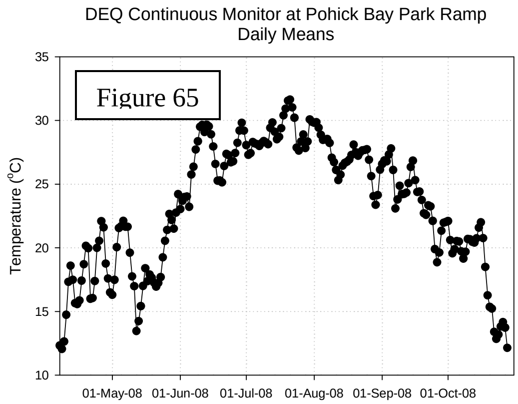
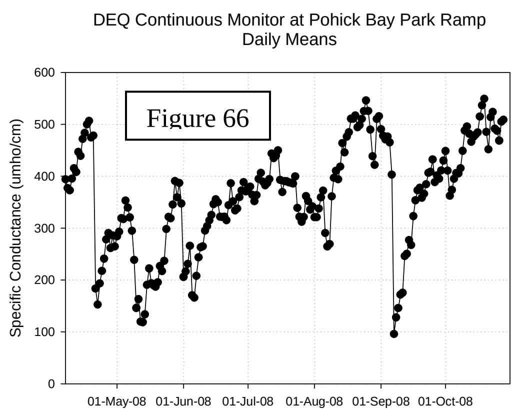
DISCUSSION

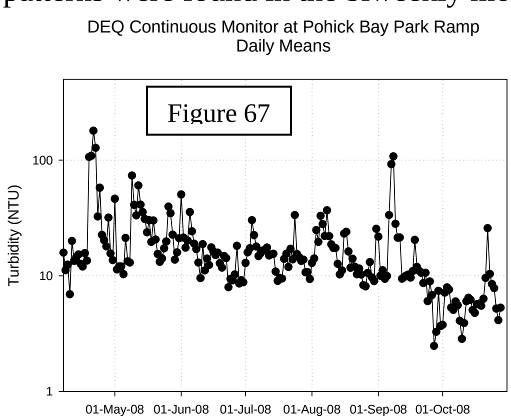
A. 2008 Data

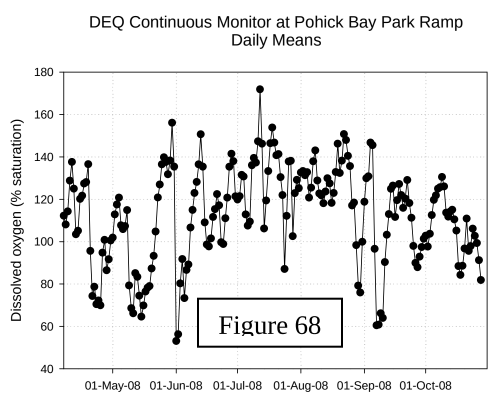
The outstanding weather events in 2008 were the warmer than average temperatures especially in June and the higher than average rainfall during all months except August. There were 8 days with high temperatures above 90°F (32.2°C) in June which is unusual. This was reflected in high water temperatures observed in that month (Figure 65, DEQ continuous monitor data). Potomac River flows were above average in late April and May with two large surges of up to 10,000 cfs. June and July had near normal flows, but August was below normal reflecting low rainfall in that month. Flows again exceeded normal in September. Local tributary flows were also above normal in spring and well below normal in August. The low water temperatures observed in May probably reflected both slightly below normal temperatures and frequent flushing by runoff.



Specific conductance was relatively high through mid April, but declined markedly in May and then slowly increased through the remainder of the year as depicted by our biweekly monitoring (Figure 6). The daily data from the DEQ monitor (Figure 66) show that there were actually a series of steep declines and subsequent recoveries which were due to the high rainfall events from late April through early June. These storm events also affect other water quality parameters. For example, turbidity (Figure 67) increases and dissolved oxygen (Figure 68) shows a marked decrease as storm runoff impacts the cove. Similar, but more broadly based patterns were found in the biweekly monitoring data.







A number of other parameters exhibited a relationship to the high flows events in May by either increasing or decreasing markedly. Ammonia nitrogen, total phosphorus, and total suspended solids increased markedly at both cove and river stations. TSS increases were directly related to the increased flows bringing in more water laden with suspended solids and resulted in substantially decreased water clarity (Secchi disk depth and light attenuation coefficient). Both phosphorus and ammonia nitrogen bind to solids and this could be responsible for their increases. Alkalinity and chloride both decreased markedly in May and chlorophyll *a* showed a clear decline. The response of plankton was less clear. In the cove phytoplankton density increases were delayed until June, but biovolume rose in late May. In the river phytoplankton density and biovolume actually peaked in mid May and then declined in late May. Rotifer density was suppressed in the cove until early June. *Bosmina* and *Diaphanosoma* remained low in spring, but *Daphnia* actually showed its strongest peak of the year in May in the cove. Adult and juvenile copepods also were at high levels in the cove in May, although not in the river.

In the aftermath of the high May inflows, most parameters resumed their usual seasonal and spatial patterns. Temperature increased rapidly in June and remained above 25°C through mid September. Specific conductance rebounded strongly in June and then gradually increased through the remainder of the summer as did chloride. Dissolved oxygen was generally above saturation in the cove reflecting strong photosynthesis whereas values were generally somewhat below saturation in the river. Consistently higher pH was observed in the cove than the river consistent with higher DO's. Secchi depth rebounded in June and stabilized at 60-80 cm for the remainder of the study period. Ammonia nitrogen decreased in June remaining somewhat higher in the river. Nitrate showed minimal response to the May flows and did not vary much for the rest of the year remaining generally higher in the river. Organic nitrogen showed a gradual rise through the summer in the cove, but little change in the river. Following the May spike, total P dropped back at both sites remaining virtually constant at equivalent at about 0.07 mg/L at both sites. SRP showed little seasonal pattern being very low in the cove and somewhat higher in the river. N:P ratio was similar at both sites exhibiting a mild summer peak, always indicating P limitation. BOD was consistently higher in the cove, but did not change much seasonally. TSS and VSS settled to constant levels after May. TSS values were similar at both sites and VSS was consistently higher in the cove.

In the cove chlorophyll concentrations rebounded strongly in late May and continued to climb through July reaching higher levels than in recent years. In the river chlorophyll increased through June at much lower levels and declined slowly for the remainder of the year. In the cove phytoplankton density and biovolume increased strongly in June and remained high for the remainder of the summer. In the river there was little change in density seasonally, but a late summer increase in biovolume. Cyanobacteria dominated phytoplankton density in the cove alternating between *Oscillatoria* and *Aphanocapsa*. In the river densities were much lower and an unknown cyanobacterium and *Chroococcus* alternated with *Oscillatoria*. Cryptophytes were also important in density values in the river. Biovolume in the cove increased strongly in late May led by cryptophytes and then diatoms in June including both *Melosira* and discoid centrics. The rest of the summer saw a diverse assemblage of all of the major groups. In the river diatoms were most important all year, principally *Melosira* and discoid centrics.

Rotifers regained abundance in June and remained numerous throughout he year in the cove, with *Brachionus* being dominant for most of the year. In the river rotifers were much less abundant with only a single peak in late August. The small cladoceran *Bosmina* was found in moderate numbers in summer samples from both sites with a peak in the river in late August. The larger cladoceran *Diaphanosoma* was quite high in late June and July at both sites. Following its high abundance in mid May, *Daphnia* was fairly uncommon. *Leptodora* was most common in June reaching similar maxima in both cove and river. Copepod nauplii were present at moderate values in the cove over the entire year and showed two peaks in the river. *Eurytemora* was abundant in some samples in May and June and was rarer in the late summer and fall. *Diaptomus* peaked in May and June in the cove, but was rare all year in the river. Cyclopoid copepods were abundant in the cove in the spring and in the river in summer.

In 2008 ichthyoplankton was dominated by *Dorosoma* sp (gizzard shad) and *Morone* sp. (white perch or striped bass) which comprised over 90% of the catch. Alosids and yellow perch were found reduced numbers.

In trawls, the majority of the catch was composed of 4 species: bay anchovy, bluegill sunfish, pumpkinseed, and white perch. The high abundance of bay anchovy was mainly due to one very large catch at the end of the sampling season. As usual, white perch was found throughout the year at all stations. The sunfish were found throughout the year, but mainly at cove sites. In both groups, adults tended to be captured in spring and juveniles in the late summer. The most abundant species collected in seines was gizzard shad followed by banded killifish, the dominant in most recent years, and white perch, a distant third. Gizzard shad abundance was due to large numbers of juveniles collected in July and August. Banded killifish and white were collected at all stations and throughout the year. Our first northern snakehead was collected in April in Pohick Bay.

Submersed aquatic vegetation (SAV) continued to be present at high densities in both Pohick and Accotink Bays and to penetrate the inner portions of Gunston Cove in 2008. A fringe of SAV was observed all along the Gunston Cove shoreline and a band of lower density SAV was found across the cove mouth. Coverage reported by aerial surveys was much elevated over pre-2005 levels, but slightly reduced from 2007 and less extensive than in 2005. This was associated with reduced water transparency which in 2008 was due more to phytoplankton than in 2007.

B. Water Quality Trends: 1983-2008

To assess long-term trends in water quality, data from 1983 to 2008 were pooled into a single data file. Then, subgroups were selected based on season and station. For water quality parameters, we focused on summer (June-September) data as this period is the most stable and often presents the greatest water quality challenges and the highest biological activity and abundances. We examined the cove and river separately with the cove represented by Station 7 and the river by Station 9. We tried several methods for tracking long-term trends, settling on a scatterplot with LOWESS trend line. Each observation in a particular year is plotted as an open circle on the scatterplot. The LOWESS (locally weighted sum of squares) line is drawn by a series of linear regressions moving through the years. We also calculated the Pearson correlation coefficient and performed linear regressions to test for statistical significance of a linear relationship over the entire period of record (Tables 10 and 11). This was similar to the analysis performed in previous report.

Table 10
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1984-2008
GMU Water Quality Data
June-September

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Temperature	0.156	0.064	0.015	0.068	----	NS
Conductivity, standardized to 25°C	0.160	2.98	0.015	0.003	----	NS
Dissolved oxygen, mg/L	0.016	----	NS	0.164	0.031	0.023
Dissolved oxygen, percent saturation	0.048	----	NS	0.171	0.400	0.017
Secchi disk depth	0.628	1.49	<0.001	0.292	0.603	<0.001
Light extinction coefficient	0.553	0.112	<0.001	0.062	----	NS
pH, Field	-0.116	----	NS	0.067	----	NS
Chlorophyll, depth-integrated	-0.454	-4.15	<0.001	-0.172	-0.677	0.019
Chlorophyll, surface	-0.463	-4.47	<0.001	-0.170	-0.799	0.017

For Station 7, n=226-245 except pH, Field where n=179 and Light extinction coefficient where n=166.
For Station 9, n=185-199 except pH, Field where n=147 and Light extinction coefficient where n=136.

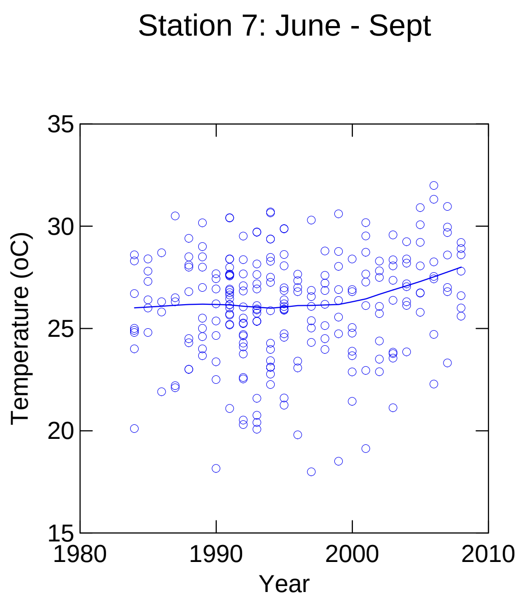
Significance column indicates the probability that a correlation coefficient this large could be due to chance alone. If this probability is greater than 0.05, then NS (not significant) is indicated.

Table 11
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1983-2008
Fairfax County Environmental Laboratory Data
June-September

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Chloride	0.052	----	NS	0.061	----	NS
Lab pH	-0.292	-0.026	<0.001	-0.257	-0.018	<0.001
Alkalinity	-0.110	----	NS	0.070	----	NS
BOD	-0.547	-0.191	<0.001	-0.444	-0.065	<0.001
Total Suspended Solids	-0.239	-0.961	<0.001	0.056	----	NS
Volatile Suspended Solids	-0.342	-0.810	<0.001	-0.356	-0.181	<0.001
Total Phosphorus	-0.465	-0.0043	<0.001	-0.250	-0.0010	<0.001
Soluble Reactive Phosphorus	0.054	----	NS	0.213	0.0004	<0.001
Ammonia Nitrogen	-0.182	-0.015	0.001	-0.238	-0.0034	<0.001
Un-ionized Ammonia Nitrogen	-0.216	-0.0042	<0.001	-0.297	-0.0005	<0.001
Nitrite Nitrogen	-0.264	-0.0031	<0.001	-0.138	-0.0012	0.023
Nitrate Nitrogen	-0.445	-0.036	<0.001	-0.520	-0.037	<0.001
Organic Nitrogen	-0.458	-0.055	<0.001	-0.287	-0.014	<0.001
N to P Ratio	-0.139	-0.218	0.010	-0.469	-0.678	<0.001
Chlorophyll a, surface	-0.254	-3.01	0.004	-0.172	-1.14	0.05

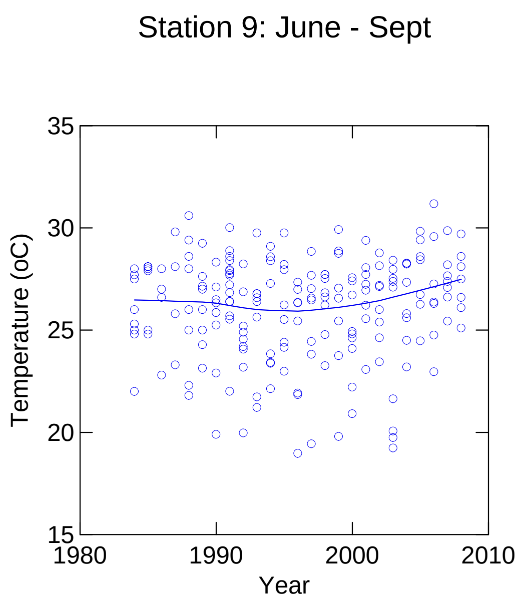
For Station 7, n=309-349 except Nitrite Nitrogen where n=271 and Chlorophyll a where n=130.
For Station 9, n=308-357 except Nitrite Nitrogen where n=270 and Chlorophyll a where n=130.

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



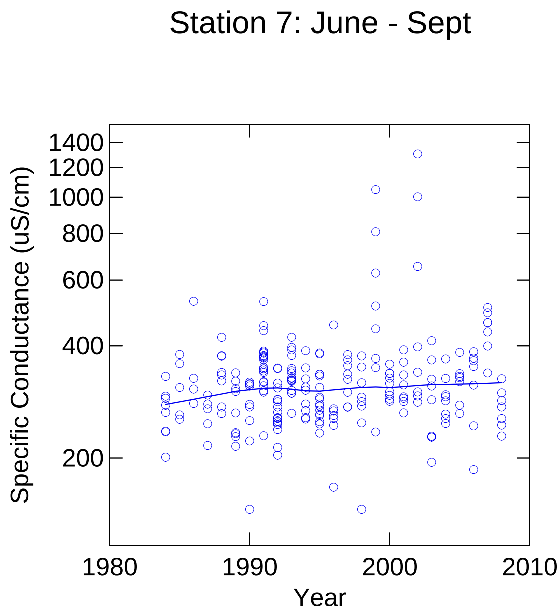
Water temperatures during the summer months generally varied between 20 and 30°C over the study period (Figure 69). The LOWESS curve indicated an average of about 26°C with a distinct upward trend in the last few years approaching 28ºC. Linear regression analysis indicated a significant linear trend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

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



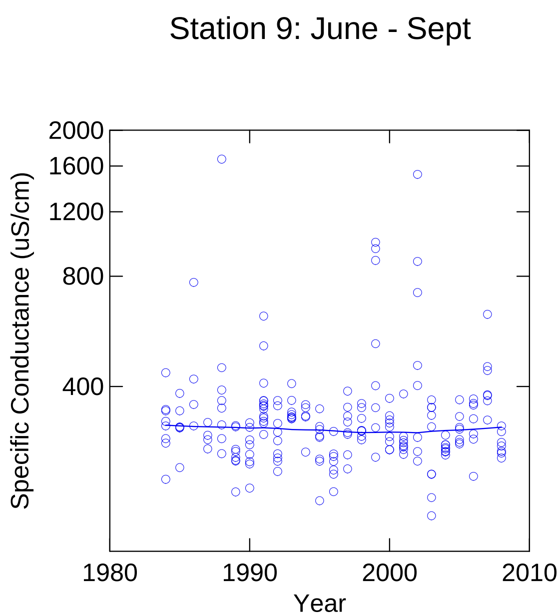
In the river summer temperatures have occupied a similar range to that in the cove (Figure 70). The trend line did show a little dip in the mid-1990's and a slight rise since then. Linear regression over the study period was not significant (Table 10). The increase over the last 5 years is less obvious than in the cove data.

