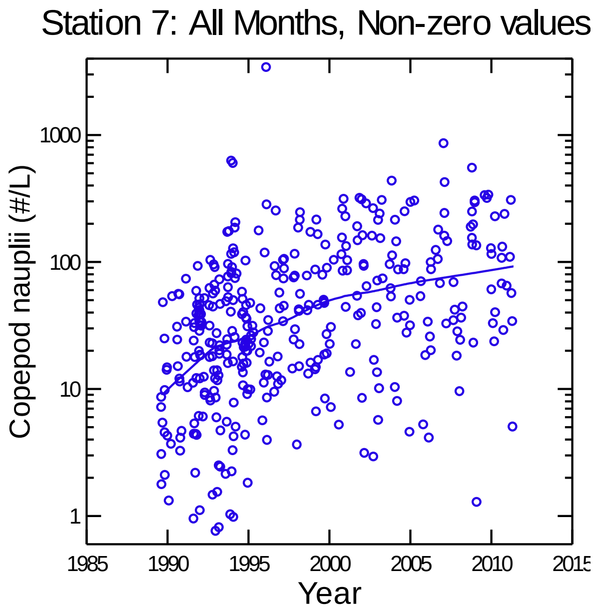
In the cove the trend line for *Leptodora*, the large predaceous cladoceran, has stabilized at about 100/m^3, down from its high of about 200/m^3 in 1994, but above the 1990 value of 10/m^3 (Figure 131). There was no evidence for a significant linear change in *Leptodora* over the entire study period (Table 13).

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



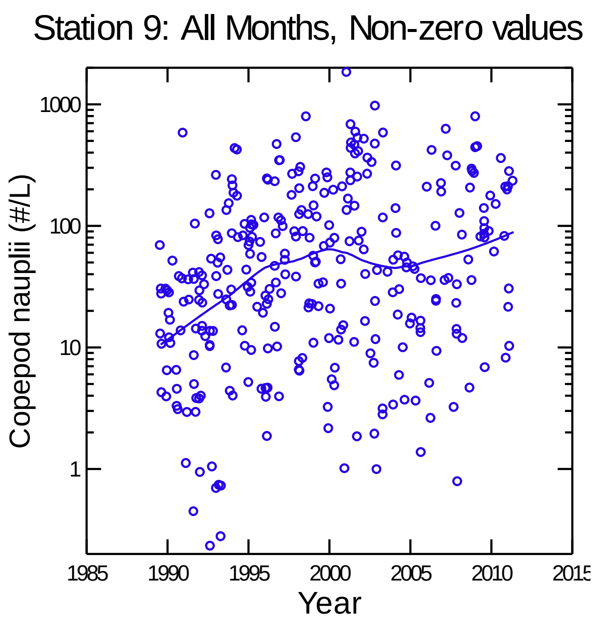
In the river, *Leptodora* densities continued to increase following a decline which began in 1995 resulting in trend line values of about 200/m^3 for 2011 (Figure 132). These values are well above those observed in 1990, and are approaching the peak of 300/m^3 in 1994. Linear regression analysis did not detect a significant linear trend when the whole study period was considered (Table 13).

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



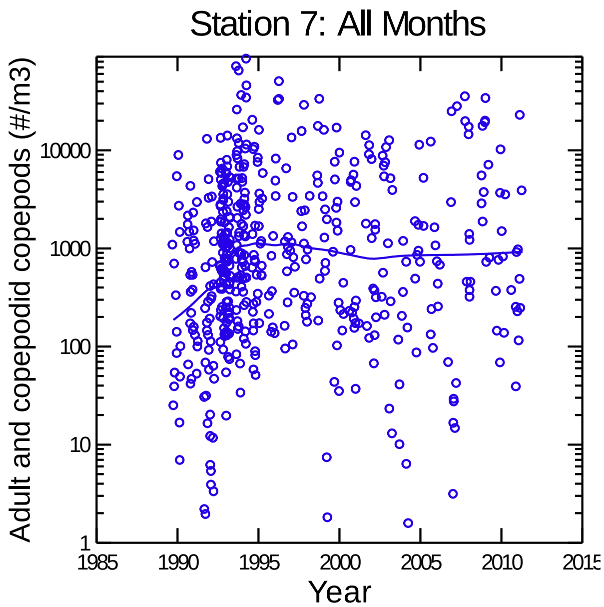
Copepod nauplii, the immature stages of copepods, continued their upward trend in 2011 (Figure 133). Trend line values reached 100/L in 2011 well above the initial level of 10/L observed in 1990. A strong linear increase was observed over the study period (Table 13).

Figure 133. Long term trend in Copepod Nauplii. Station 7. Gunston Cove.



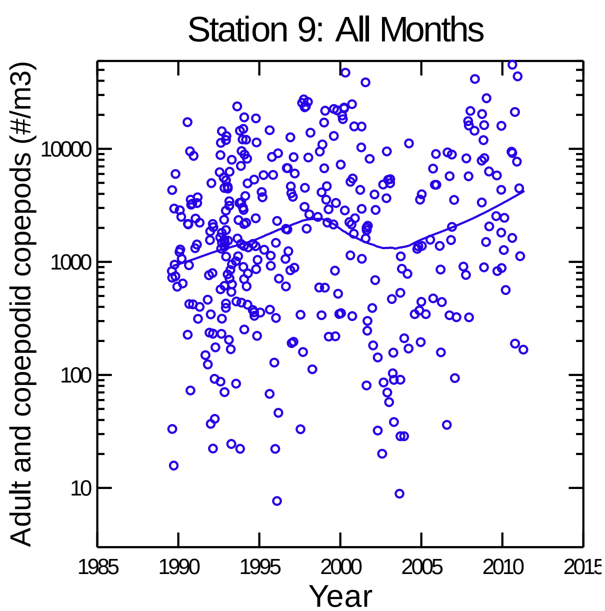
In the river, copepod nauplii showed a gradual increase following a decline begun in 2000 (Figure 134). The 2011 LOWESS trend line value was 90/L, up from an initial value of 10/L in 1990, just overtaking the previous peak of about 70/L. And recent values have been above the trend line. A significant linear increase was found for nauplii over the study period (Table 13).

Figure 134. 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 135). Copepods did not exhibit a significant linear trend in the cove over the study period (Table 13).

Figure 135. Long term trend in Adult and Copepodid Copepods. Station 7. Gunston Cove.



Adult and copepodid copepods continued to increase following a slight decline begun in 1998 (Figure 136). The trend line in 2011 reached 4000/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 13).

Figure 136. 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 resulting juvenile abundance may indicate that other factors (e.g., lack of significant refuge for settling juveniles) are modifying the abundance of a year-class. For example, there is more variability in the smoothed trend of fish density from seine and trawl catches for species such as river herring, gizzard shad, and white perch, than there is in the larval density trends. This situation has multiple explanations including a change in distribution of larvae during development and significant year-class modifications that occur during late larval and early juvenile stages.

For all of the dominant species of ichthyoplankton, densities have exhibited a slightly declining or relatively flat trend over the course of monitoring on this survey until 2010. Clupeid larvae (which are primarily river herring and gizzard shad), *Morone* sp. (mostly white perch), atherinids (inland silversides), and yellow perch all exhibited a spike in density during the earliest five years of monitoring. In all cases, this pattern was followed by a rapid decline to a relatively flat trend in density during the past decade. For clupeids, *Morone* sp. and atherinids, 1995 was an exceptional year with high mean larval densities.

More recent data indicate that higher densities of larval fish are returning (Table 14). The years 2010 and especially 2011 showed higher larval abundances than the five years before that, caused by a 3.3-fold increase in *Dorosoma* sp. from 2009 to 2010, and another 2.2-fold increase from 2010 to 2011 (Table 14). *Alosa* sp. larvae have increased again since 2009 as well.

The peaks in abundance over the season reflect characteristic spawning times of each species. The earliest are yellow perch (Figure 144) and white perch (Figure 140), followed by gizzard shad and river herring (Figure 138), and inland silversides (Figure 142). Yellow perch tend to have a narrower spawning period – thus the larval density peaks at the beginning of the sampling season and tapers rapidly. By comparison, white perch begin spawning early but have a more protracted spawning period. Consequently, white perch larvae are found throughout most of the sampling season. Gizzard shad and river herring show a more pronounced peak in mean larval density that is centered around the last weeks of May.