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



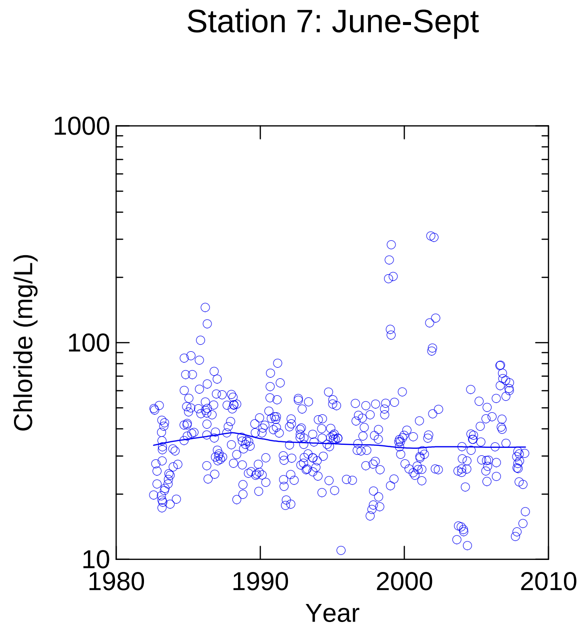
Specific conductance was generally in the range 200-400 uS/cm over the study period (Figure 71). Some significantly higher readings have been observed sporadically. A slight increase in specific conductance was suggested by the LOWESS line over the study period. This was confirmed by linear regression analysis which found a significant linear increase of 3.0 uS/cm per year over the long term study period (Table 10). The results for 2007 were even greater than this trend line would indicate due to the very dry fall which reduced dilution of ions whereas in 2008 values fell below the trend line due to wetter conditions.

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



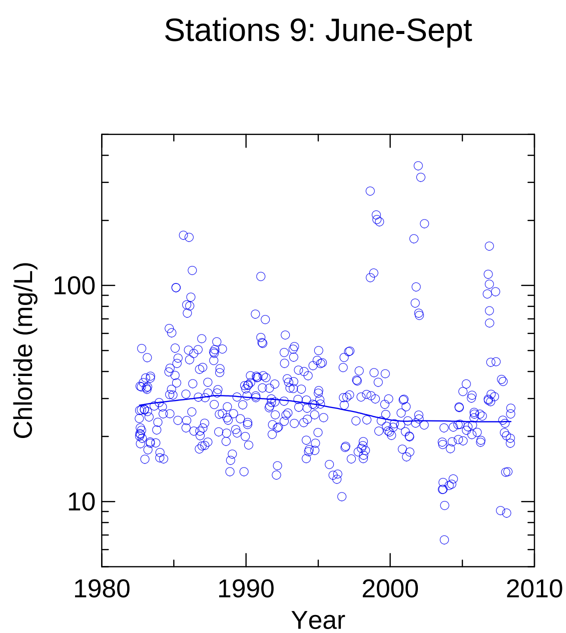
Conductivity values in the river were in the same general range as in the cove (Figure 72). Most values were between 200 and 400 uS/cm with a few much higher values. These higher values are probably attributable to intrusions of brackish water from downstream during years of low river flow. Linear regression did not reveal a significant trend in river conductivity (Table 10). In 2007 values were well above the trend line due to dry conditions, whereas in 2008 they were below the trend line due to higher runoff.

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



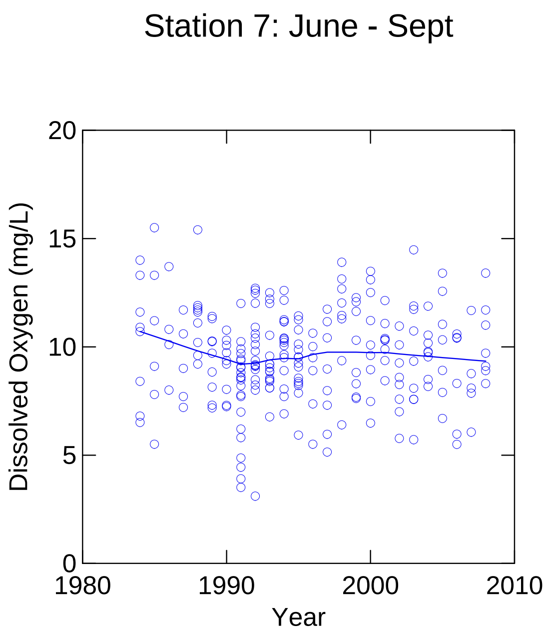
Chloride levels were clustered in a relatively narrow range of 20-60 mg/L for the entire study period (Figure 73). Higher values observed in some years were probably due to the estuarine water intrusions that occur in dry years. The trend line indicated a slight decline during the middle years and a slight increase recently, but a linear regression was not statistically significant (Table 11). 2008 was a wet year yielding lower chloride levels.

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



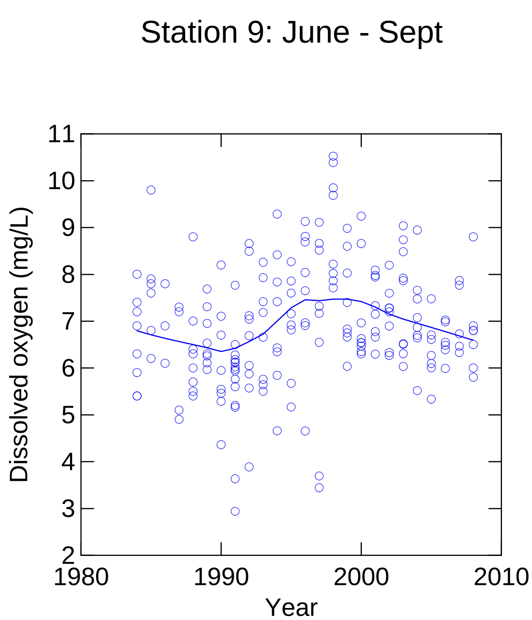
Chloride in the river has been slightly more variable than that in the cove, but in the same general range (Figure 74). The higher readings are again due to brackish water intrusions in dry years. A slight trend of increasing values in the 1980's followed by decreases in the 1990's and leveling in the 2000's was suggested by the LOWESS trend line. However, regression analysis was not statistically significant (Table 11). The 2007 values were well above the trend line, again due to dry conditions. 2008 was below the line due to high runoff

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



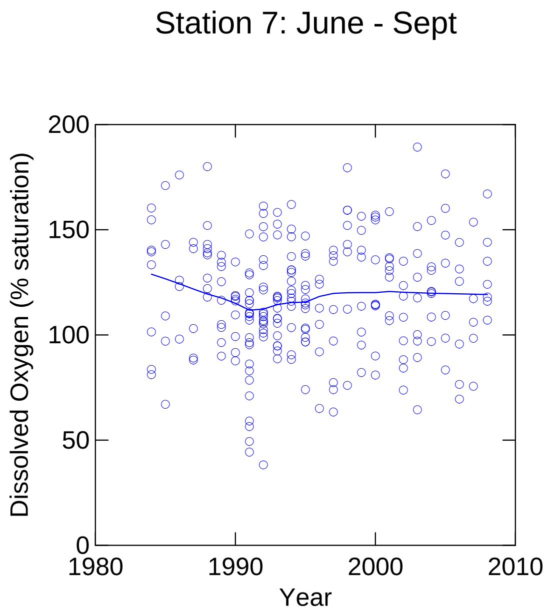
Dissolved oxygen in the cove has generally been in the range 7-12 mg/L during the summer months (Figure 75). A slight downward trend was observed through 1990, but since then the trend line has flattened, suggesting little consistent change and a mean of about 10 mg/L. In the cove dissolved oxygen (mg/L)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

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



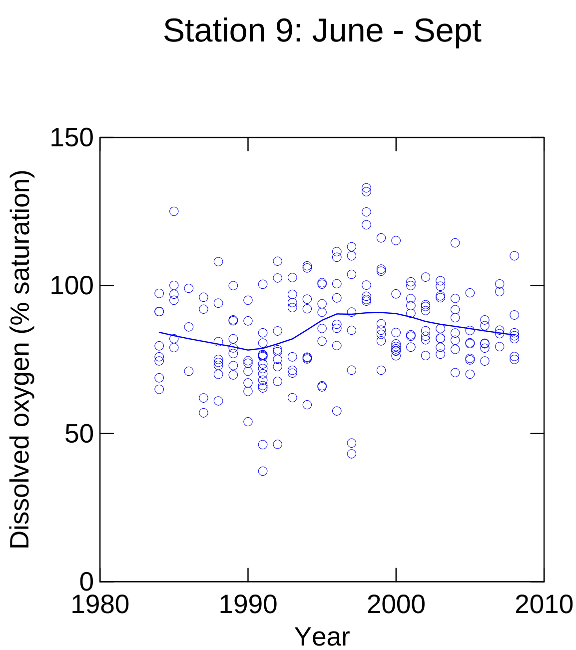
In the river dissolved oxygen values generally were in the range 5-9 mg/L over the long term study period (Figure 76). The LOWESS trend line suggested a decline in the 1980's, an increase in the early to mid 1990's and a decline in the 2000's. The linear regression analysis over the entire period indicated a significant positive trend with slope of 0.031 mg/L per year (Table 10). This implies an increase of 0.9 mg/L over the 26 year study period. However, 2008 readings look very similar to those of 1983.

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



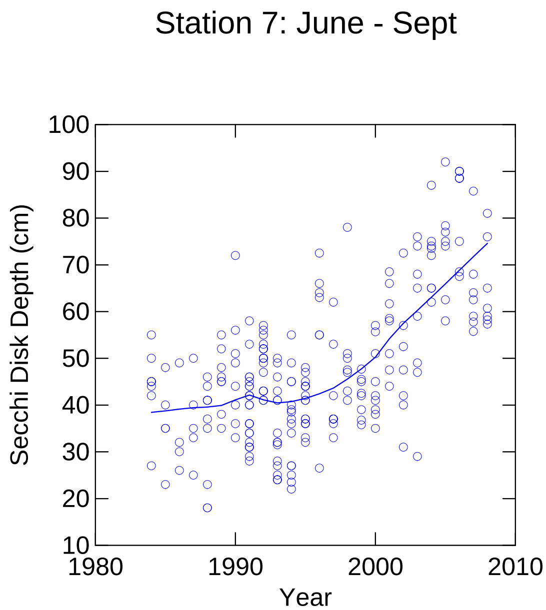
Dissolved oxygen was generally in the range 100-150% saturation in the cove over the long term study period indicating the importance of photosynthesis in the cove (Figure 77). A decline was indicated by the trend line through 1990 followed by a slight recovery in subsequent years. Percent saturation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

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



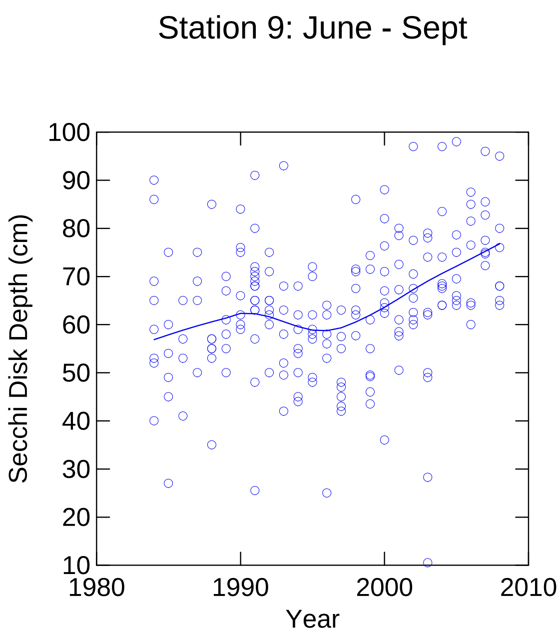
In the river dissolved oxygen was generally less than 100% indicating that photosynthesis was much less important in the river than in the cove (Figure 78). The temporal pattern showed a slight decline in the 1980's, an increase in the 1990's, and a subsequent slight decline in the 2000's. In the river a significant linear increase was indicated by regression analysis with a slope of 0.4% per year yielding a 10.4% increase over the 26 year study (Table 10). However, 2008 readings occupy a similar range to those observed in 1983.

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



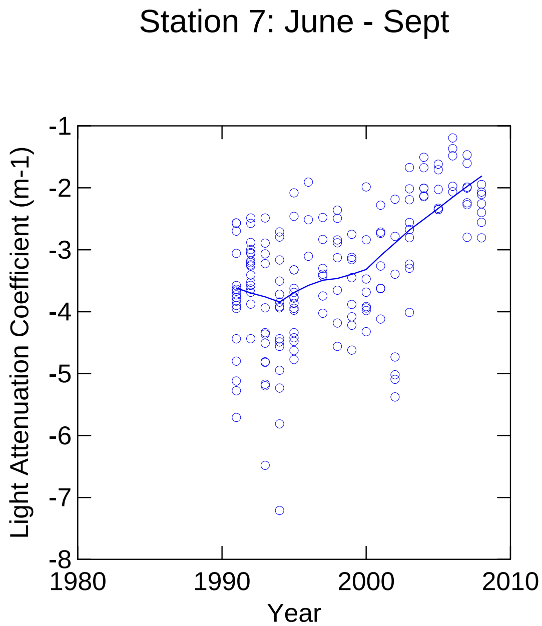
Secchi disk transparency is a measure of water clarity. Secchi disk was fairly constant from 1984 through 1995 with the trend line at about 40 cm (Figure 79). Since 1995 there has been a steady increase in the trend line from 40 cm to nearly 80 cm in 2008. Linear regression was highly significant with a predicted increase of 1.49 cm per year or a total of 37 cm over the long term study period (Table 10).

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



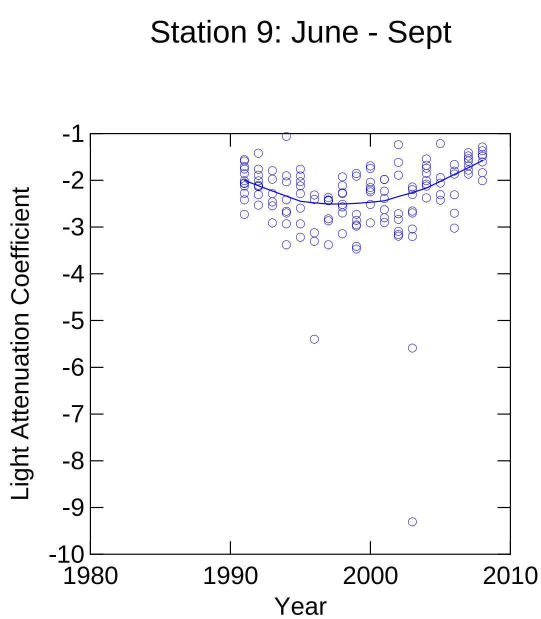
In the river Secchi depth was somewhat greater than in the cove initially (Figure 80). The trend line rose from 55 cm in 1984 to 62 cm in 1991. This was followed by a decline to about 58 cm in 1996 and then a steady increase to the 2008 level of about 78 cm. Linear regression revealed a significant increase of 0.60 cm per year with total increase of 15 cm predicted over the 25 years of study (Table 10).

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



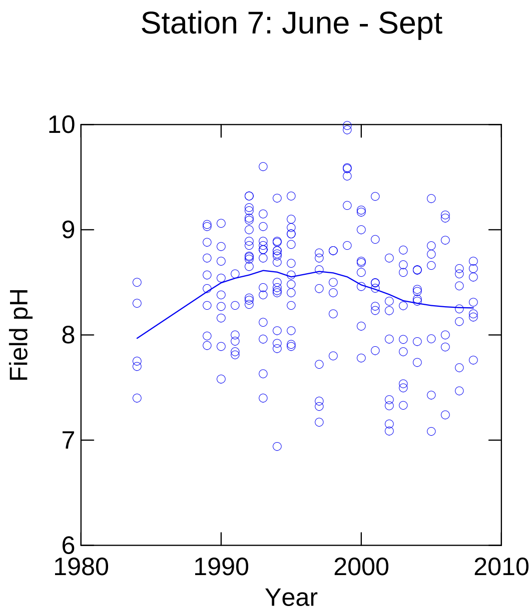
Light attenuation coefficient, another measure of water clarity, reinforced the conclusion that water clarity has been improving in the cove since 1995 (Figure 81). Trend line for the coefficient rose from about -4 to less than -2 m^{-1} during this time. Consistent with this was the regression analysis which revealed a significant linear increase in light attenuation coefficient over the period 1991-2008 with a slope of 0.11 per year yielding a prediction that light attenuation improved by about 1.9 units (Table 10).

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



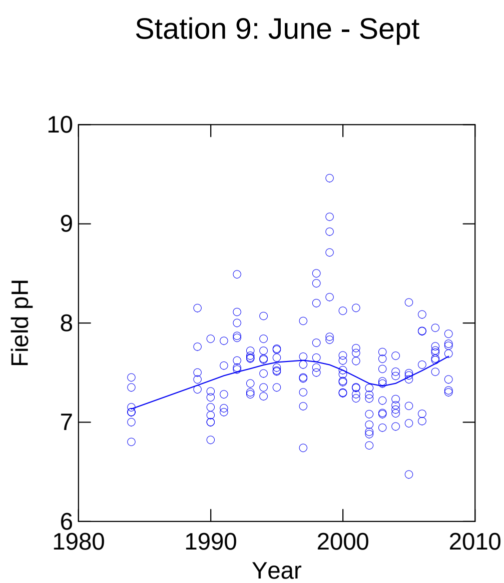
In the river light attenuation coefficient suggested a decline in light transparency between 1991 and 1997 followed by an increase since that time (Figure 82). Regression did not reveal a significant linear trend over the entire period (Table 10).

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



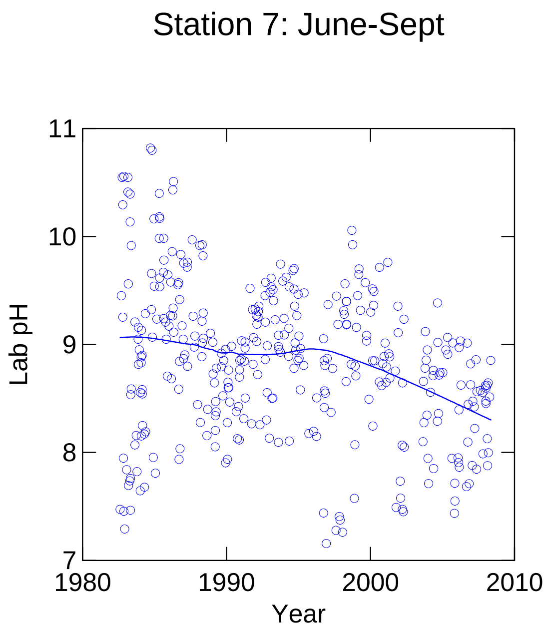
Field pH has not been measured as consistently over the entire study period as other parameters. However, since the mid 1990's there has been a clear decline from about 8.5 to 8.1 in the mean pH value in the cove (Figure 83). Linear regression analysis did not provide evidence of a linear trend when the entire study period was (Table 10).

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



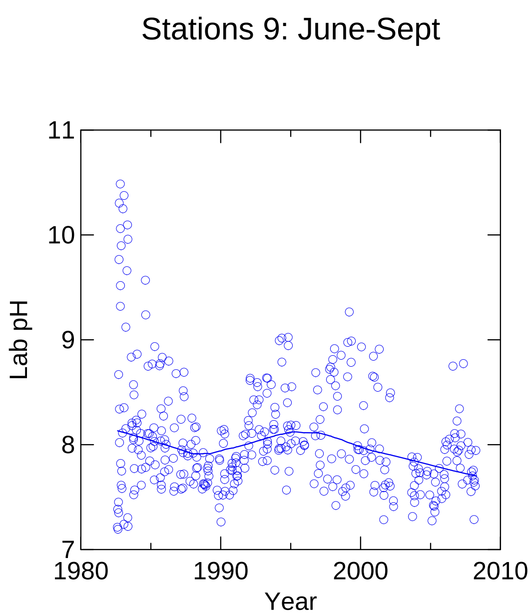
In the river a similar pattern has been observed over this period (Figure 84). pH in the river has been consistently lower by about 1 pH unit than in the cove. A gradual increase from 7.2 in 1989 to 7.7 in 1998 has been recently followed by a decline to about 7.2. In recent years pH has again increased.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

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



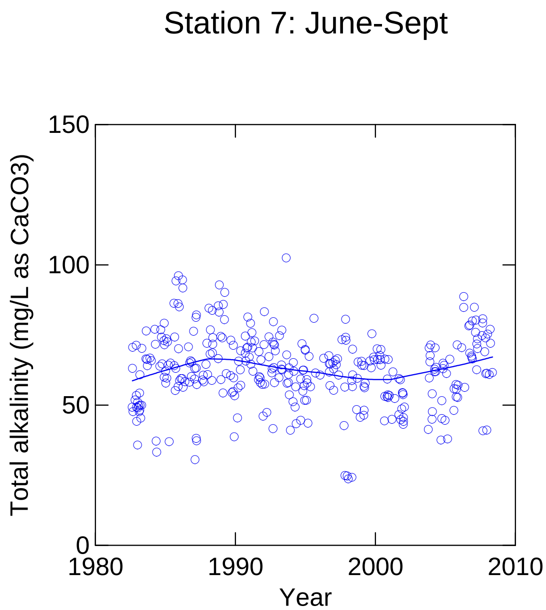
Lab pH as measured by Fairfax County personnel were generally in the range 8 to 9.5 over the long term study period (Figure 85). Since about 1998 a decline is evident with the trend line decreasing from about 9 to about 8.3. Linear regression indicated a significant decline in lab pH over the study period at a rate of about 0.026 pH units per year or a total of 0.65 units over 26 years (Table 11).

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



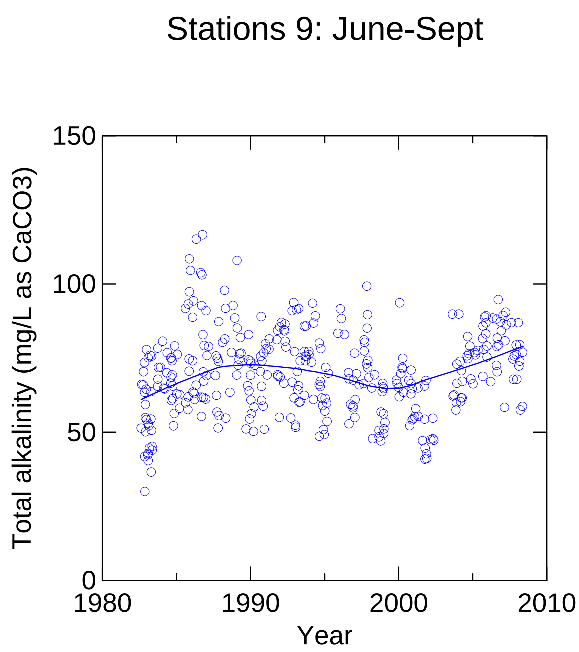
In the river, long term pH trends as measured by Fairfax County lab personnel indicate that most values fell between 7 and 9 (Figure 86). The trend line has increased and decreased slightly over the years with data since 1998 showing a slight decline. pH in the river showed a significant linear decline with a rate of 0.018 per year yielding a total decline of 0.45 units over the 25 years (Table 11).

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



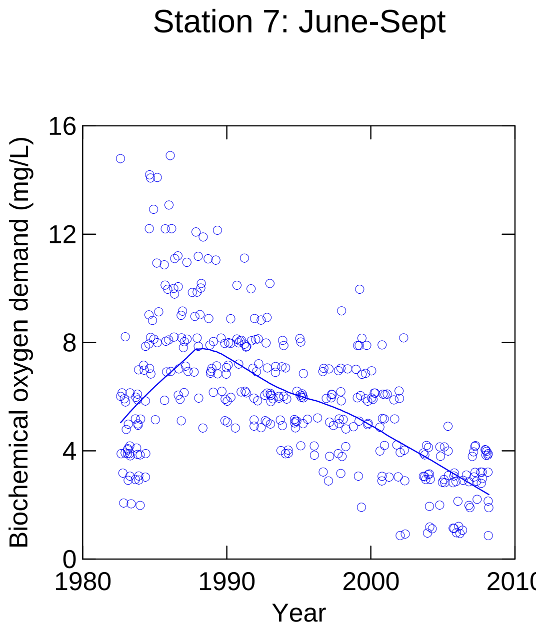
Total alkalinity as measured by Noman Cole lab personnel exhibited a rise from 1983 to 1990, a slow decline during the 1990's and a slow increase in the 2000's (Figure 87). The trend line at 2008 was slightly higher than it was in 1983. Overall, there has not been a statistically significant linear trend in total alkalinity in the cove over this period (Table 11).

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



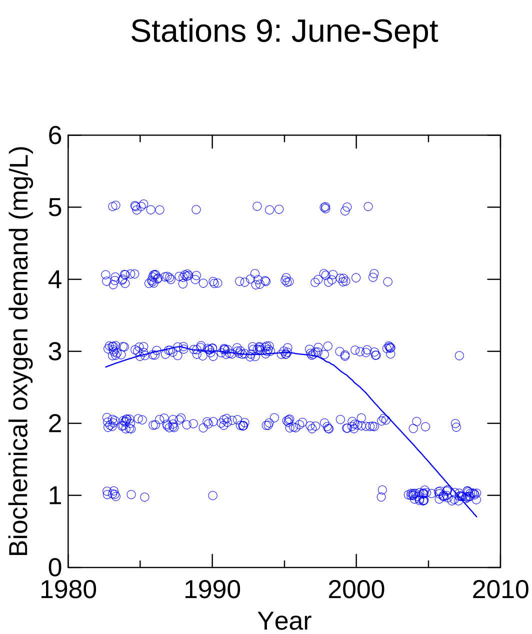
In the river a similar pattern has been observed over the three decadal intervals (Figure 88). Likewise, linear trends in total alkalinity have not been statistically significant in the river when the entire time frame is considered (Table 11).

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



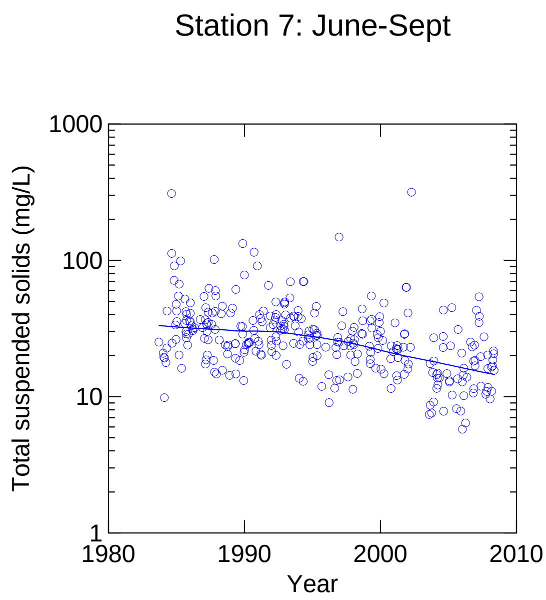
Biochemical oxygen demand has shown a distinct pattern over the long term study period in Gunston Cove (Figure 89). In the 1980's the trend line rose from about 5 mg/L to 8 mg/L by 1987. Since then there has been a steady decline such that the trend line has dropped back to about 2 mg/L. BOD has shown a significant linear decline over the entire study period at a rate of 0.19 mg/L per year yielding a net decline of 4.8 mg/L over the entire period of record (Table 11).

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



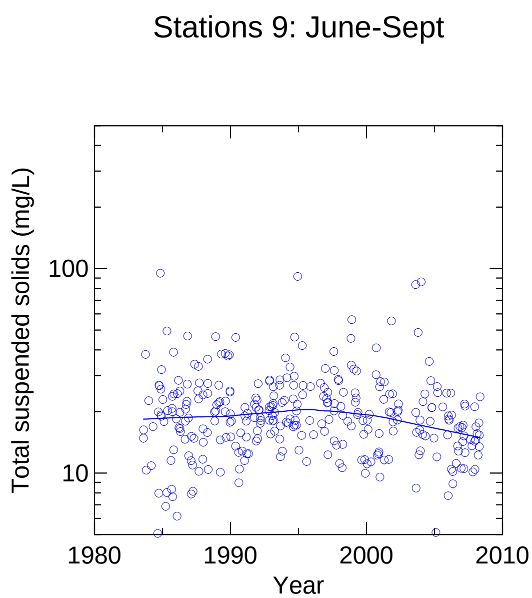
In the river biochemical oxygen demand exhibited a less distinct pattern through the mid 1990's (Figure 90). However, since that time it has decreased steadily to a median value of 1 mg/L. BOD in the river has exhibited a significant linear decrease at a rate of 0.06 units when the entire period of record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

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



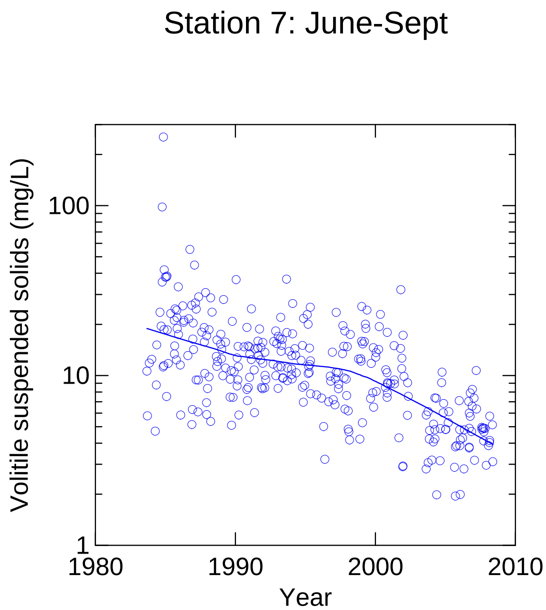
Total suspended solids (TSS) has shown a great deal of variability over the long term study period. Nonetheless, a decreasing trend has been detected in TSS in the cove with the trend line decreasing from about 30 mg/L in 1983 to about 13 mg/L in 2008 (Figure 91). Linear regression was significant indicating a decline of 0.96 mg/L per year yielding a total decline of 23 mg/L since 1984 (Table 11).

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



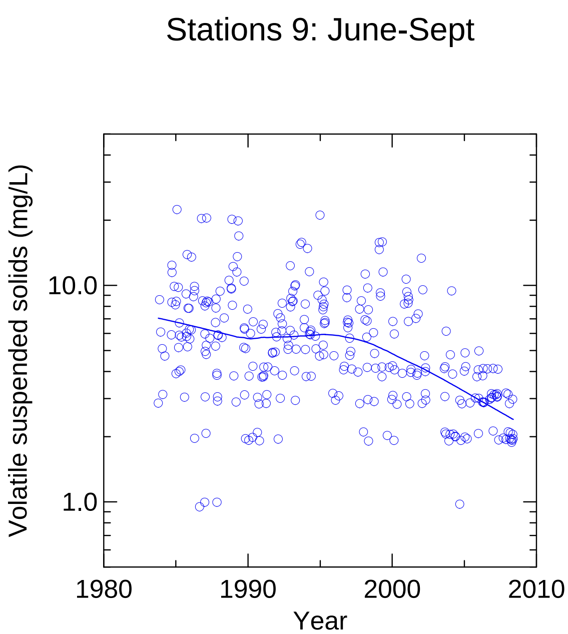
In the river TSS trends have not been as apparent (Figure 92). While much higher values have been observed sporadically, the LOWESS line remained steady at about 20 mg/L through 2000. Since then a slight decline is suggested. In the river TSS did not exhibit a significant linear trend over the period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

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



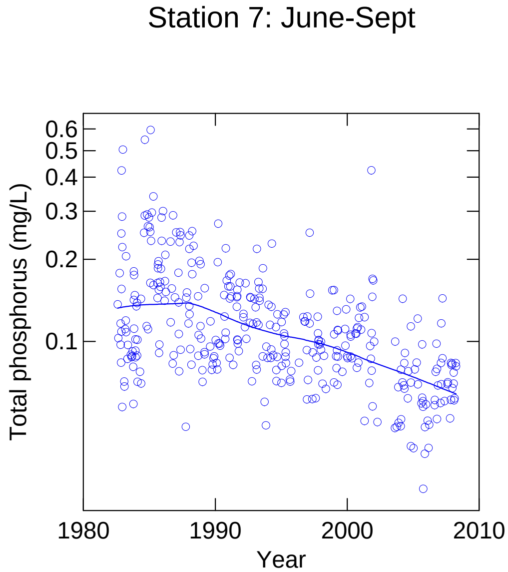
Volatile suspended solids have consistently declined over the study period and this decline seems to have accelerated in recent years (Figure 93). The LOWESS trend line has declined from 20 mg/L in 1984 to 4 mg/L in 2007. VSS has demonstrated a significant linear decline at a rate of 0.81 mg/L per year or a total of 19 mg/L over the study period (Table 11).