Table 14. The larval fishes collected in Gunston Cove and the Potomac River in 2005-11

Taxon	Common Name	2005	2006	2007	2008	2009	2010	2011	Total (%)
Alosa sp.	American shad, alewife, hickory shad, or blueback herring	1219	63	109	15	224	1332	968	3930 (12.5)
Dorosoma sp.	gizzard shad or threadfin shad	2110	254	992	510	1768	5846	13110	24590 (78.4)
Brevoortia tyrranus	menhaden	0	0	0	2	0	0	0	2 (<0.1)
Morone sp.	white perch or striped bass	242	52	233	427	414	504	413	2285 (7.3)
Perca flavescens	yellow perch	0	136	70	6	2	86	3	303 (1.0)
Menidia beryllina	inland silverside	26	54	31	8	10	87	17	233 (0.7)
Erimyzon oblongus	creek chubsucker	1	0	0	0	0	0	0	1 (<0.1)
Strongylura marina	Atlantic needlefish	0	0	0	1	1	0	0	2 (<0.1)
Lepomis sp.	sunfish	0	0	0	0	0	1	5	1(<0.1)
Unidentified		0	0	5	0	0	0	0	5 (<0.1)
Total		3598	559	1440	969	2419	7856	14516	

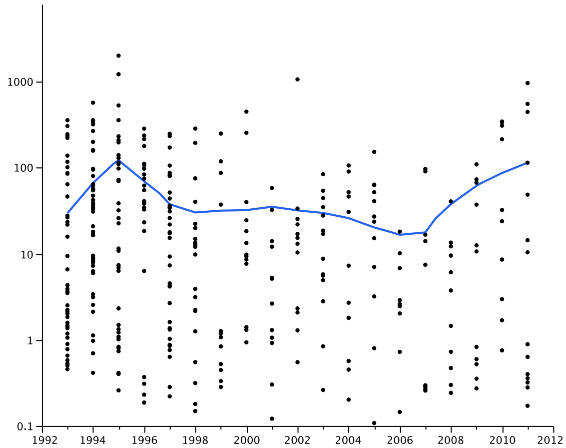


Figure 137. Long term trend in Clupeid Larvae (abundance 10 m^{-3}).

A graph of clupeid fish larvae averaged over all stations from 1993 through 2011 is shown in Figure 137. Because of the difficulty of distinguishing post yolk sack clupeids, this graph groups all clupeid species. The trend line remains steady at about from 1999-2007, but then numbers increase, reaching peak levels again in 2011 that occurred in 1995.

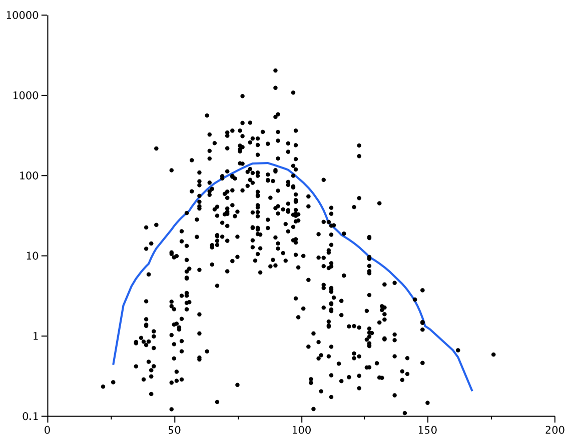
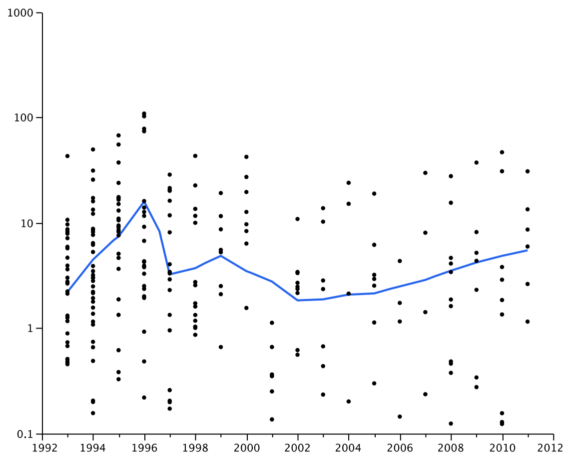


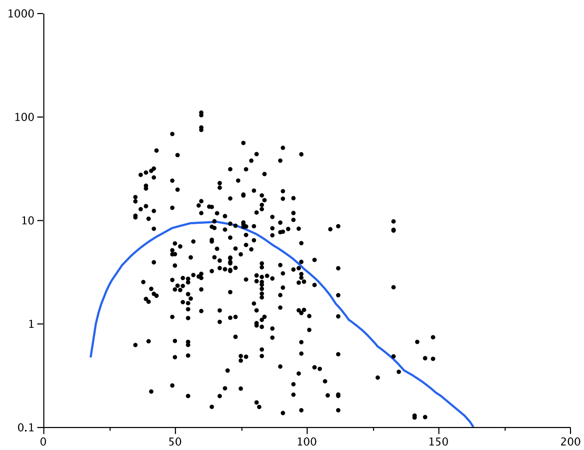
Figure 138. Seasonal pattern in Clupeid larvae (*Alosa* sp. and *Dorosoma* sp.; abundance 10 m^{-3}). The x-axis represents the number of days after March 1.

The seasonal pattern in clupeid larvae for 1993-2011 (Figure 138) shows that a peak in density occurs about 80-85 days after March 1, or in the last two weeks of May. A first explanation of the timing and breadth of the peak most certainly lies in the interannual variability of the development of warming of the creek and cove water. A second explanation is the sequentially extended spawning period by the three dominant clupeid species. The occurrence of the peak late in the spring may indicate a dominance of gizzard shad larvae in the data.



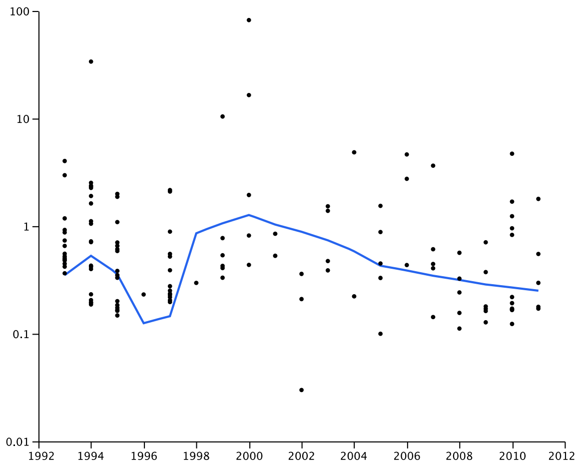
The trend in number of white perch larvae per 10 m^3 since 1993 is depicted in the LOWESS graph in Figure 139. A decline in catch is apparent from 1996 to 2002, but a slow but steady increase in catch is seen again from 2002 to 2011.

Figure 139. Long term trend in *Morone* Larvae (abundance 10 m^{-3}).



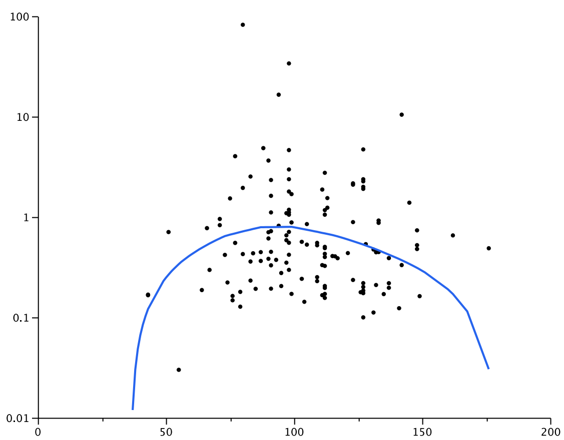
The seasonal occurrence of number of white perch larvae per 10 m^3 is shown in Figure 140. The highest density of larvae occurs on the earliest date that larvae appear in the collections and declines thereafter. This peak occurs in early April.

Figure 140. Seasonal pattern in *Morone* Larvae (abundance 10 m^{-3}).
The x-axis represents the number of days after March 1.



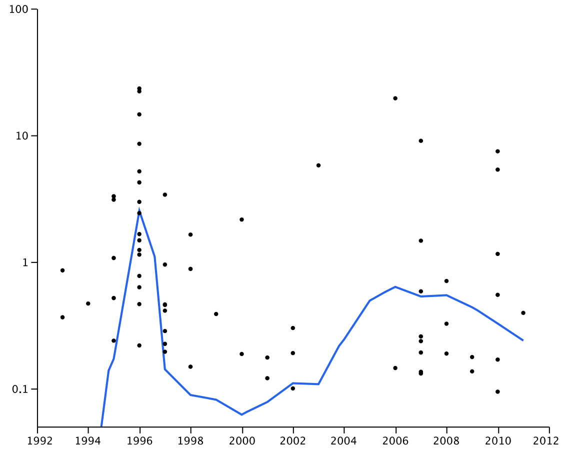
The long term trend in density of atherinid larvae (probably all inland silverside larvae) is presented in a LOWESS graph in Figure 141. The number of atherinid larvae per $10m^3$ caught has remained low. These open water collections are probably not totally representative of the population of larvae in the cove, since they may remain in the shallows along the shore or in the submerged weed beds where they are spawned.

Figure 141. Long term trend in Atherinid larvae (abundance 10 m^{-3}).



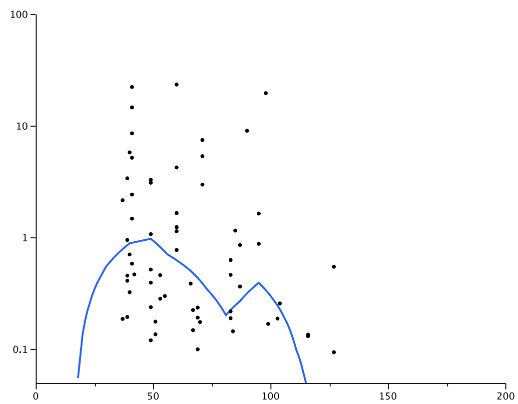
The seasonal occurrence of atherinid larvae per $10m^3$ is shown in a LOWESS graph in Figure 142. The pattern shows maximum density around 90 days after March 1, or around the first week of June. However, the peak is not pronounced, and the density persists at a slightly lower level into the fall.