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



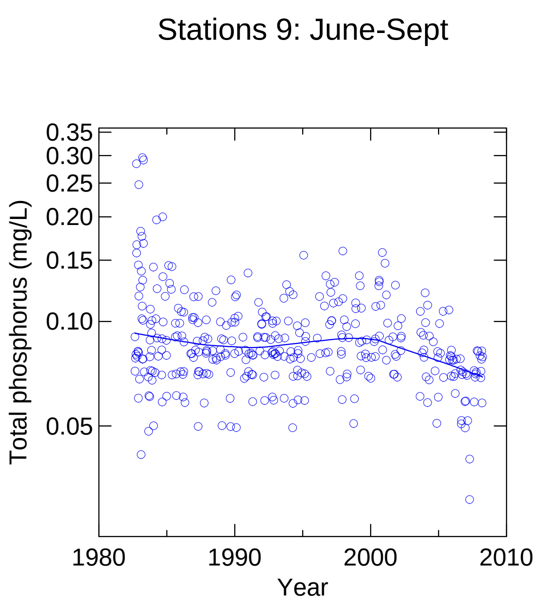
In the river the trend line for volatile suspended solids (VSS) was steady from 1984 through the mid 1990's, but has decreased consistently since then. Trend line values of about 7 mg/L in 1984 have dropped to 2.5 mg/L in 2008 (Figure 94). VSS in the river demonstrated a significant linear decline at a rate of 0.18 mg/L per year or 4.3 mg/L since 1984 (Table 11).

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



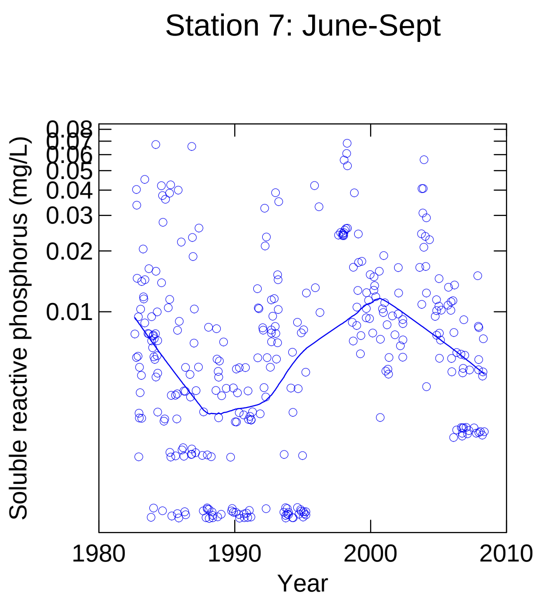
In the cove, total phosphorus (TP) has undergone a long steady decline since the late 1980's in the cove (Figure 95). By 2007 the trend line had dropped below 0.07 mg/L. Linear regression over the entire period of record indicated a significant linear decline of 0.004 mg/L per year or 0.1 mg/L over the entire study period (Table 11).

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



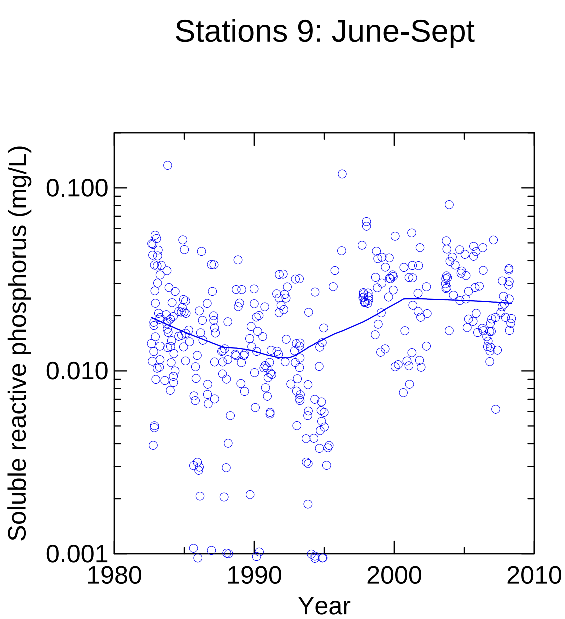
Total phosphorus (TP) values in the river have shown less of a trend over time (Figure 96). Values were steady through about 2000, but have recently shown a decline. TP exhibited a slight, but significant linear decrease in the river over the long term study period (Table 11).

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



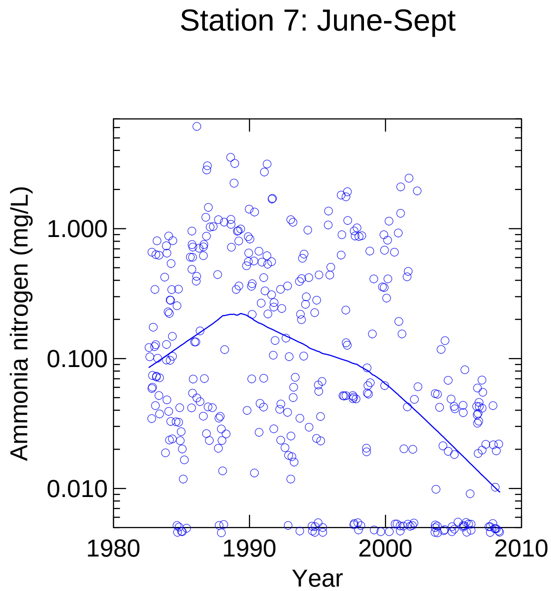
Soluble reactive phosphorus (SRP) declined in the cove during the first few years of the long term data set, but demonstrated an increase to near its initial level by 2000 (Figure 97). Since then a decline has ensued. The pattern through 2000 was consistent with the concept that SRP is negatively correlated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

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



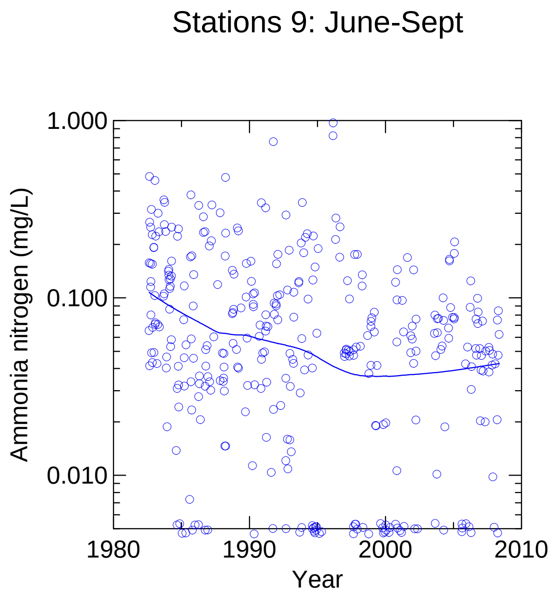
Soluble reactive phosphorus (SRP) in the river has generally been present at higher levels than in the cove, but has undergone a similar decline and resurgence (Figure 98). By 2008 the trend line in the river was at 0.025 mg/L compared to less than 0.01 mg/L in the cove. Again, this may reflect less demand for P in the river; algae in the river may be more light-limited. Values in the river in 2008 were slightly higher than in the 1980's. In the river SRP showed a positive linear trend over the study period (Table 11).

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



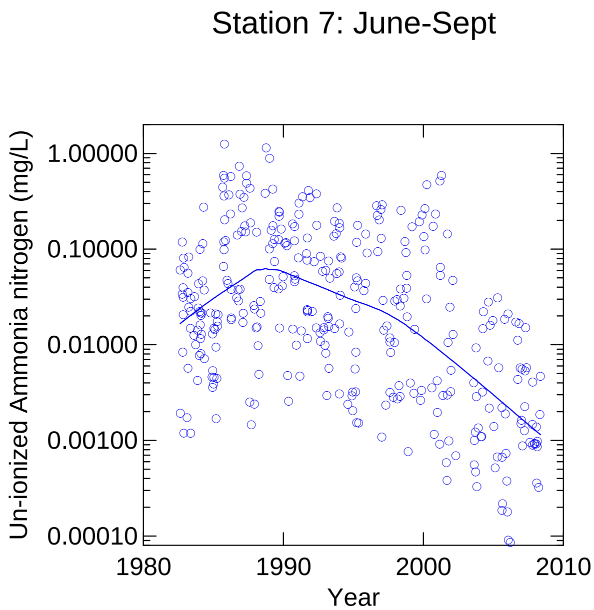
Ammonia nitrogen levels were very variable over the long term study period in the cove, but a trend of decreasing values is evident from the LOWESS trend line (Figure 99). Since 1989 the trend line has decreased from about 0.2 mg/L to about 0.01 mg/L. Linear regression has revealed a significant decline over the entire period of record with a rate of 0.015 mg/L per year yielding a total decline of 0.38 mg/L (Table 11).

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



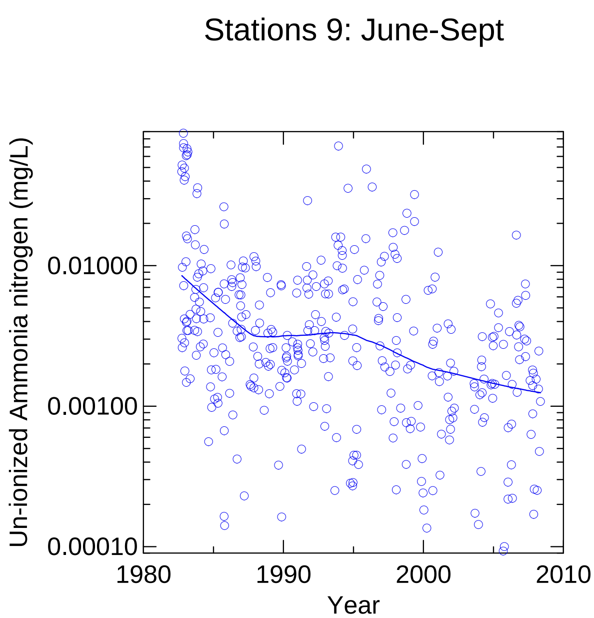
In the river a decreasing trend in ammonia nitrogen has also been observed over most of the study period (Figure 100). Between 1983 and 1999 the trend line dropped from 0.1 mg/L to 0.04 mg/L. Since 1999 it has risen slightly. Overall, in the river ammonia nitrogen has demonstrated a significant decline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

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



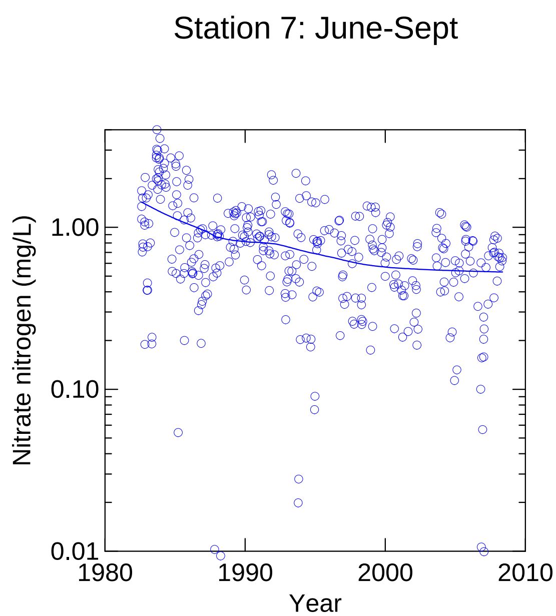
Un-ionized ammonia nitrogen in the cove demonstrated a clear increase in the 1980's with a continuous decline since that time (Figure 101). The LOWESS trend peaked at about 0.07 mg/L and is now at about 0.001 mg/L. When considered over the entire time period, there was a significant decline at a rate of 0.004 mg/L per year or a total of 0.1 mg/L over the 25 years (Table 11).

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



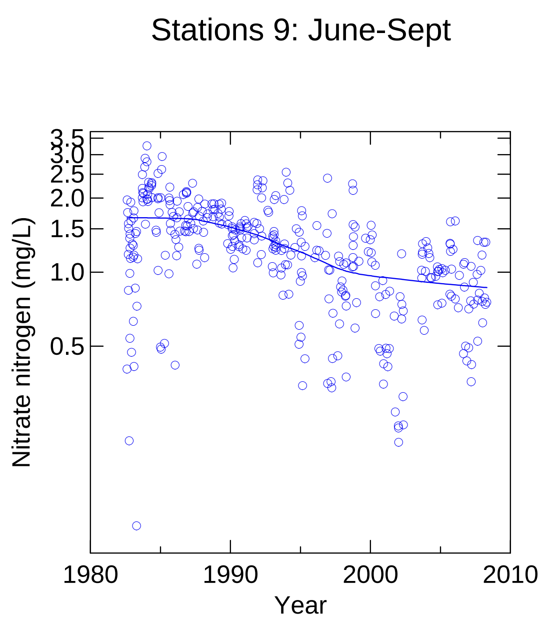
Un-ionized nitrogen in the river declined during the 1980's, was stable in the early 1990's and has declined since (Figure 102). LOWESS values have dropped from about 0.018mg/L to about 0.001 mg/L. Linear regression analysis over the entire period of record suggested a significant decline at a rate of 0.0005 units per year (Table 11).

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



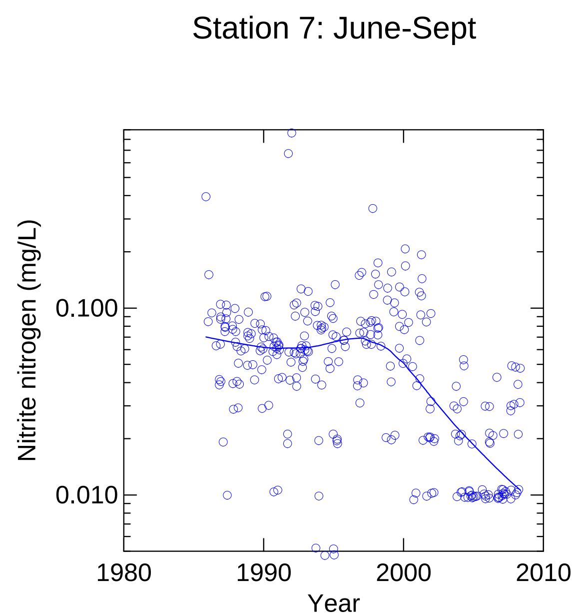
Nitrate nitrogen has demonstrated a steady decline in the cove over the entire period of record (Figure 103). The trend line was at 1.5 mg/L in 1983 and by 2008 was at 0.5 mg/L. Linear regression suggested a decline rate of 0.036 mg/L per year yielding a total decline of 0.9 mg/L over the long term study period (Table 11).

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



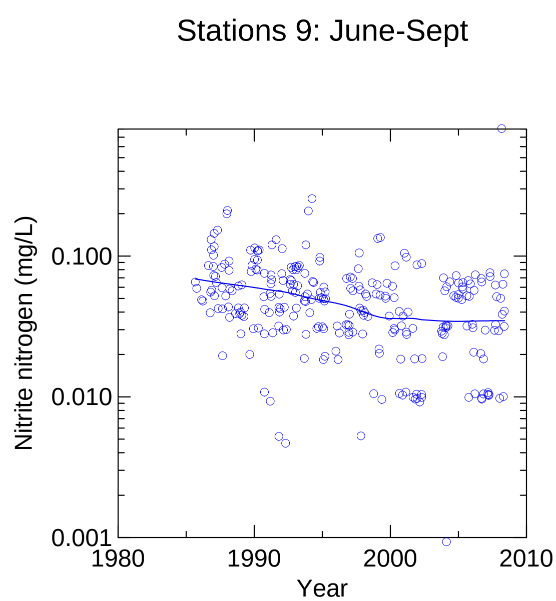
In the river nitrate nitrogen declined steadily through 2001 and has remained steady or declined more slowly since (Figure 104). The trend line dropped from 1.6 mg/L in the mid 1980's to 0.9 mg/L in 2008. Linear regression indicated a similar rate of drop as in the cove which would have yielded a 0.95 mg/L decline in nitrate nitrogen over the study period (Table 11).

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



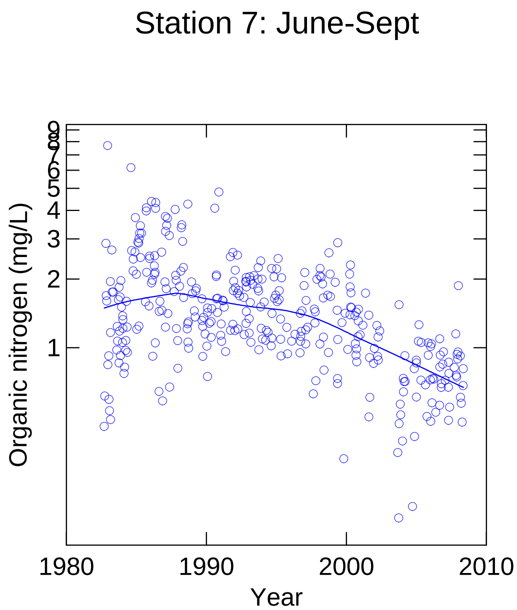
The trend line for nitrite nitrogen indicated steady values at about 0.06-0.07 mg/L through 1999 (Figure 105). Since then there is clear evidence for a decline with the LOWESS line reaching 0.01 in 2008. Linear regression revealed a significant decline when the entire period of record was considered (Table 10).

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



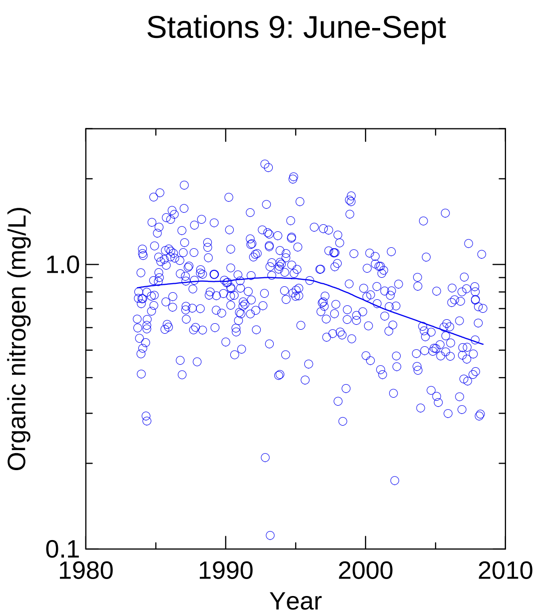
Nitrite nitrogen in the river demonstrated a pattern of decrease during the long term study period (Figure 106). The LOWESS line dropped from 0.07 mg/L in 1986 to 0.03 mg/L in 2007. Linear regression indicated a significant linear decline at a rate of 0.001 mg/L per year or 0.02 mg/L over the study period (Table 11).

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



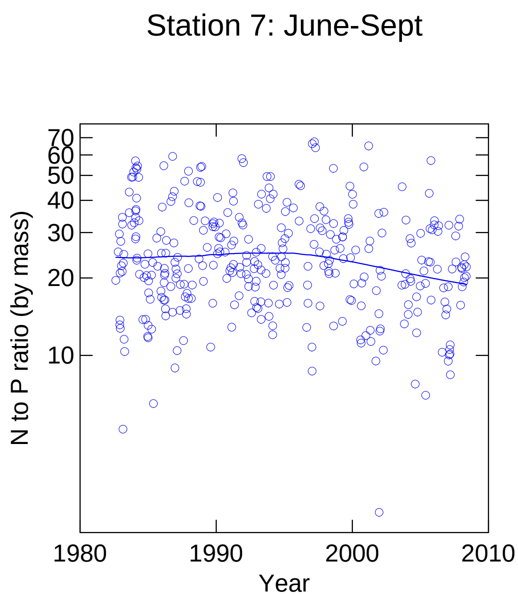
Organic nitrogen in the cove increased in the 1980's and has since undergone a consistent decline through 2008 (Figure 107). In 1983 the trend line was at 1.5 mg/L, rose to 1.8 mg/L in 1987, and dropped to 0.7 mg/L in 2008. Regression analysis indicated a significant decline over the study period at a rate of about 0.055 mg/L per year or a total of 1.38 mg/L over the whole study period (Table 11).

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



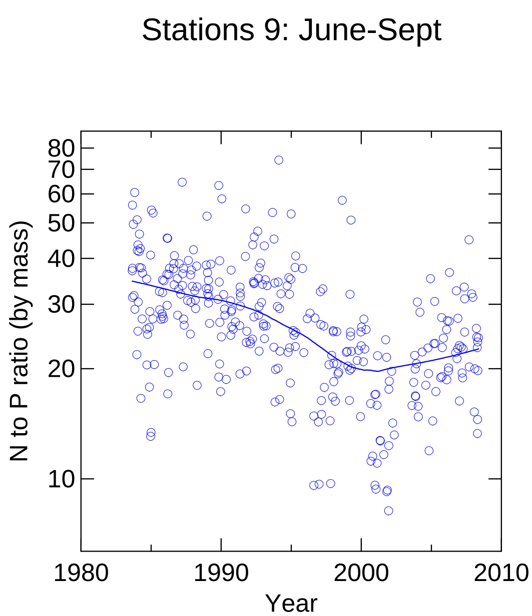
In the river organic nitrogen showed was steady from 1984 through 1995 and since then has consistently declined (Figure 108). The LOWESS line peaked at about 0.9 mg/L and has dropped to about 0.5 mg/L. Regression analysis indicated a significant linear decline at a rate of 0.014 mg/L when the entire period of record was considered for a total decline of 0.35 (Table 11).

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



Nitrogen to phosphorus ratio (N/P ratio) in the cove exhibited large variability, but the trend line was flat until about 1998. Since then, there has been a clear decline with the LOWESS line approaching 19 by 2008 (Figure 109). Regression analysis over the period of record indicates a statistically significant decline at a rate of 0.22 per year or about 5.5 units over the entire period (Table 11).

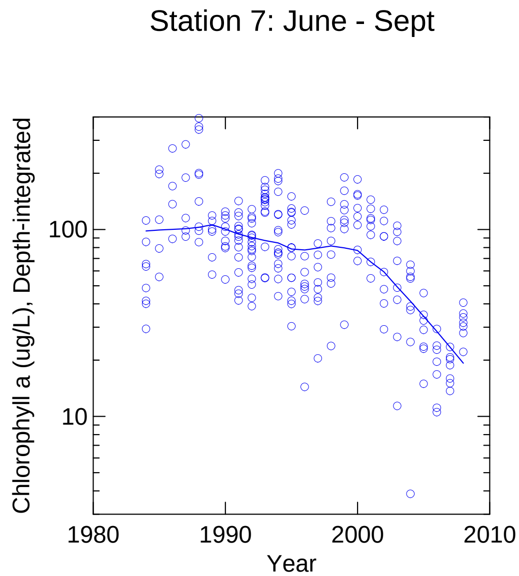
Figure 109. Long term trend in N to P Ratio (Fairfax County Lab Data). Station 7. Gunston Cove.



Nitrogen to phosphorus (N/P) ratio in the river exhibited a strong continuous decline through about 2000 (Figure 110). The LOWESS trend line declined from about 35 in 1984 to 20 in 2007. Since then a gradual increase is suggested. Linear regression analysis confirmed this decline and suggested a rate of 0.7 units per year or a total of 17 units over the long term study period (Table 11).

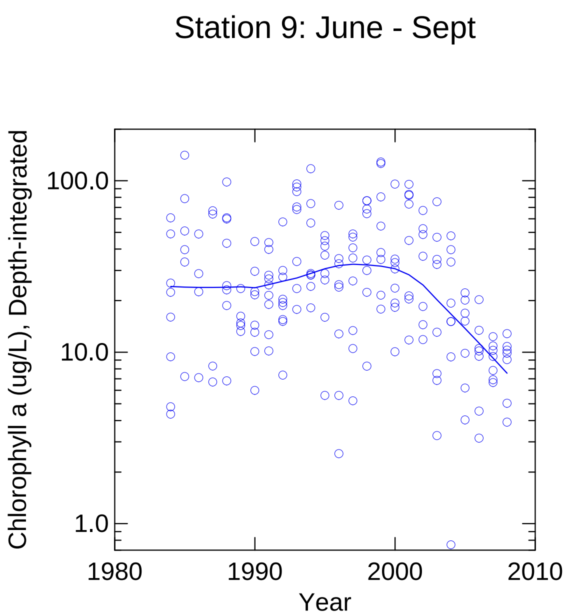
Figure 110. Long term trend in N to P Ratio (Fairfax County Lab Data). Station 9. River mainstem.

C. Phytoplankton Trends: 1984-2008



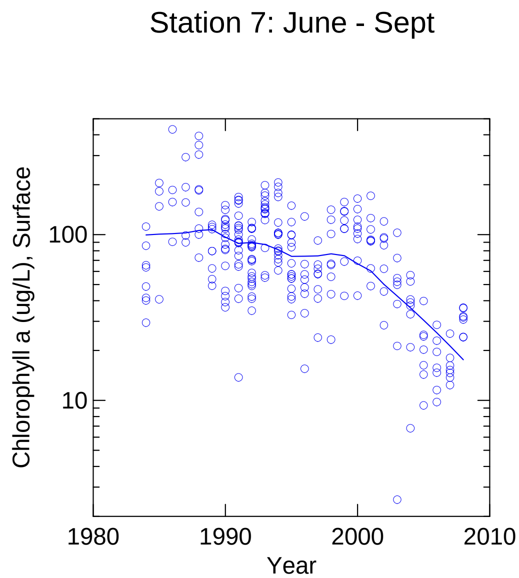
Depth-integrated chlorophyll *a* in the cove demonstrated a gradual decline from 1988 to 2000 and a much stronger decrease since then (Figure 111). The LOWESS line has declined from about 100 ug/L to a level of about 20 ug/L in 2008. However, 2008 chlorophylls fell well above this line. The observed decrease is bringing chlorophyll values into the range of water clarity impairment-based criteria which are 43 ug/L and 11 ug/L to allow SAV growth to 0.5 m and 1.0 m, respectively (CBP 2006). Regression analysis has revealed a clear linear trend of decreasing values at the rate of 4.1 ug/L per year or about 100 ug/L over the 25 year long term data set (Table 10).

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



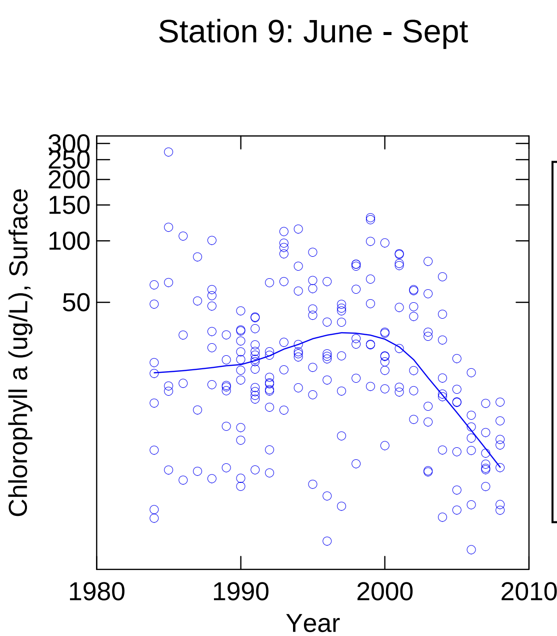
In the river depth-integrated chlorophyll *a* was fairly consistent through 2000 with the trend line varying between 20 and 30 ug/L (Figure 112). However, in recent years a strong decline has been observed with values now at about 10 ug/L. Some measurements in 2008 were above the trend line. Regression analysis revealed a significant linear decline when the entire period is considered (Table 10).

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



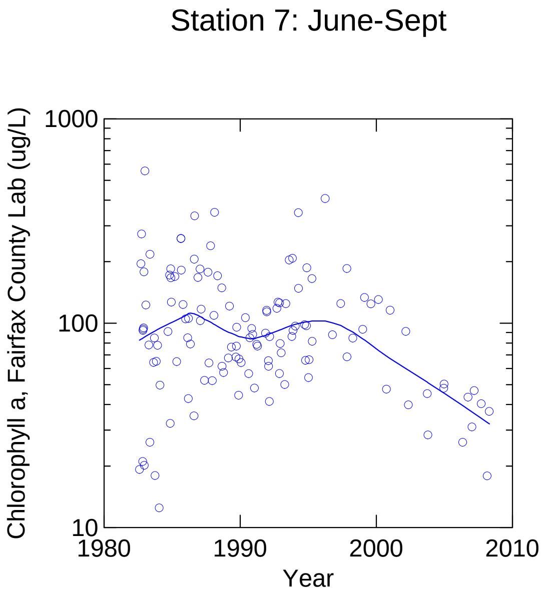
Surface chlorophyll *a* in the cove exhibited a clear decline over the long term study period, especially since 2000 (Figure 113). Trend line values of just over 100 ug/L in 1988 dropped to about 20 ug/L in 2008. 2008 values were well above the trend line. The observed decrease is bringing chlorophyll values into the range of water clarity impairment-based criteria which are 43 ug/L and 11 ug/L to allow SAV growth to 0.5 m and 1.0 m, respectively. Linear regression confirmed the linear decline and suggested a rate of 4.5 ug/L per year or 112 ug/L over the entire study (Table 10).

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



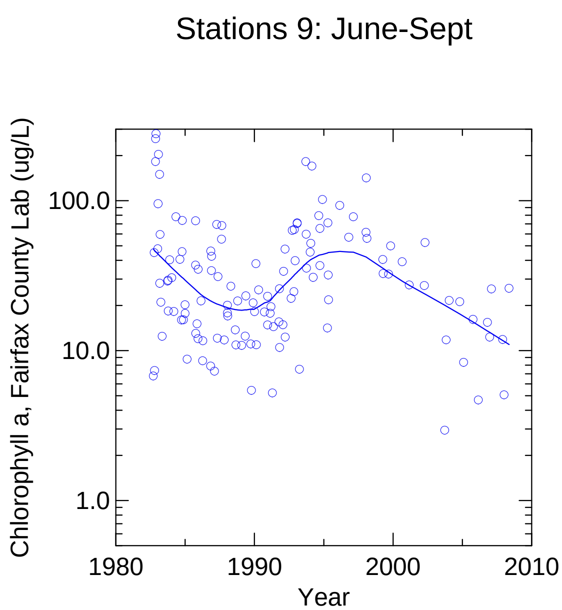
In the river the LOWESS line for surface chlorophyll *a* increased slowly from 1983 to 2000 and then declined markedly (Figure 114). Linear regression revealed a significant decline in surface chlorophyll across this period (Table 10).

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



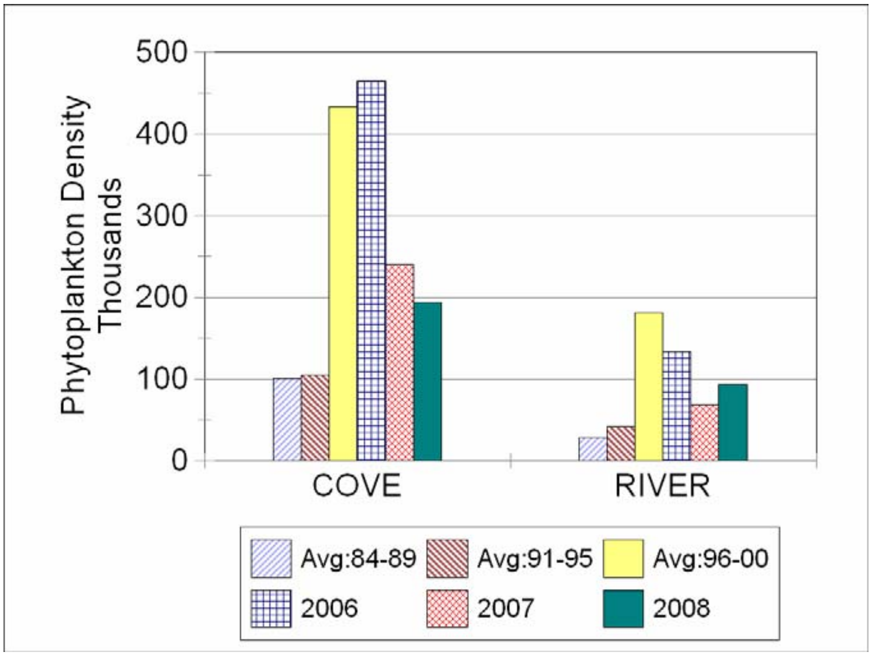
Surface chlorophyll *a* in the cove measured by the Fairfax County Lab exhibited a clear decline over the long term study period, especially since 1998 (Figure 115). Trend line values of just over 100 ug/L in 1988 dropped to about 35 ug/L in 2008. Regression analysis indicated a significant linear decline at a rate of 3.0 ug/L bringing the total decline to about 75 ug/L (Table 11). The observed decrease is bringing chlorophyll values into the range of water clarity impairment-based criteria which are 43 ug/L and 11 ug/L to allow SAV growth to 0.5 m and 1.0 m, respectively.

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



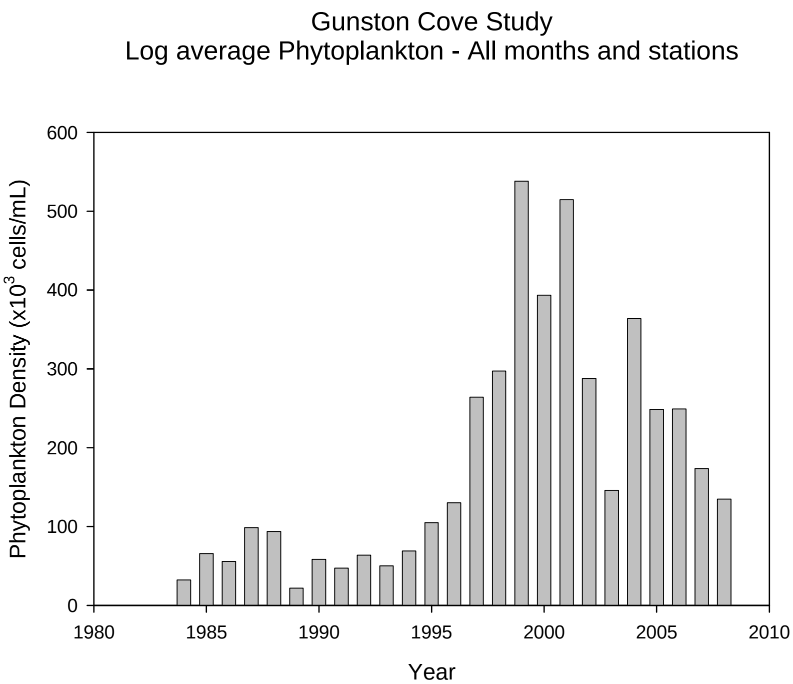
In the river surface chlorophyll *a* exhibited changing trends over the study period (Figure 116). The trend line decreased from about 45 ug/L in 1983 to 20 ug/L by 1990, then increased to about 50 ug/L by 1995. Since that time a steady decline has been observed bringing the trend line to about 10 ug/L.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

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



Phytoplankton density in both cove and river in 2008 was similar to that observed in 2007 and lower than in recent years as well as lower than the average from 1996-2000 (Figure 117). Most of the cells are relatively small so the relatively high number of cells does not mean an increase in phytoplankton biomass.