Figure 142. Seasonal pattern in Atherinid larvae (abundance 10 m^{-3}).
The x-axis represents the number of days after March 1.



The LOWESS graph in Figure 143 gathers the trend in density of yellow perch since 1993. Following unusually high densities in 1996, abundances decreased while the general trend remains highly variable.

Figure 143. 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 LOWESS graph in Figure 144. The greatest densities occur in early to mid April, but larvae persist as late as early June.

Figure 144. 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: 1984-2011

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 15, Figure 145). 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 145). High catch rates in 2007 and 2010 turn a general trend of declining catches to a slow increase in catches since 1996 (Figure 146). On average, catch rates of fishes within the cove are approximately the same again of what was recorded in the first few years of the survey (Figure 146). The overall catch rate for the inner cove (stations 7 and 10) in 2011 was under the long-term mean (119) for the survey. At station 9 in the main stem of the river, catch rate of all species combined was also below the long-term mean (57). At station 9, juvenile fishes are less common than in shallower nursery habitats represented by stations inside the cove. Therefore, catch rates at station 9 exhibited less variability than in the cove and generally reflected more older fish in these samples than at the other stations. Annual trends in total catch rate at station 9 were still driven by white perch (Figure 161). With the exception of 2007, which had the highest catch rate on the survey, white perch catch rates at station 9 have demonstrated a relatively flat trend. White perch is a large proportion of catches at station 9 as well (Figures 162 & 163). It is interesting to note that the peak density of white perch at station 9 occurred in 2007, while at station 7 and 10 it occurred in 2010. Because the station 9 collections mainly consist of adults, while station 7 and 10 collections mainly consist of juveniles, this could mean that the high spawning biomass in 2007 resulted in a successful cohort of juveniles in 2010.

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

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

Table 15. 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
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

*2010 data: Sta 10 not sampled late July – Sept. **2011 data: Sta 10 not sampled in August

Table 16. Mean catch of adult and juvenile fishes per trawl for all months at Station 9

Year	All Species	white perch	American eel	bay anchovy	spottail shiner	brown bullhead	channel cat	tessellated darter	hogchoker
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 17. Mean catch of adult and juvenile fishes per trawl for all months at Stations 7, 9, and 10 combined

Year	All Species	white perch	blueback herring	alewife	gizzard shad	bay anchovy	spottail shiner	brown bullhead	channel catfish
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

*2010 data: Sta 10 not sampled late July – Sept. **2011 data: Sta 10 not sampled in August

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

Year	Station 7	Station 9	Station 10
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

*2010 data: Sta 10 not sampled late July – Sept. **2011 data: Sta 10 not sampled in August

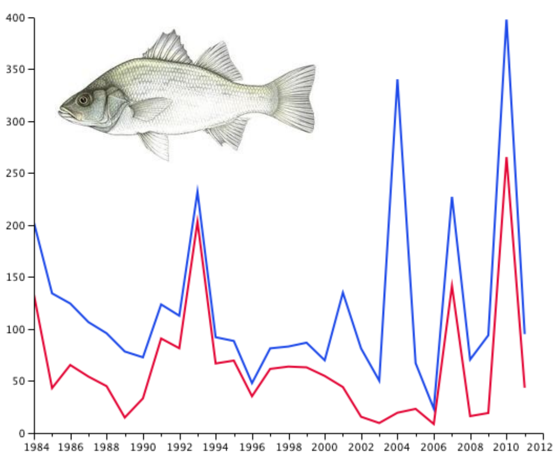


Figure 145. Trawls. Annual Averages. All Species (blue) and White Perch (red). Cove Stations 7 and 10.

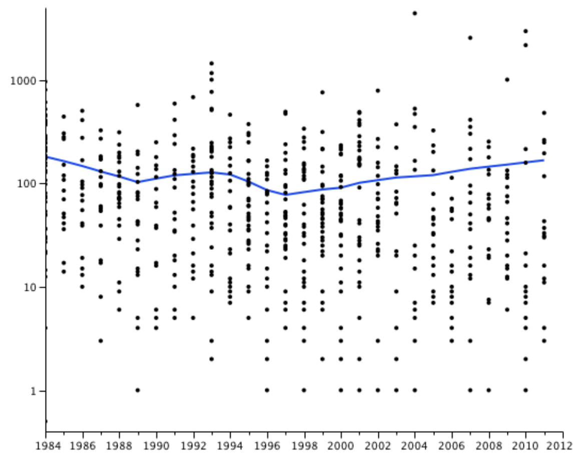


Figure 146. Trawls. Long Term Trend in Total Catch

Mean total number of fish per trawl sample has remained steady over the course of the study (Table 15 and Figure 146); the pattern is highly dominated by catches of white perch. Strong cohorts punctuated white perch catch rates in 1993, 2007, and 2010, which kept the overall trend from declining (Figure 145). Excepting the strong year-classes, white perch catch rates appear to have gone through three phases: low to moderate catch rates between 1985 and 1990, high to moderate catch rates between 1991 and 2000, and with exception of two strong year classes, low catch rates between 2001 and 2011. The remaining component of the 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 2010. 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 148).

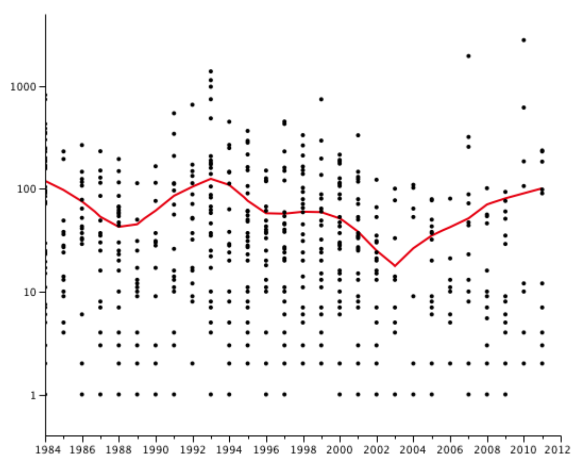


Figure 147. Trawls. Long Term Trend in White Perch (#/trawl). Stations 7 & 10.

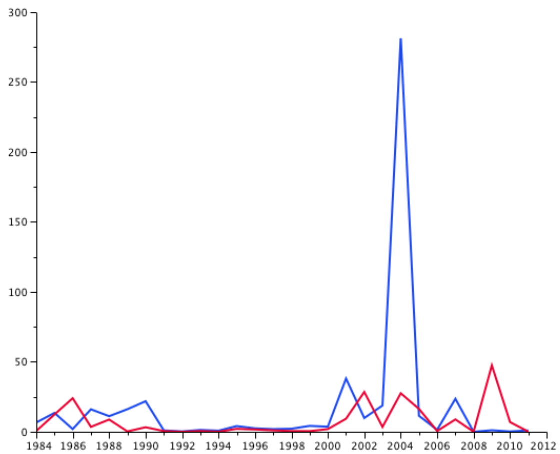


Figure 148. Trawls. Annual Averages. Blueback Herring (blue) and Alewife (red). Cove Stations 7 and 10.

Although the strong year-class effects varied by species for the anadromous fishes, the same three phases of abundance for white perch were also evident for juvenile river herring (collectively, alewife and blueback herring). Moderate catch rates until 1990 were followed by a period of consistently low catch rates until 2000, after which catch rates have been moderate to high. The LOWESS trends recognize an general decline in blueback herring since 2004, while there is a slow but steady increase in alewife since 1994 (Figures 149 & 150).

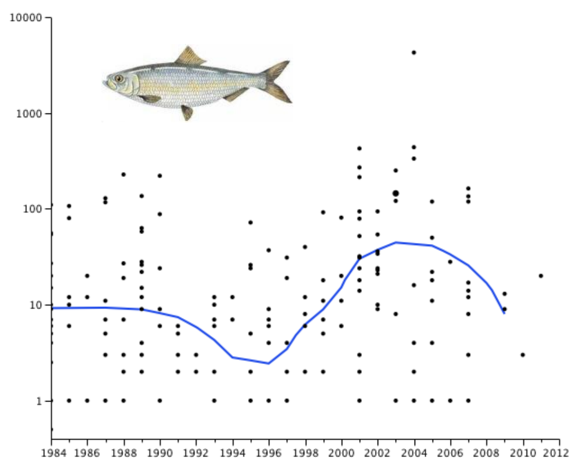


Figure 149. Trawls. Long term trend in Blueback Herring (*Alosa aestivalis*; #/trawl). Cove Stations 7 and 10.

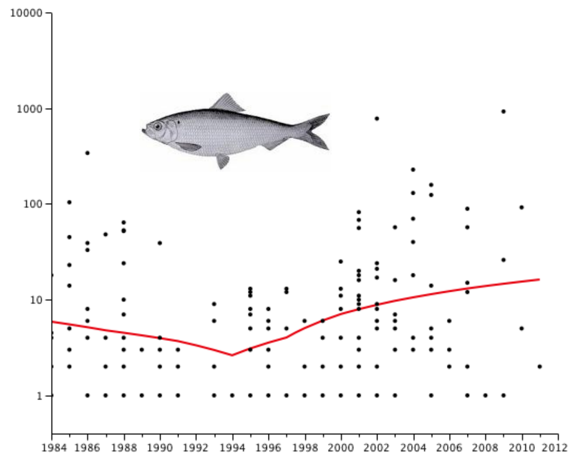


Figure 150. Trawls. Long term trend in Alewife (*Alosa pseudoharengus*; #/trawl). Cove Stations 7 and 10.