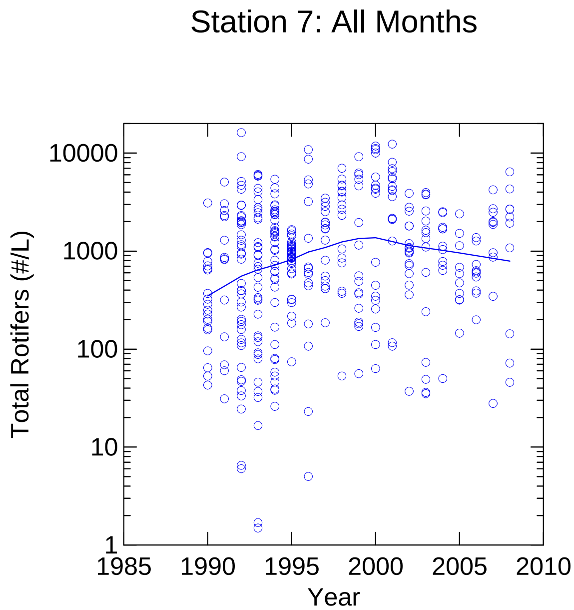
Figure 117. Interannual Comparison of Phytoplankton Density by Region.



By looking at individual years (Figure 118), we see that phytoplankton densities in the 2008 were lower than in 2004-2006 and, in fact, are consistent with a continuing decline in phytoplankton densities which began in about 2000.

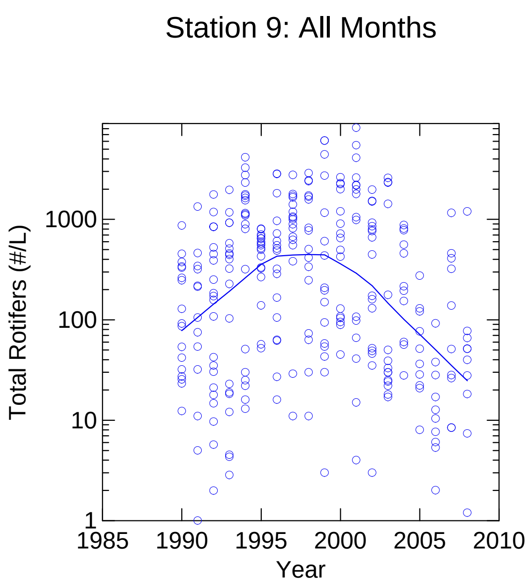
Figure 118. Interannual Trend in Average Phytoplankton Density. Units are thousands of cells per mL.

D. Zooplankton Trends: 1990-2008



In the Cove total rotifers continued to show a slight decline after an initial period of steady increase (Figure 119). The LOWESS fit line indicated about 800/L in 2008, up from about 400/L in 1990, but less than about 1200/L in 2000. Linear regression analysis continued to indicate a statistically significant linear increase in total rotifers over the period since 1990 (Table 12).

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



In the Potomac mainstem, rotifers have exhibited a more marked decline in abundance that began in about 1998 (Figure 120). The LOWESS line had dropped to about 30/L whereas it had been at about 500/L in 1996-1999 period. This was even lower than the 80/L observed in 1990. When the entire 1990-2003 period was considered, total rotifers exhibited a statistically significant linear decline in the river (Table 12).

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

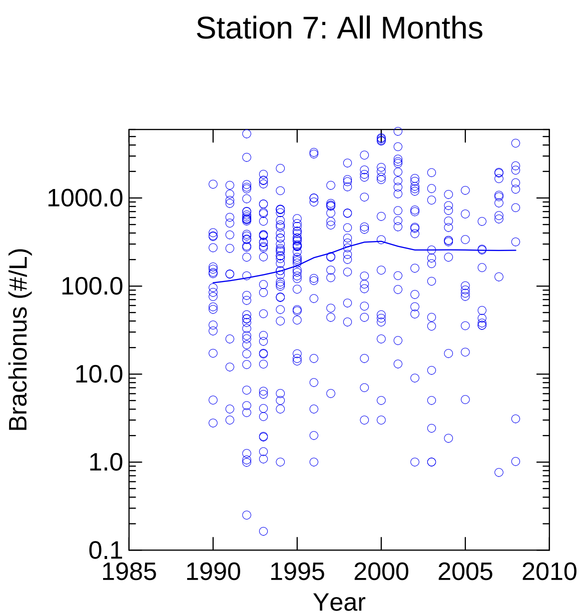
Table 12
Correlation and Linear Regression Coefficients
Zooplankton Parameters vs. Year for 1990-2008
All Nonzero Values Used, All Values Logged to Base 10

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Brachionus (m)	0.137 (343)	0.025	0.011	-0.019 (267)	----	NS
Conochilidae (m)	0.178 (299)	0.024	0.002	-0.083 (226)	----	NS
Filinia (m)	0.213 (289)	0.037	<0.001	0.052 (183)	----	NS
Keratella (m)	0.269 (354)	0.041	<0.001	0.000 (277)	----	NS
Polyarthra (m)	0.169 (339)	0.025	0.002	-0.053 (259)	----	NS
Total Rotifers (m)	0.183 (369)	0.024	0.001	-0.016 (289)	-0.019	0.049
Bosmina (M)	0.107 (193)	----	NS	0.093 (227)	----	NS
Diaphanosoma (M)	0.004 (283)	----	NS	0.001 (186)	----	NS
Daphnia (M)	0.141 (242)	0.030	0.028	0.006 (147)	----	NS
Chydorid cladocera (M)	0.298 (196)	0.054	<0.001	0.339 (118)	0.052	<0.001
Leptodora (M)	0.017 (143)	----	NS	0.089 (94)	----	NS
Copepod nauplii (m)	0.374 (348)	0.044	<0.001	0.184 (285)	0.184	0.002
Adult and copepodid copepods (M)	0.049 (465)	----	NS	0.023 (330)	----	NS

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

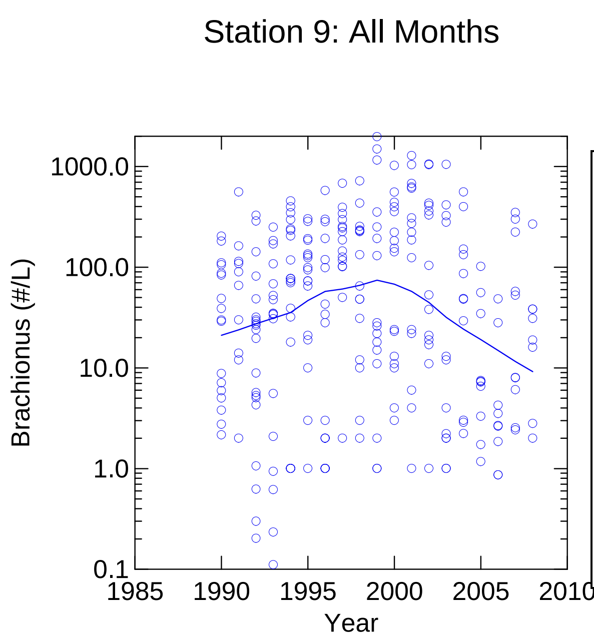
Significance column indicates the probability that a correlation coefficient this large could be due to chance alone. If this probability is greater than 0.05, then NS (not significant) is indicated.

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



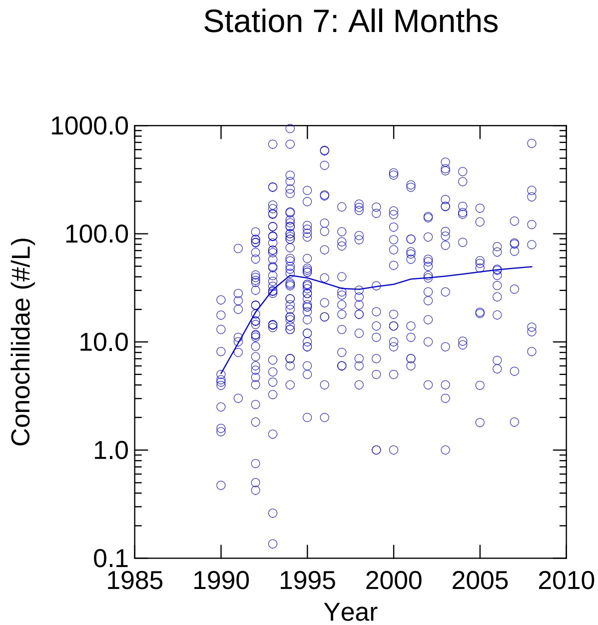
Brachionus is the dominant rotifer in Gunston Cove and the trends in total rotifers are mirrored in those in *Brachionus* (Figure 121). The LOWESS line for *Brachionus* suggested about 2500/L in 2008, down from 400/L in 1999, but greater than the 100/L found in 1990. Note that 2007 and 2008 had higher levels than the immediately previous years. A statistically significant linear increase was found over the study period (Table 12).

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



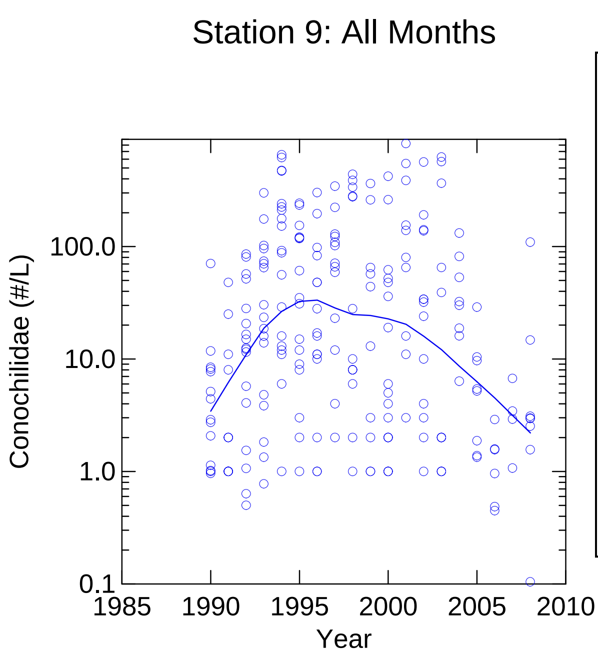
In the river the LOWESS line for *Brachionus* increased through 2000, but has since dropped markedly. The LOWESS value in 2008 was about 10/L, well below the peak of 80/L in 1999 (Figure 122). No linear trend was indicated when the entire study period was considered (Table 12).

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



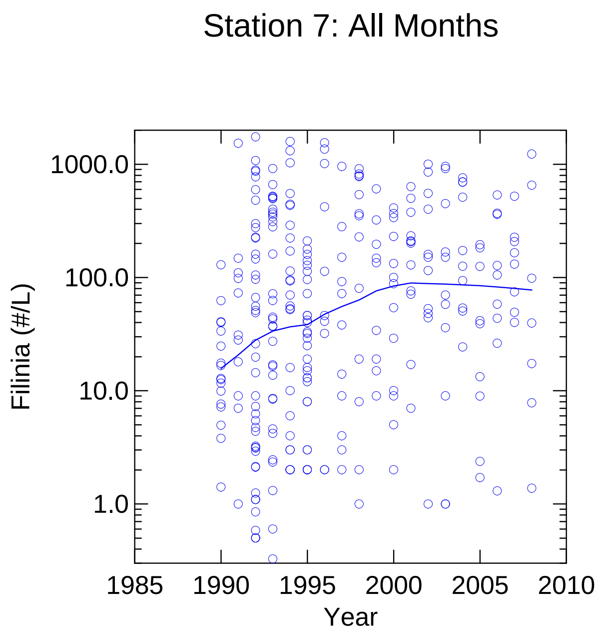
Conochilidae increased strongly from 1990-1995, but has since leveled off. In 2007 the LOWESS trend line stood at about 50/L similar to other recent years (Figure 123). This was well above levels of about 5/L in 1990. Over the entire period of record, a significant linear increase was found (Table 12).

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



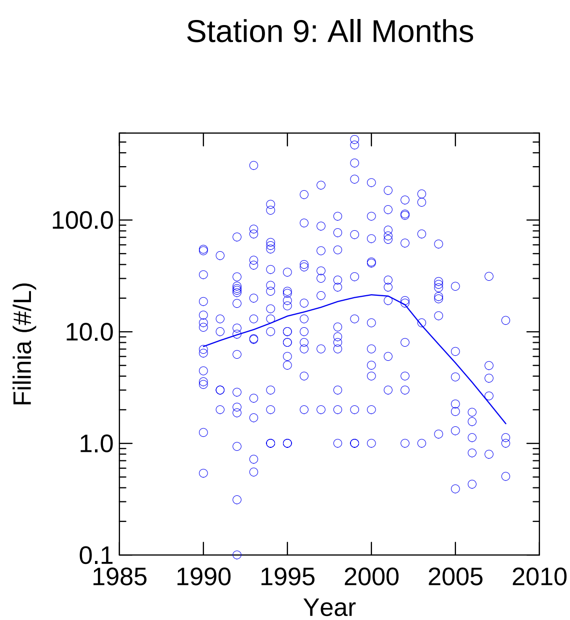
In the river, Conochilidae exhibited a strong increase in the early 1990's similar to that observed in the cove (Figure 124). However, since that time densities have declined steadily in the river. The trend line has gone from 3/L in 1990 to 35/L in 1995 to 3/L in 2008. When the entire period of record was examined, no linear trend was found (Table 12).

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



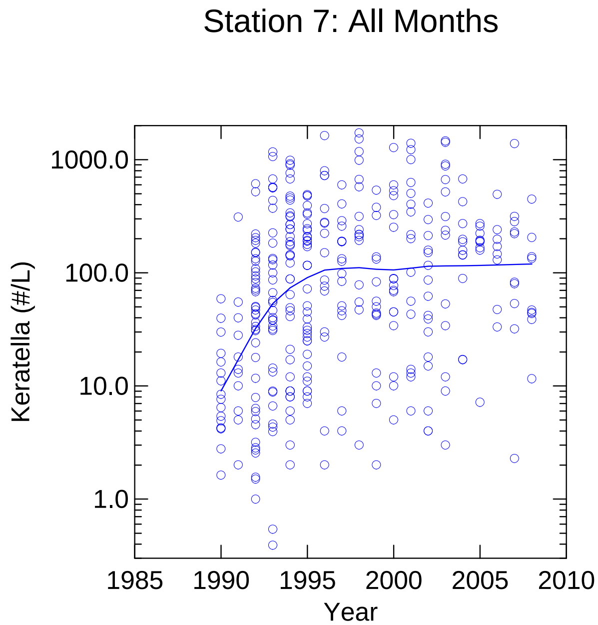
In the cove *Filinia* exhibited a steady increase from 1990 through 2000 rising from about 20/L to nearly 100/L (Figure 125). It has now leveled off at about 90/L. When the entire period of record was considered, there is strong evidence for a linear increase in the cove (Table 12).

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



In the river *Filinia* demonstrated an increase through about 2001, but has declined strongly since. The trend line indicates about 2/L in 2008, below both the 7/L in 1990 and well as the peak of 20/L (Figure 126). When the entire period of record was examined, there was not a significant linear trend (Table 12).

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



Keratella increased strongly from 1990 to 1995 and has shown a stable density pattern since then at about 100/L (Figure 127). When the entire period of record was examined, there was strong evidence for a linear increase (Table 12).