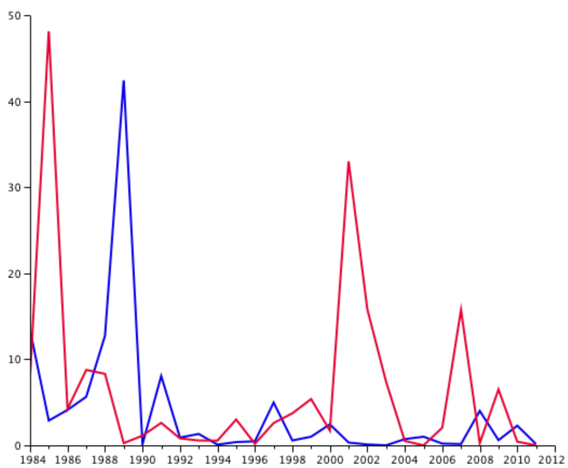


Figure 151. Trawls. Annual Averages. Cove Stations 7 and 10. Gizzard shad (blue) and bay anchovy (red).

Gizzard shad catch rates in trawls in 2011 contribute to a pattern of low and variable abundance that appears to have started in 1992 or earlier (Figure 151 & 152). Trend analysis with LOWESS emphasized declining gizzard shad catch rates for stations 7 and 10. Bay anchovy catch rates were variable at cove stations, and LOWESS trend analysis suggests a downward trend since 2001 (Figure 153). Although they are primarily resident in more saline portions of the estuary, their sporadic occurrence in tidal freshwater may represent significant transport of productivity from the lower regions of the Potomac. In addition, as they are an annual species, the sinusoidal trend in mean catch rates over the course of the survey (Figure 153) is more indicative of prevailing environments (favorable versus unfavorable for early life stages and estuarine transport) than spawning stock abundance.

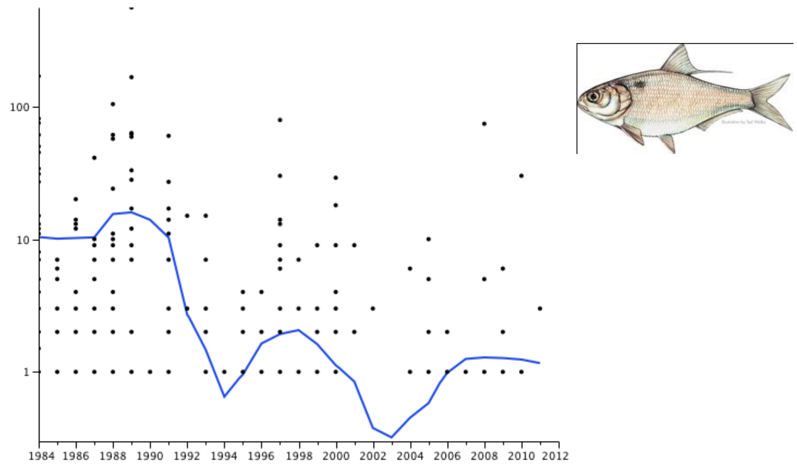


Figure 152. Trawls. Long term trend in Gizzard Shad (*Dorosoma cepedianum*). Stations 7 and 10.

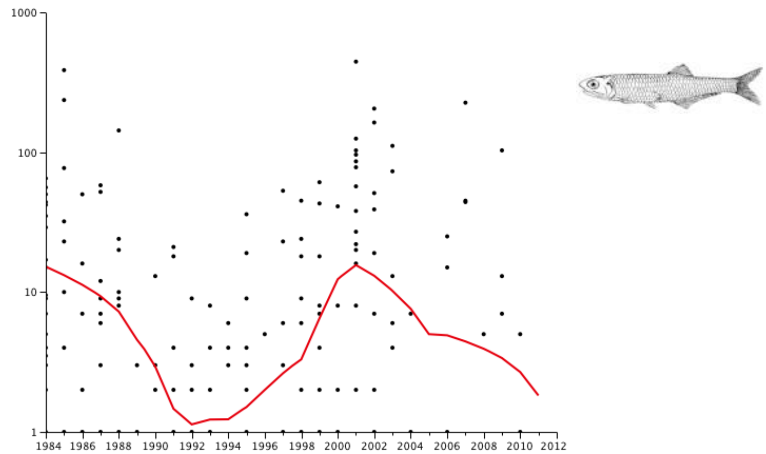


Figure 153. Trawls. Long term trend in Bay Anchovy (*Anchoa mitchilli*). Stations 7 and 10.

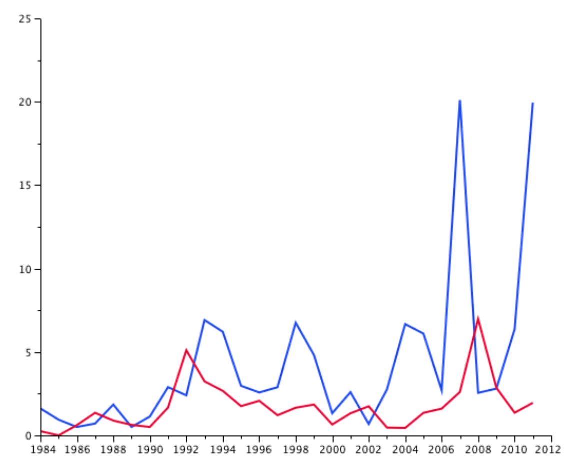


Figure 154. Trawls. Annual Averages. Spottail Shiner (blue) and Pumpkinseed (red). Cove Stations 7 and 10.

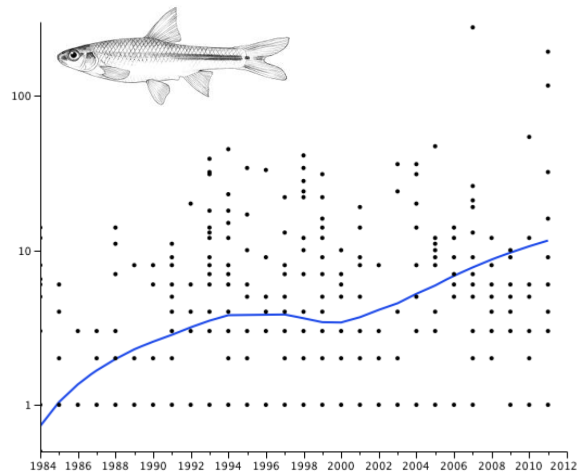


Figure 155. Trawls. Long-term Trends in Spottail Shiner (*Notropis hudsonius*). Cove Stations 7 and 10.

Spottail shiner and sunfish (bluegill and pumpkinseed) are typically captured in low numbers relative to anadromous species, but they are consistently observed in the majority of all trawl and seine samples (Figure 154-157). 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 and do not show a clear increase.

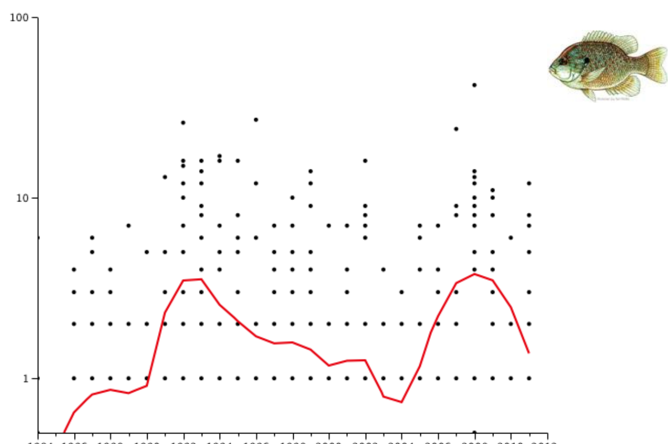


Figure 156. Trawls. Long term trend in Pumpkinseed (*Lepomis gibbosus*). Cove stations 7 and 10.

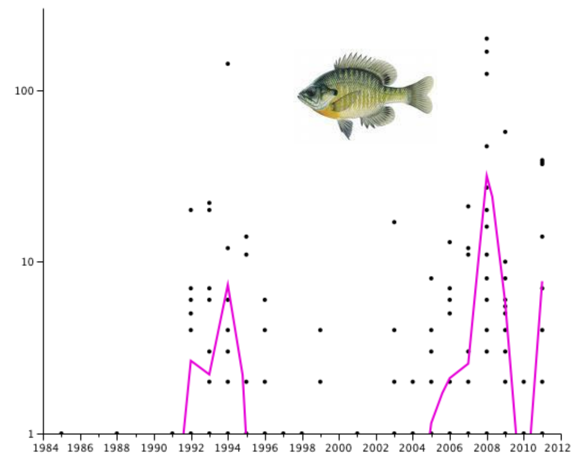


Figure 157. Trawls. Long term trend in Bluegill (*Lepomis macrochirus*). Cove stations 7 and 10.

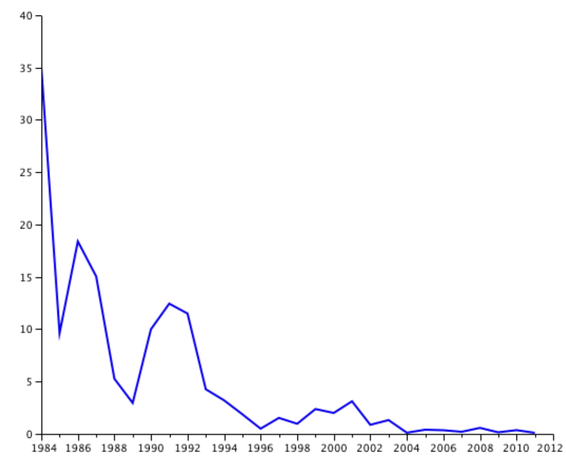


Figure 158. Annual Averages. Brown Bullhead. Cove Stations 7 and 10.

Very few brown bullhead were captured during 2011, 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 158 & 159).

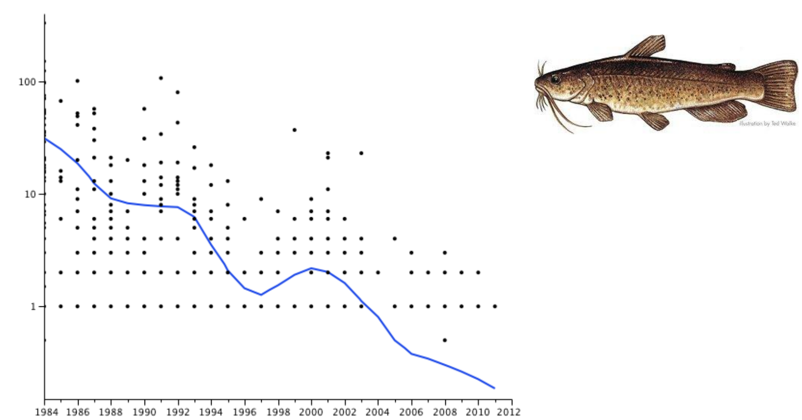


Figure 159. Trawls. Long term trend in Brown Bullhead (*Ameirus nebulosus*; #/trawl). Cove stations 7 and 10.

Tessellated darter were consistently encountered at low abundance in trawl samples - at typical abundances of 1 to 2 individuals per trawl when observed at stations 7 and 10 (Figure 160).

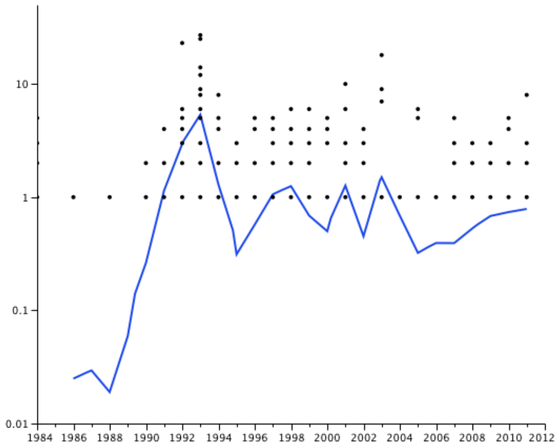


Figure 160. Trawls. Long term trend in Tessellated Darter (*Etheostoma olmstedi*). Cove stations 7 and 10.

At the river channel station (station 9), 2011 marks a four-year downward trend in total fish catch rate (Figure 161). Overall, catch rates of white perch and all species combined at station 9 were typically lower and less variable than at inner cove stations. Much of the variation at station 9 is directly attributable to the catch of white perch, but other species have become more important in recent years. These trends are also evident in the LOWESS curves, both for total catch and white perch (Figures 162 & 163). The recent low catches do not bring catches to a historic low, however; trends in mean catch rate for total catch and white perch at station 9 have changed markedly through the history of the survey.

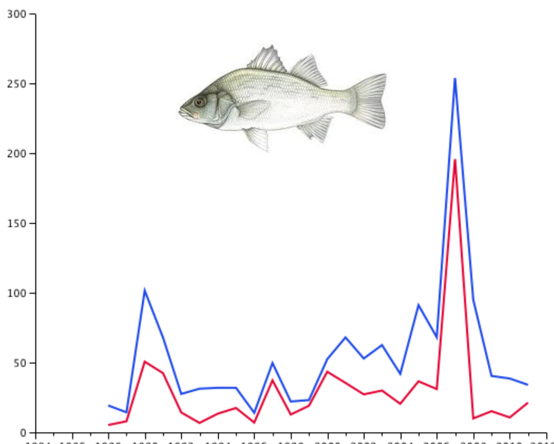


Figure 161. Trawls. Annual Averages. River Station (9). Total catch (blue), white perch (red)

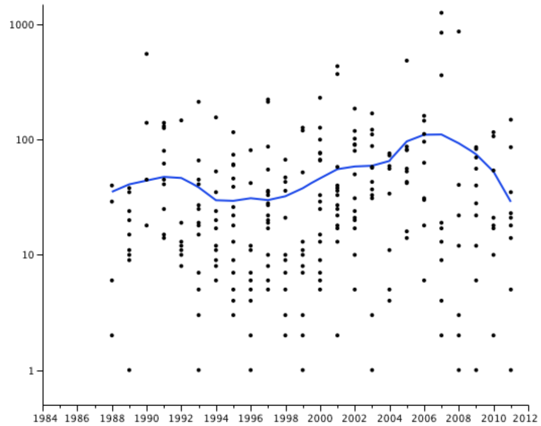


Figure 162. Trawls. Long term trend in Total Catch. River Station (9).

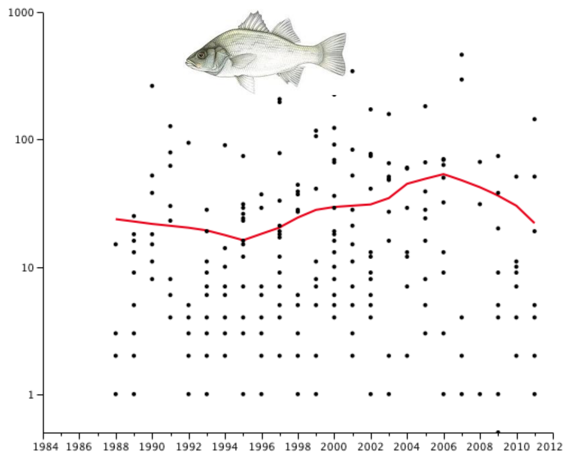


Figure 163. Trawls. Long term trend in White Perch (*Morone americana*). River Station (9).

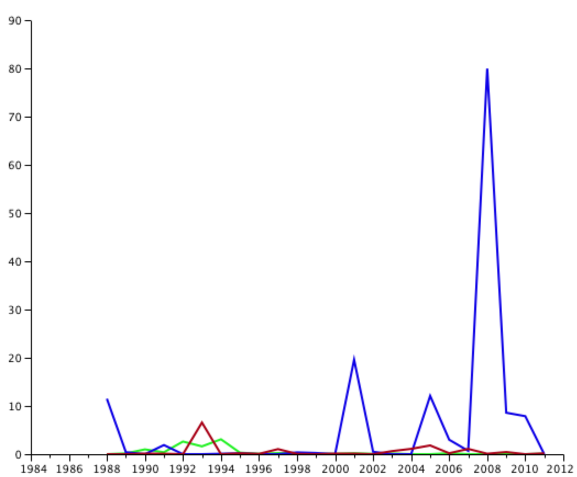


Figure 164. Trawls. Annual Averages. River Station (9). Bay anchovy (Blue) Spottail shiner (red) Americal eel (green)

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 164-166). Trends in mean catch rates for bay anchovy and spottail shiner were qualitatively similar to stations 7 and 10, but the absolute values were lower with one notable exception. A record catch of bay anchovy in September of 2008 was the highest on record and indicates strong reproductive success and/or upstream transport.

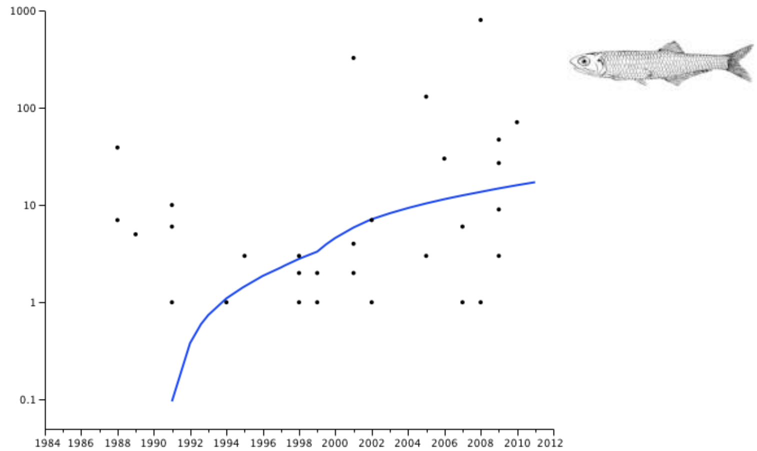


Figure 165. Trawls. Long term trend in Bay Anchovy (*Anchoa mitchilli*). River station (9).