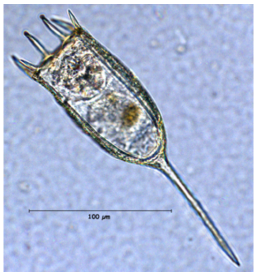
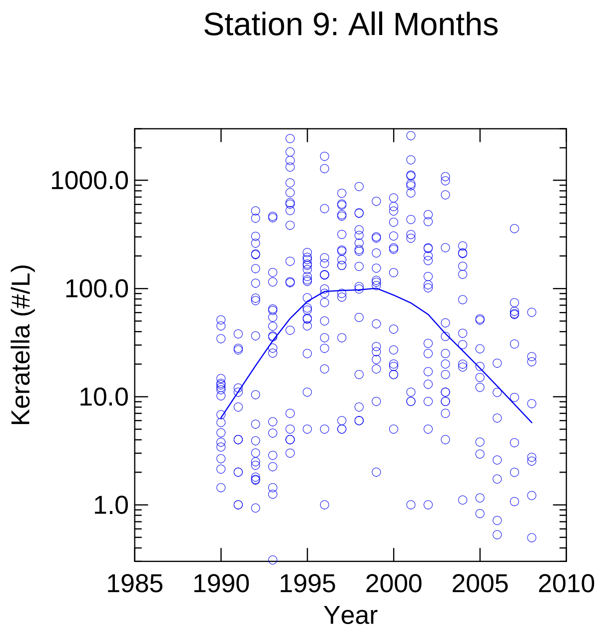
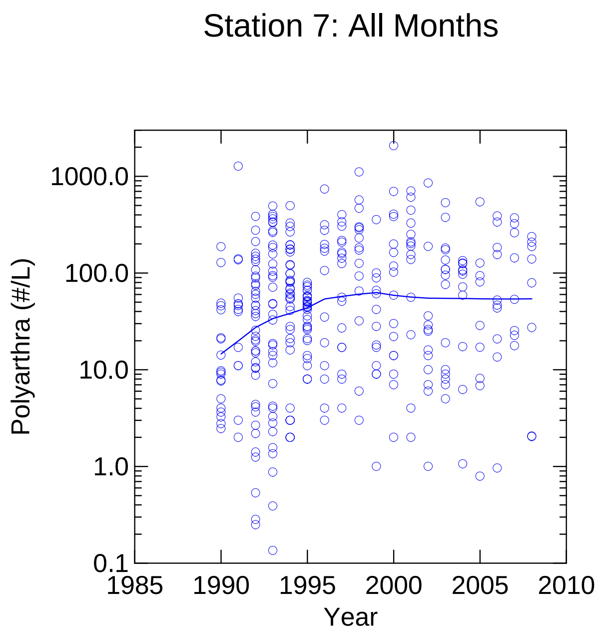


Figure 127. Long term trend in *Keratella*. Station 7. Gunston Cove.



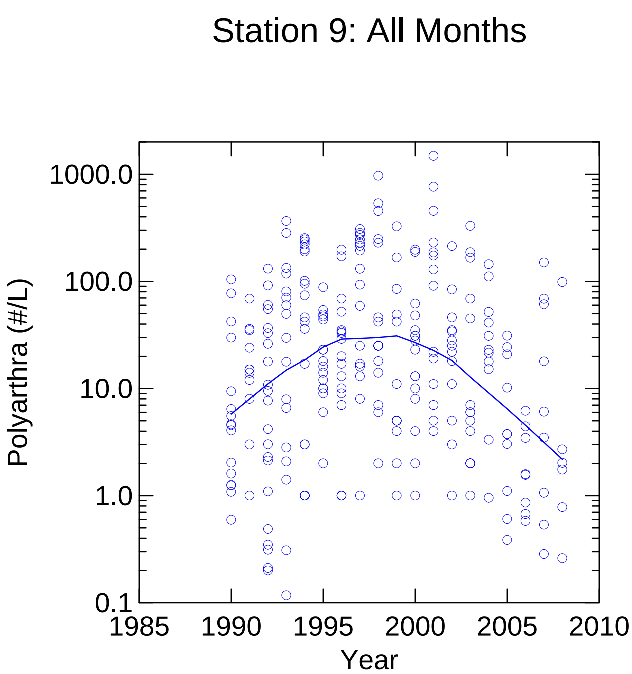
In the river *Keratella* has shown a continuing decline from peak values of about 100/L in the mid to late 1990's and is approaching about 6/L similar to the low values of 1990 (Figure 128). Linear regression showed no significant trend when the entire study period was considered (Table 12).

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



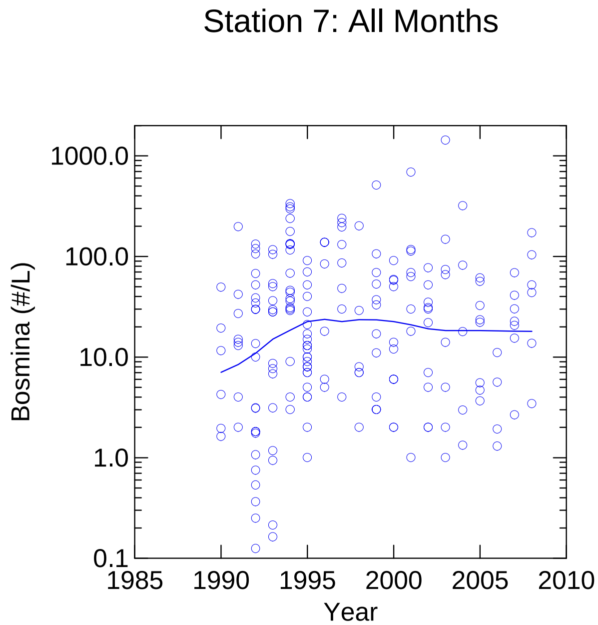
The trend line for *Polyarthra* in the cove increased steadily from 1990 to about 2000 rising from 15/L to about 60/L (Figure 129). Since 2000 densities have remained relatively steady. Regression analysis indicated a significant linear increase when the entire period of record was examined (Table 12).

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



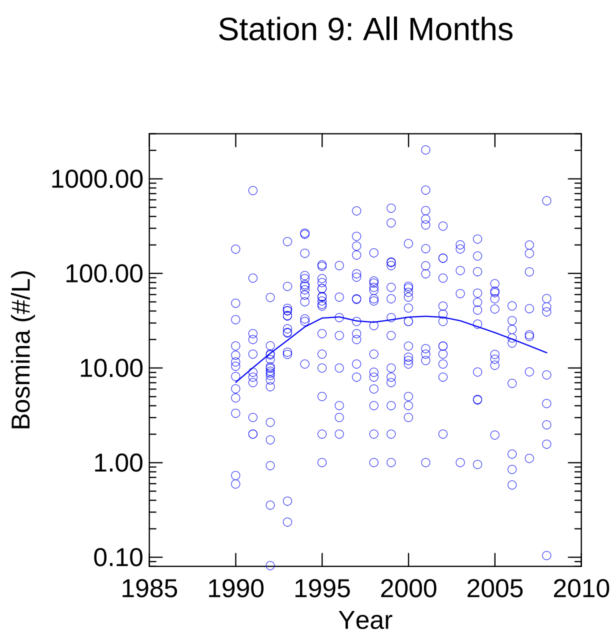
In the river *Polyarthra* continued a marked decline with the LOWESS line reaching about 2/L, down from about 30/L in 1997, and even lower than the 5/L observed in 1990 (Figure 130). Linear regression analysis did not indicate a significant trend over the period of record (Table 12).

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



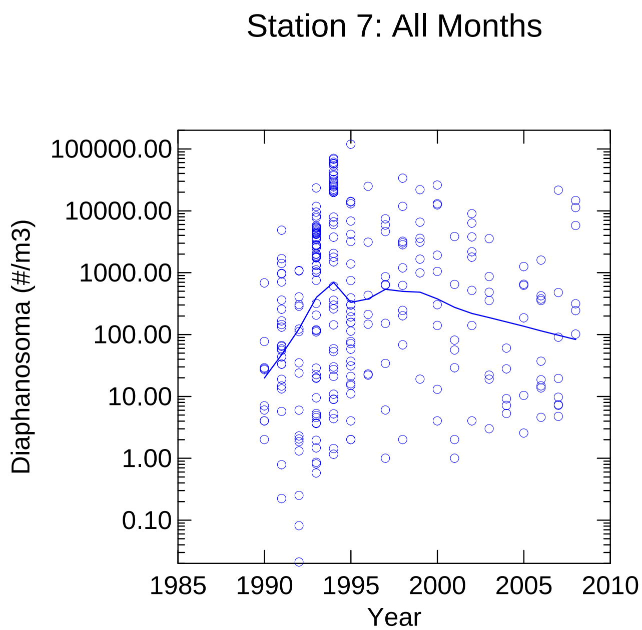
Bosmina in the cove showed an increase from 7/L in 1990 to about 25/L in 2000 (Figure 131). Since 2000 a very modest decline has occured reaching 20/L in 2008. Linear regression did not indicate a significant trend in the cove over the entire period of record (Table 12).

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



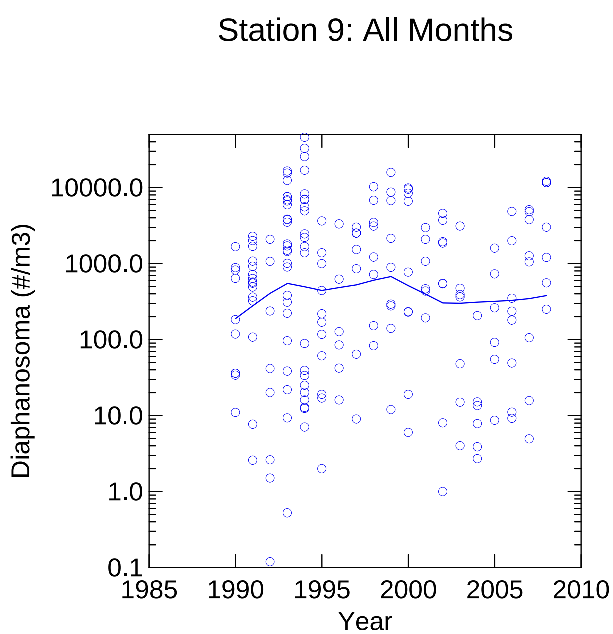
In the river mainstem the LOWESS curve for *Bosmina* increased from 1990 to 1995, was flat through 2001 and has declined slightly since (Figure 132). The current trend line value of 15/L remains higher than the 6/L found for 1990. Regression analysis did not indicate a significant linear increase over the entire period of record (Table 12).

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



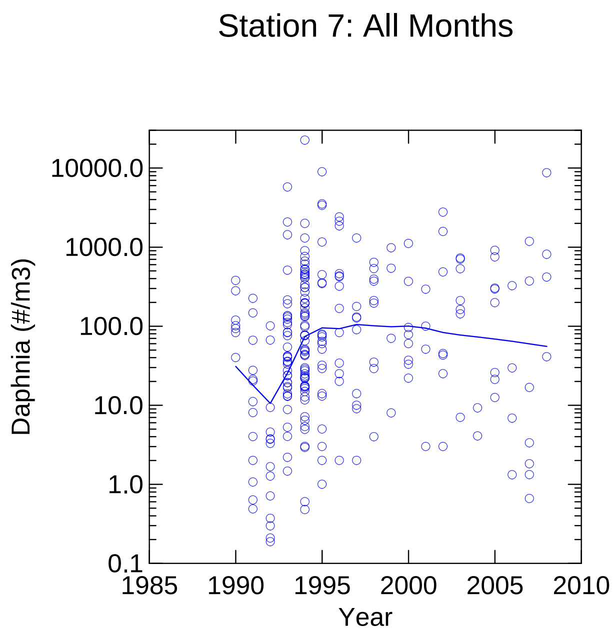
Diaphanosoma increased in 2008, but not enough to stabilize the trend line which continued slowly downward (Figure 133). This followed a strong increase in the early 1990's. The LOWESS line suggested 100/m^3 in 2008 compared with 500/m^3 in 1997. Both values were above the 20/m^3 observed in 1990. Linear regression analysis of the entire period of record indicated a no significant linear trend (Table 12).

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



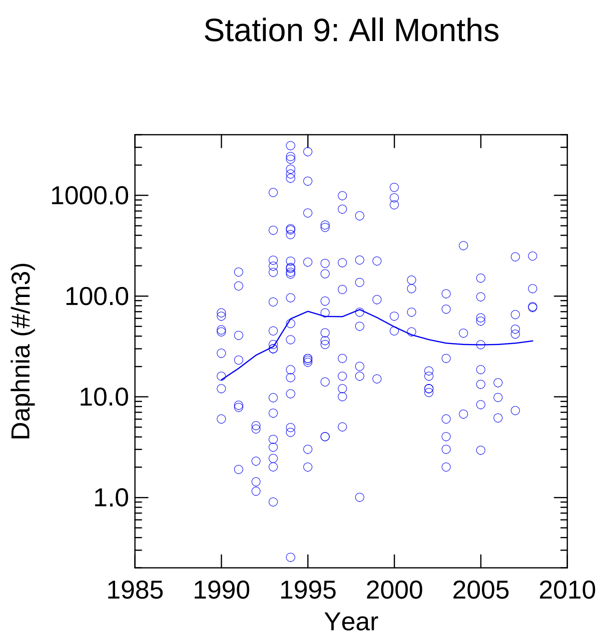
In the river the LOWESS line suggested continuation of a decline in *Diaphanosoma* which started in 1999 (Figure 134). The trend line value of 100/m^3 found in 2007 compared with values as high as 800/m^3 in 1999 and 1993 and is also lower than the 200/m^3 in 1990. Regression analysis indicated no significant linear trend over the period of record (Table 12).

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



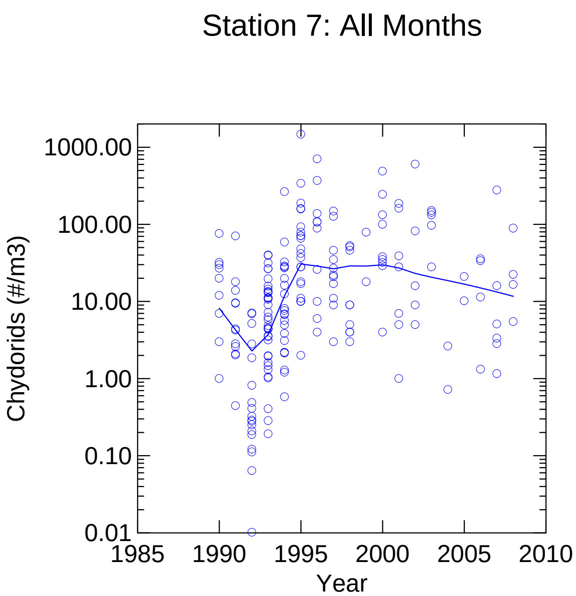
Daphnia in the cove was higher in 2008, but the trend line continued a slow decline reaching about 50/m^3 in 2008, down from about 100/m^3 in 1995 (Figure 135). This is up from the low of about 10/m^3 in 1992 and the value of 40/m^3 in 1990. Regression analysis examining the entire period of record gave some support for a linear increase (Table 12).

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



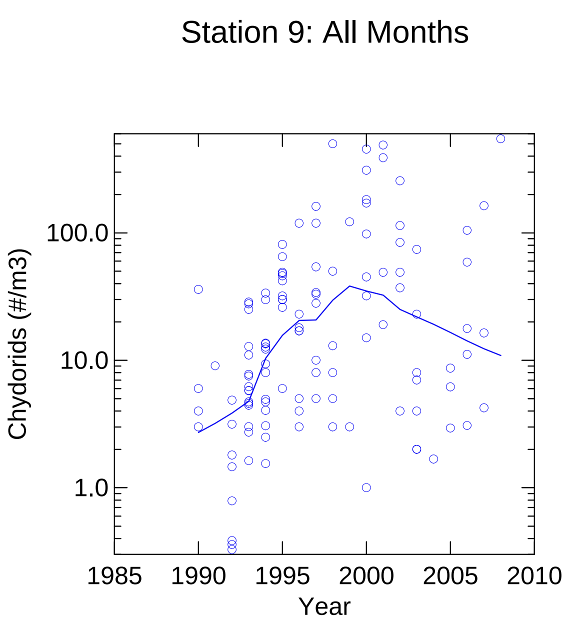
Daphnia in the river showed signs of reversing a decline which had been apparent since 1998 (Figure 136). The trend line in 2005 reached 40/m^3, substantially higher than the level observed at the beginning of the record in 1990, but down from the peak of 80/m^3 in 1994. Regression analysis indicated no significant linear trend over the study period (Table 12).

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



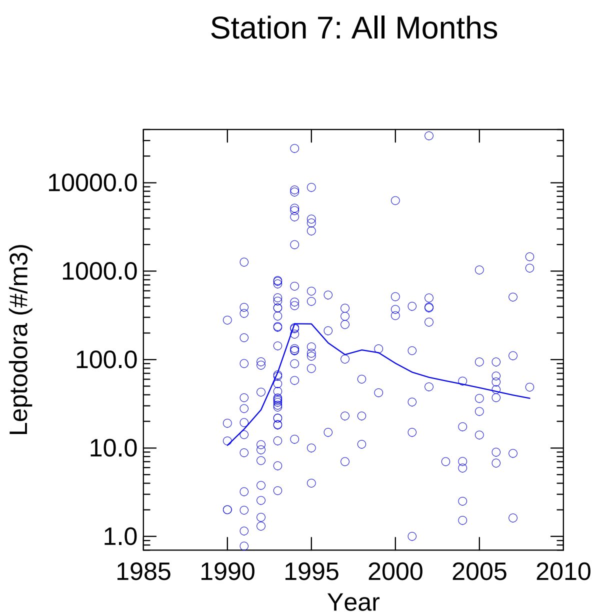
Chydorid cladocera in the cove continued a slight decline to about 10/m^3, substantially higher than the low of 3/m^3 in 1992 and the initial value of 8/m^3 in 1990, but below trend line values of 30/m^3 observed between 1995 and 2000 (Figure 137). Regression analysis gave evidence for a linear increase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

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



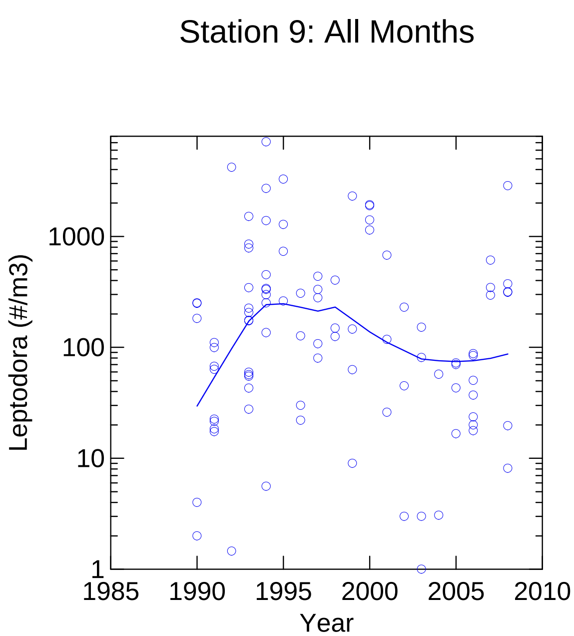
In the river chydorids continued a decline in 2007 to about 10/m^3, down from the 1999 high of 40/m^3, but still above the low of about 4/m^3 in the early 1990's (Figure 138). There was evidence for a linear increase in chydorids over the entire study period as indicated by linear regression analysis (Table 12).