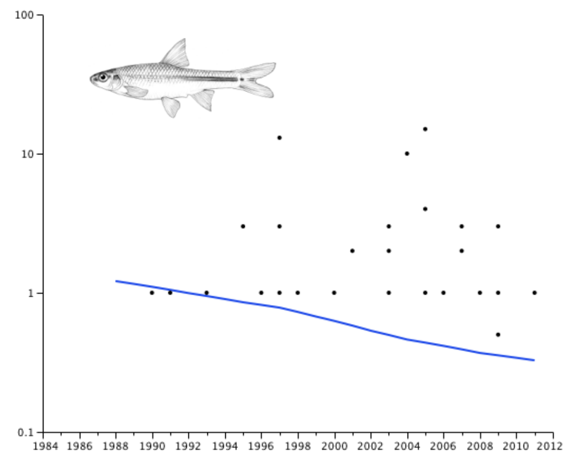


Figure 166. Trawls. Long term trend in Spottail Shiner (*Notropis hudsonius*). River station (9).

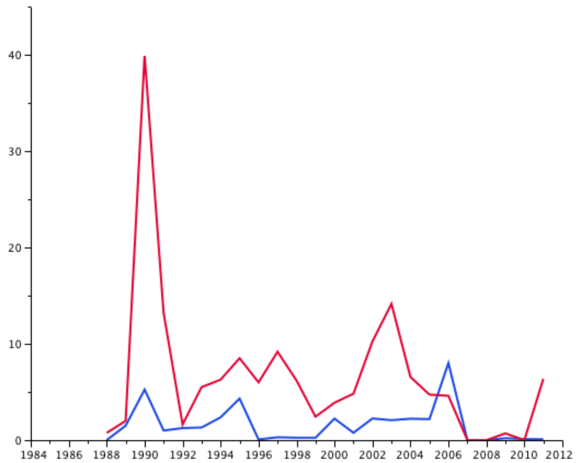


Figure 167. Trawls. Annual Averages. River Station (9). Brown bullhead (blue) and channel catfish (red).

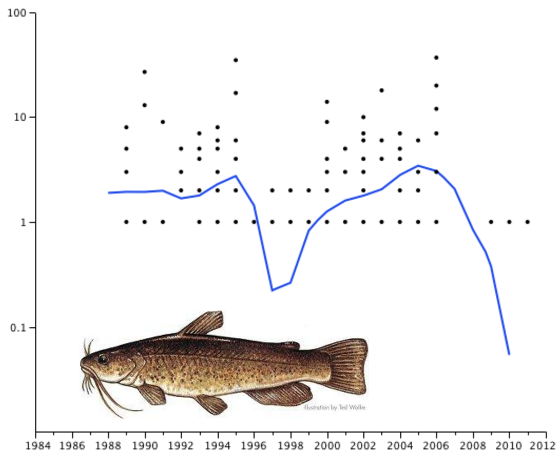


Figure 168. Trawls. Long term trend in Brown Bullhead (*Ameiurus nebulosus*). River Station (9).

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 167-170). 2011 ranked as the lowest year (together with 2007) in mean catch rate for brown bullhead at station 9, while channel catfish catch rates were relatively high compared to the last 6 years. Long-term mean trends are variable but seem to identify a decline in both brown bullhead and channel catfish (Figures 168 & 169). 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 170). The blue catfish could very well be replacing other catfishes and bullheads. A detailed study into this possible replacement mechanism is warranted and will be initiated in 2012.

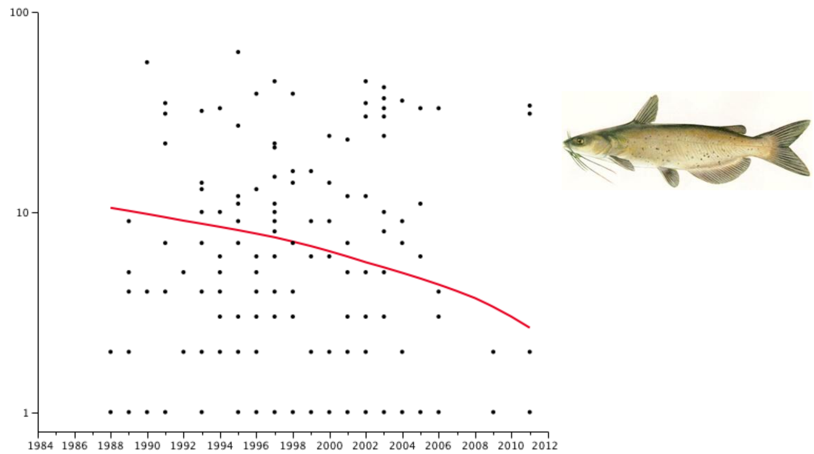


Figure 169. Trawls. Long term trend in Channel Catfish (*Ictalurus punctatus*). River Station (9).

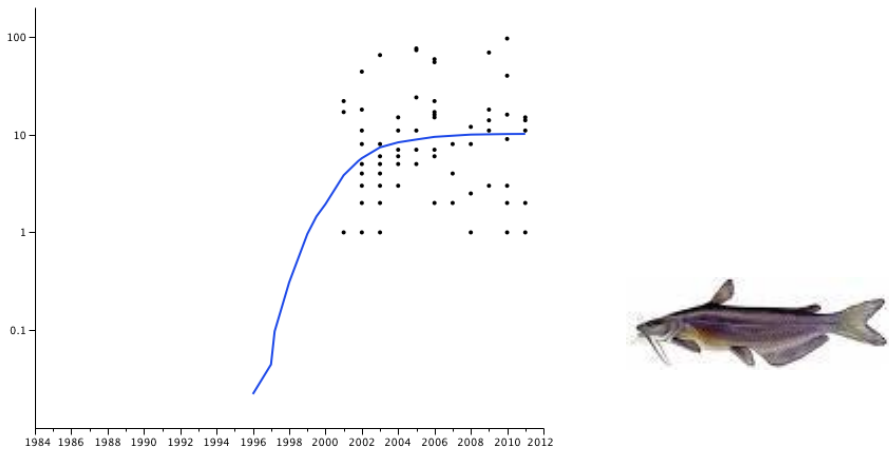


Figure 170. Trawls. Long term trend in Blue Catfish (*Ictalurus furcatus*). River Station (9).

Station 9 represented low but consistent catch rates for the demersal species tessellated darter and hogchoker (Figure 171-173). On rare occasions, catches exceeded 50 individuals per trawl, but when encountered typical catch rates for either species were less than 4 per trawl. The mean annual trend does seem to indicate a general decline in catch rates for each of these species over the time-span of the survey. These declines could be an indication of reduced environmental quality. Though both not very sensitive, these species are closely associated with the bottom and can thereby be good indicators of potentially harmful pollutants that accumulate in the sediment. No separate study has been performed however to determine the cause of the decline.

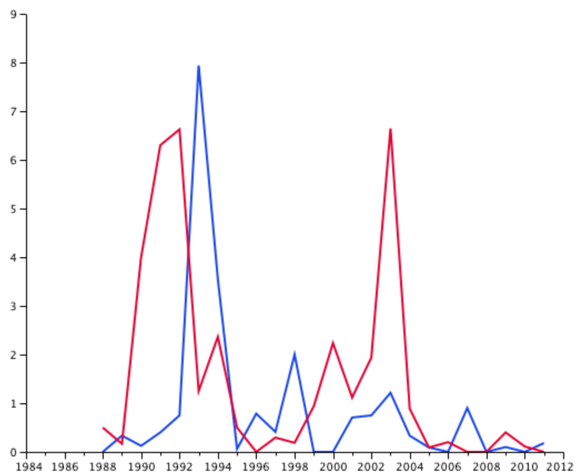


Figure 171. Trawls. Annual Averages. Tessellated Darter (blue) hogchoker (red). River Station (9).

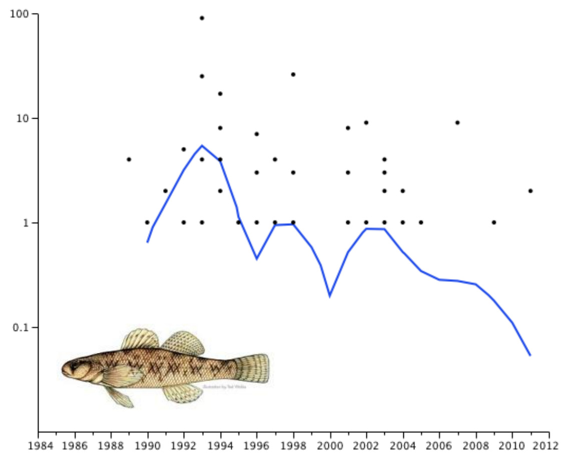


Figure 172. Trawls. Long term trend in Tessellated Darter (*Etheostoma olmstedi*). River Station (9).

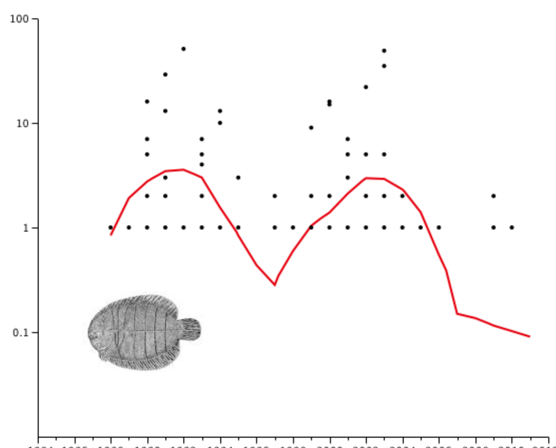


Figure 173. Trawls. Long term trend in Hogchoker (*Trinectes maculatus*). River Station (9).

Seines

Mean annual seine catch rates were generally less variable than trawl catch rates, but the long-term trend with a period of lower catch rates during the mid-1990s is reflected in seine samples (Figures 174 & 175). This was reflected by only a slight drop in the moving average (LOWESS trend) 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 175). 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 20; Figure 179). Overall, white perch and banded killifish have been the dominant species in seine samples throughout the survey, and this pattern also held in 2011.

Table 20. Mean catch of adult and juvenile fishes per seine at Stations 4, 6, and 11 and all months

Year	All species	white perch	banded killifish	blueback herring	alewife	spottail shiner	inland silverside
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 21. 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
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 22. Mean catch of adult and juvenile fishes per seine in all months at each station

Year	Station 4	Station 6	Station 11
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 174. Seines. Annual Average over All Stations (4, 6, and 11). All Species.

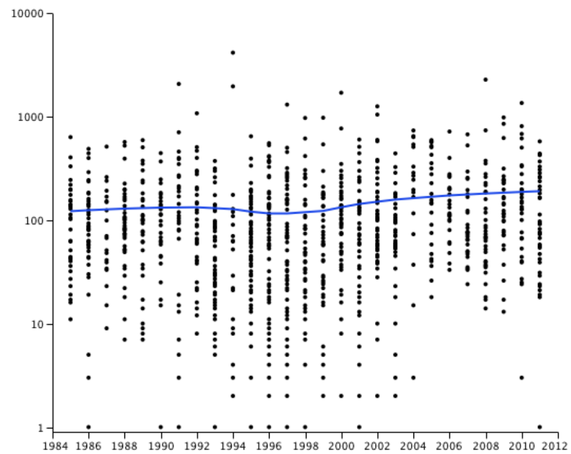


Figure 175. Seines, all stations Long term trend in Total Seine Catch.

Over the course of the survey mean annual seine catch rates of white perch have exhibited a gradual decline (Figures 176), and the LOWESS algorithm indeed shows a decline over this period (Figure 177). 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. However, the catches at the inner cove (station 7 and 10) are relatively stable over the course of the survey, and may even show an increase since 2003 (Figure 153c). 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 are needed to understand the relative importance of these factors. One approach that has been used to sample SAV was drop-ring sampling, which is reported in a manuscript that has recently been published in the journal Environmental Monitoring and Assessment (Kraus and Jones 2011). In 2012, fyke nets will be added to the sampling gear that can sample 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 the entire sampling season. Vegetated aquatic habitats may enhance fish production in estuarine and freshwater habitats by providing an abundant supply of invertebrate prey for larval and juvenile fish consumption (Yozzo and Odum 1993). This concept is supported by the fact that mean annual catch rates of banded killifish have exhibited a long-term increasing trend (Figure 176 & 178). Banded killifish have been the dominant species in seine samples during the past ten years and are known to be associated with SAV. Important diet items for banded killifish are invertebrates associated with the local vegetation like ostracods, other microcrustaceans, and small dipteran larvae (www.fishbase.org).

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.

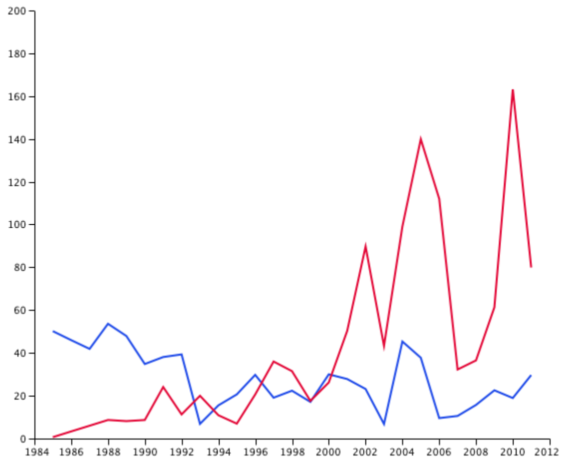


Figure 176. Seines. Annual Average Stations 4, 6, and 11. White Perch (blue) and Banded Killifish (red).

Long-term trends in mean annual catch rates (Figure 176) and long-term LOWESS trends (Figures 164b,c) for the two dominant species in seine hauls have exhibited a negative association (r=-0.33) over the course of the survey (Figure 176). 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 177 & 178).

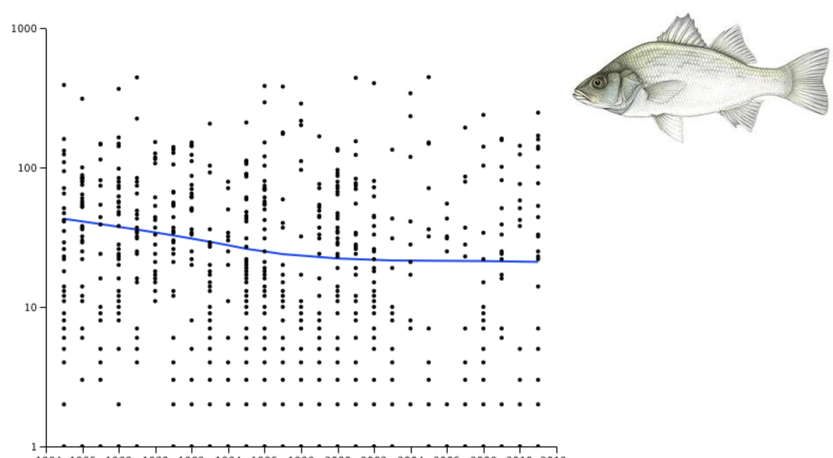


Figure 177. Seines. Long term trend in White Perch (*Morone americana*). All Stations.

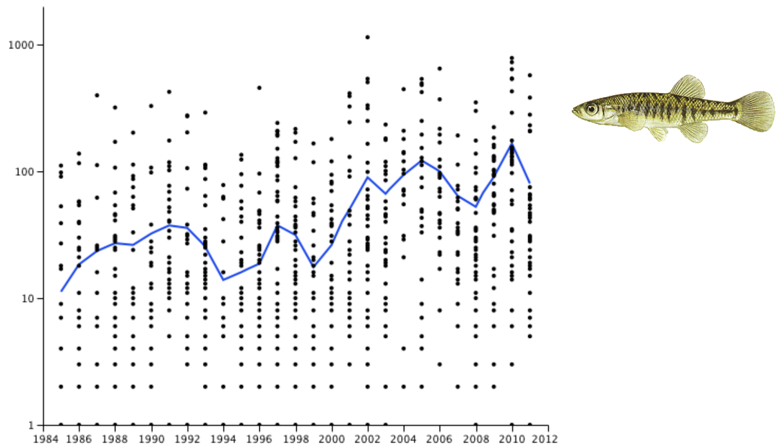


Figure 178. Seines. Long term trend in Banded Killifish (*Fundulus diaphanus*). All Stations.

Mean annual catch rates for river herring (alewife and blueback herring) have exhibited sporadic peaks related to the capture of large schools of fish (exceeding 200 for alewife and approaching 100 individuals for blueback herring) in single hauls (Figure 179). Typically, less than 10 of either species were captured in a single sample (Figures 180 & 181). Though very variable, long term trends may indicate a slight decline in overall catches of alewife and blueback herring.

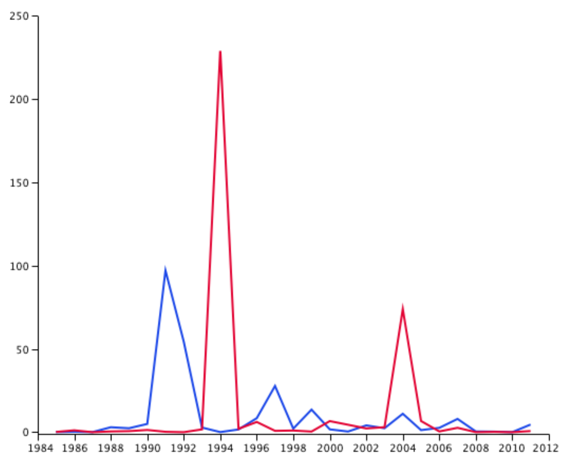


Figure 179. Seines. Annual Average over 4, 6, and 11 Stations. Blueback Herring (blue) and Alewife (red).

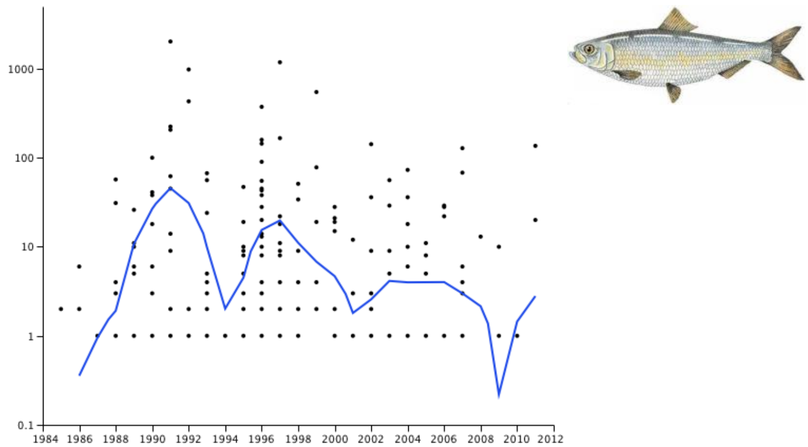


Figure 180. Seines. Long term trend in Blueback Herring (*Alosa aestivalis*). All Stations.

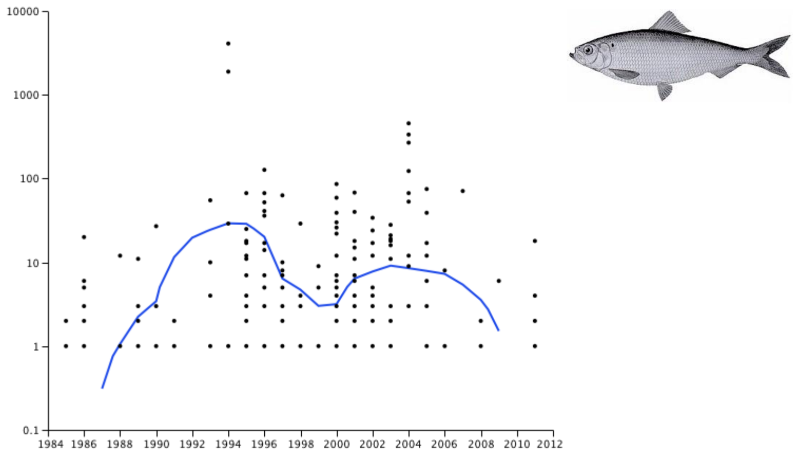


Figure 181. Seines. Long term trend in Alewife (*Alosa pseudoharengus*). All Stations.

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 182). Although a few high abundance years (1991, 2000, and 2004) have occurred, a general declining trend in catches since 2000 was present (Figure 183 & 184). This may reflect the refuge potential of SAV, as our gear does not effectively sample fishes that are protected by thick SAV stands. The addition of fyke nets in 2012 may help resolve whether declines in catches signify a decline in abundance of these species, or increased protection by SAV.

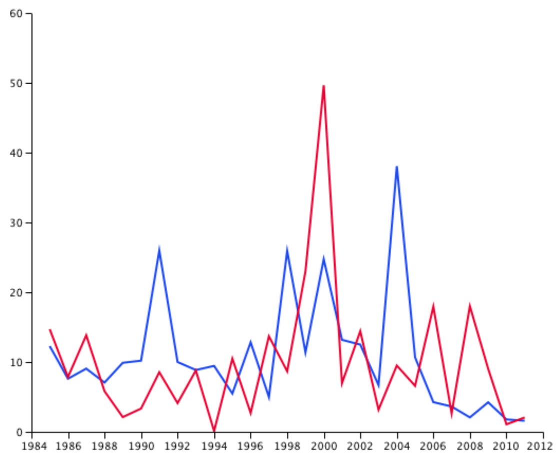
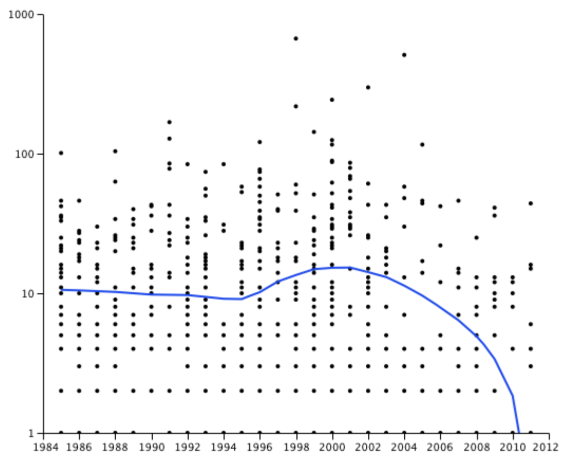


Figure 182. Seines. Annual Average over 4, 6, and 11 Stations. Spottail Shiner (blue) and Inland Silverside (red).



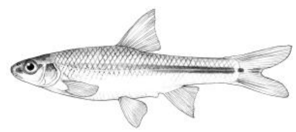
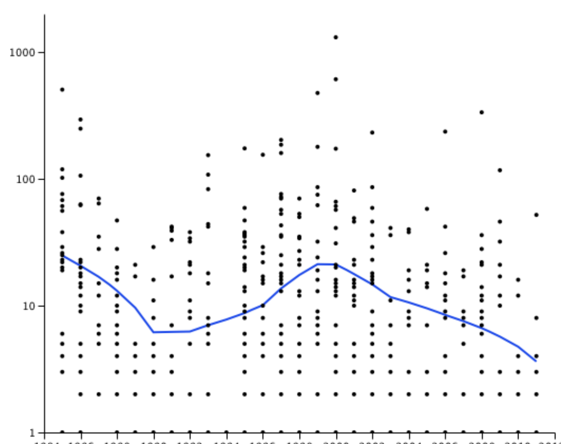


Figure 183. Seines. Long term trend in Spottail Shiner (*Notropis hudsonius*). All Stations.



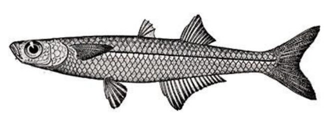


Figure 184. Seines. Long term trend in Inland Silverside. (*Menidia beryllina*). All Stations.

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

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

Currently, plans are underway to incorporate fyke nets in the standard sample design. Fyke nets are passive gear that can be set up within the SAV beds. For the 2012 sampling season, fyke nets will be set for up to 24 hours each sampling trip in stations 4 and 10. The first year will be experimental, and different mesh sizes and soaking time will be tested. When deemed successful, fyke nets will be incorporated in the standard sampling design of the survey.

G. Submersed Aquatic Vegetation (SAV) Trends: 1994-2011

A comprehensive set of annual surveys of submersed aquatic vegetation in the Gunston Cove area is available on the web at http://www.vims.edu/bio/sav/. This is part of an ongoing effort to document the status and trends of SAV as a measure of Bay recovery. Maps of SAV coverage in the Gunston Cove area are available on the web site for the years 1994-2008 except for 2001. Unfortunately, no results were available for 2011 as overflights were not successful in capturing usable images. However, we have added 2011 data on chlorophyll and Secchi to our ongoing summary graph relating these factors to SAV extent.

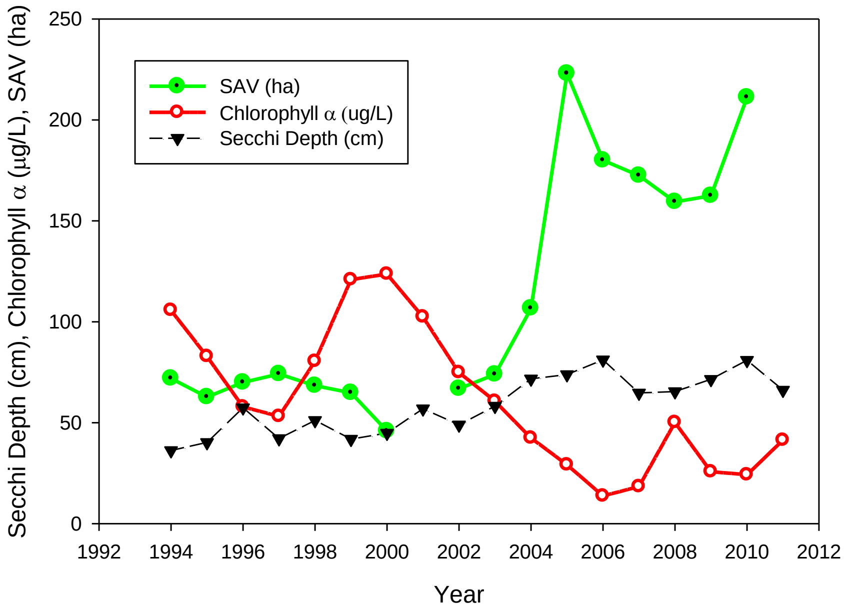


Figure 185. Inner Cove SAV Coverage. Graphed with average summer (June-September) Depth-integrated Chlorophyll a (ug/L) and Secchi Depth (cm) measured at Station 7 in Gunston Cove.

H. Benthic macroinvertebrates

Benthic invertebrates have been monitored in a consistent fashion for the last 3 years. Those data are assembled below (Table 23) and general trends are consistent among years. Oligochaetes are the most abundant at both sites. 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. Isopods were found only in 2010. The observed differences are related to sediment characteristics (very fine in cove; coarser in the river).

Table 23. Benthic macroinvertebrates: annual averages (#/petite ponar)

	Station 7 (#/petite ponar)			Station 9 (#/petite ponar)		
Taxon	2009	2010	2011	2009	2010	2011
Oligochaeta	72.5	21.1	18.3	35.9	42.7	51.6
Amphipoda	1.9	0.7	2.0	22.8	17.5	30.7
Chironomidae	16.8	7.0	5.6	0.9	0.0	1.4
Corbicula	0.0	0.0	0.2	27.5	3.2	0.4
Gastropoda	0.0	0.3	1.3	13.7	0.0	2.0
Isopoda	0.0	0.1	0.0	0.0	1.3	0.0
Turbellaria	0.0	0.6	0.0	1.2	0.9	0.0
Hirundinea	0.0	0.0	0.1	0.0	0.0	0.0
Total	72.5	21.1	18.3	102.8	65.5	86.3

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

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