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



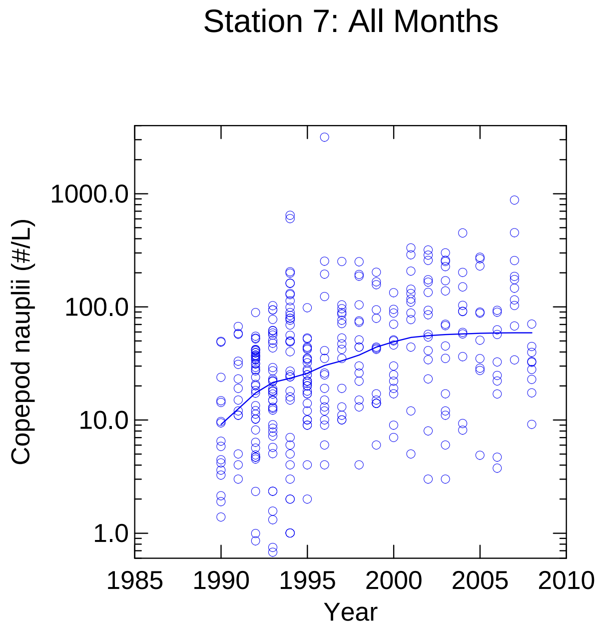
In the cove *Leptodora*, the large predaceous cladoceran, was found at increased levels in 2008, but the trend line continued a gradual decline reaching about 40/m^3, down from its high of about 200/m^3 in 1994, but above the 1990 value of 10/m^3 (Figure 139). There was not evidence for a significant linear change in Leptodora over the entire study period (Table 12).

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



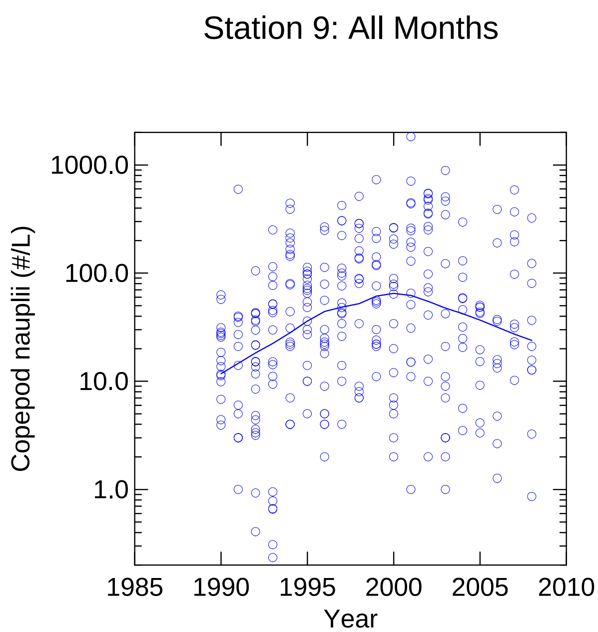
In the river, *Leptodora* densities stabilized following a decline which began in 1995 resulting in trend line values of about 90/m^3 for 2008 (Figure 140). These values are well above those observed in 1990, but are substantially lower than the peak of 300/m^3 in 1994. Linear regression analysis did not detect a significant linear trend when the whole study period was considered (Table 12).

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



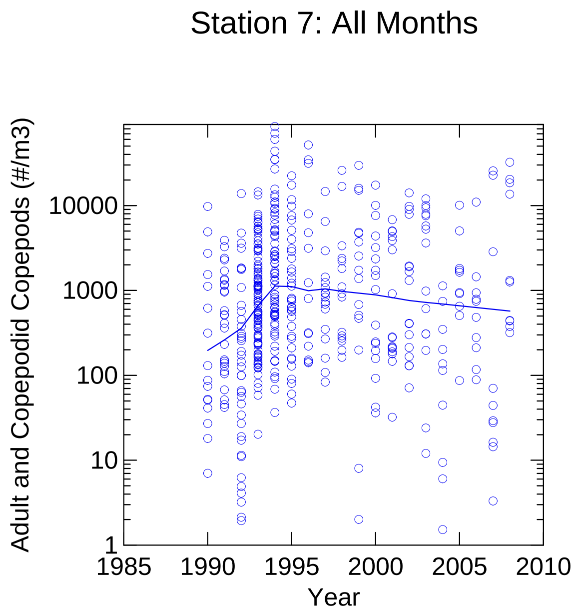
Copepod nauplii, the immature stages of copepods, were somewhat lower in 2008 resulting in a tapering of an increase begun since 1990 (Figure 141). Trend line values reached 60/L in 2007 well above the initial level of 10/L observed in 1990. A strong linear increase was observed over the study period (Table 12).

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



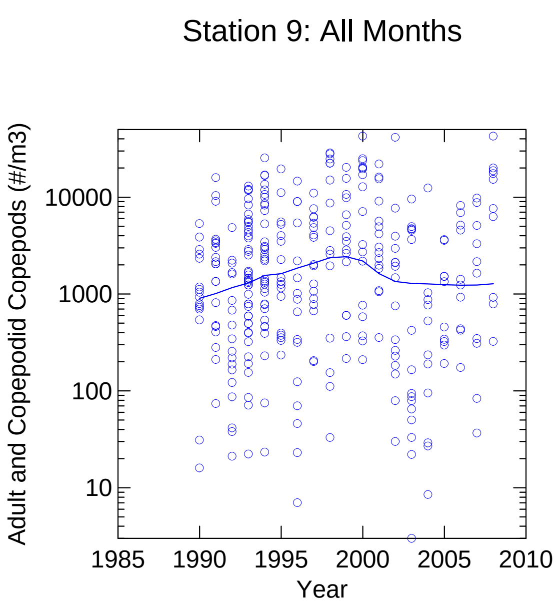
In the river, copepod nauplii continued a decline begun in 2002 (Figure 142). The 2008 LOWESS trend line value was 25/L, up from an initial value of 10/L in 1990, but below the peak of about 70/L. Nonetheless, there was still limited evidence for a significant linear increase in nauplii over the study period (Table 12).

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



Adult and copepodid copepods increased strongly in the early 1990's and since have undergone a slow decline (Figure 143). Levels in 2008 were higher resulting in a trend line level of about 600/m^3, above the initial level of 200/m^3 observed in 1990, although clearly below a peak of 1000/m^3 in 1994. Copepods did not exhibit a significant linear change over the study period (Table 12).

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



Adult and copepodid copepods stabilized in 2008 following a slight decline begun in 1998 (Figure 144). The trend line in 2008 reached 1000/m^3, well below the maximum of 2500/m^3 in 1998 and similar to the level of 1000/m^3 in 1990. There was no evidence for a significant linear trend when the entire study period was considered (Table 12).

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

E. Ichthyoplankton Trends

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

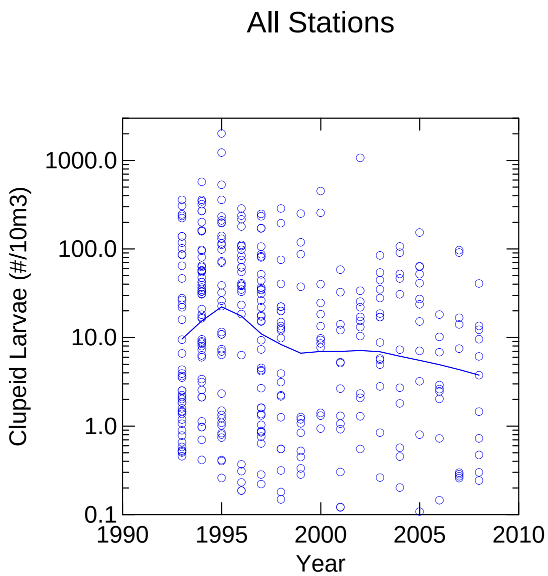
For all of the dominant species of ichthyoplankton, densities have exhibited a slightly declining or relatively flat trend over the course of monitoring on this survey. Clupeid larvae (which are primarily river herring and gizzard shad), *Morone* sp. (mostly white perch), Atherinids (inland silversides), and yellow perch all exhibited a spike in density during the earliest five years of monitoring. In all cases, this pattern was followed by a rapid decline to a relatively flat trend in density during the past decade. Comparing 2008 with the previous year, the largest change occurred for *Morone* sp. and *Dorosoma* sp. with an approximate doubling and halving of the total number captured, respectively for these groups (Table 13).

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

Table 13. The larval fishes collected in Gunston Cove and the Potomac River in 2004-08

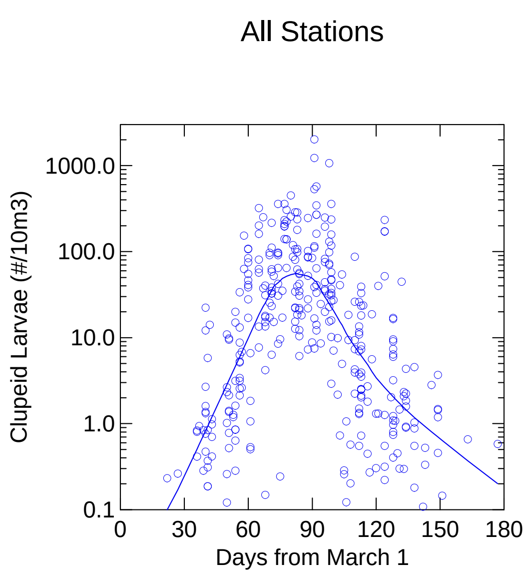
Table 13
Larval Fishes Collected, by Taxon
Gunston Cove Study – 2004-08

Taxon	Common Name	2004	2005	2006	2007	2008	Total (%)
				Number caught			
Clupeidae	herring and shad family	0	650	0	6	0	656 (7.8)
Alosa sp.	American shad, alewife, hickory shad, or blueback herring	1596	569	63	103	15	2331 (27.7)
Dorosoma sp.	gizzard shad or threadfin shad	841	2110	254	992	510	4197 (49.8)
Brevortia tyranus	menhanden	0	0	0	0	2	
Morone sp.	white perch or striped bass	377	242	52	233	427	904 (10.7)
Perca flavescens	yellow perch	0	0	136	70	6	206 (2.4)
Menidia beryllina	inland silverside	12	26	54	31	8	123 (1.5)
Cyprinus carpio	common carp	1	0	0	0	0	1 (<0.1)
Notropis hudsonius	spottail shiner	1	0	0	0	0	1 (<0.1)
Erimyzon oblongus	creek chubsucker	2	1	0	0	0	3 (<0.1)
Stongylura marina	Atlantic needlefish	0	0	0	0	1	
Unidentified		0	0	0	5		5 (<0.1)
Total		2830	3598	559	1440		8427



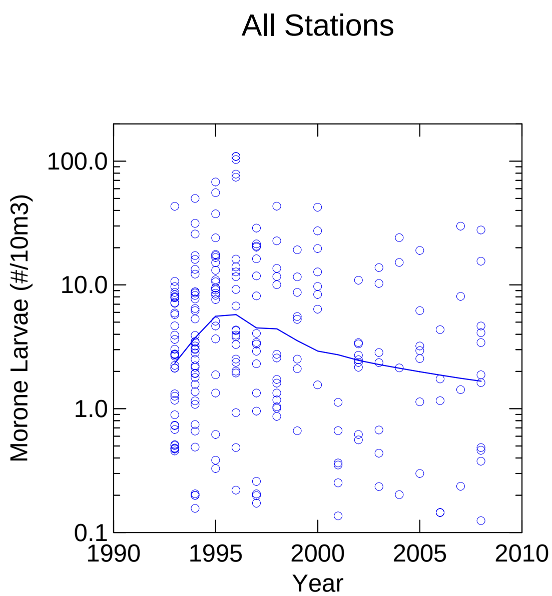
A graph of clupeid fish larvae averaged over all stations from 1993 through 2003 is shown in Figure 145. Because of the difficulty of distinguishing post yolk sack gizzard shad from the alewife and blueback herring, this graph groups all three species. The trend line remains steady at about 7 larvae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

Figure 145. Long term trend in Clupeid Larvae.



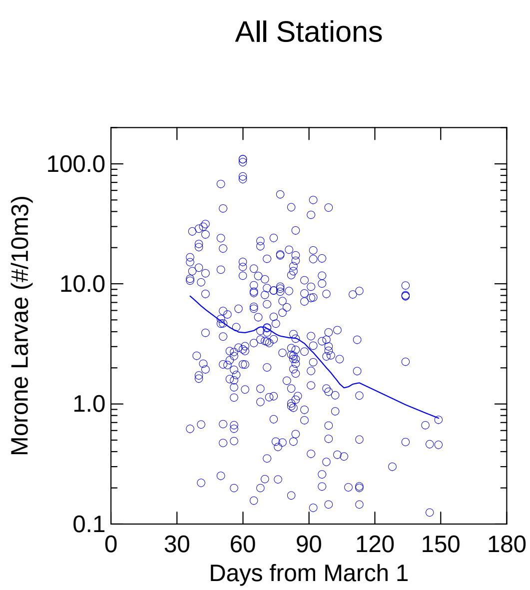
The seasonal pattern in clupeid larvae for 1993-2007 (Figure 146) shows that a peak in density occurs about 80-85 days after March 1, or in the last two weeks of May. A first explanation of the timing and breadth of the peak most certainly lies in the interannual variability of the development of warming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

Figure 146. Seasonal pattern in Clupeid Larvae.



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

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



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

Figure 148. Seasonal pattern in *Morone* Larvae.

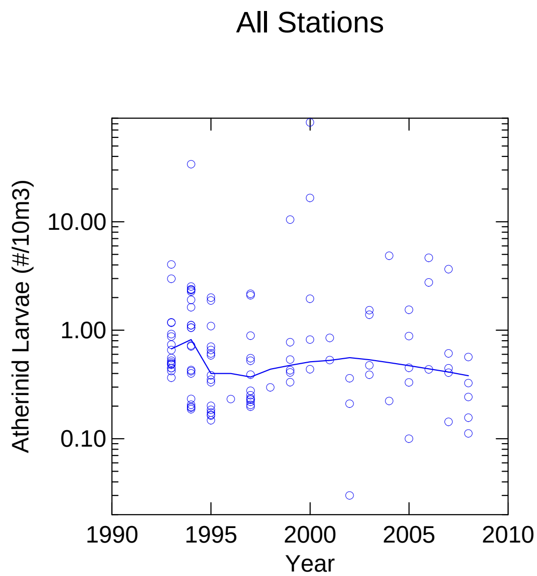


Figure 149. Long term trend in Atherinid Larvae.

The long term trend in density of Atherinid larvae (probably all inland silverside larvae) is presented in a LOWESS graph in Figure 149. The number of atherinid larvae per $10m^3$ caught in individual tows in 2007 has remained rather low. These open water collections are probably not totally representative of the population of larvae in the cove, since they may remain in the shallows along the shore or in the submerged weed beds where they are spawned.

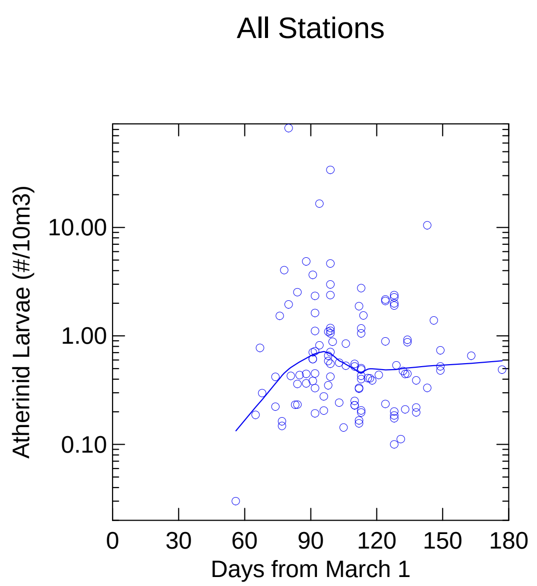
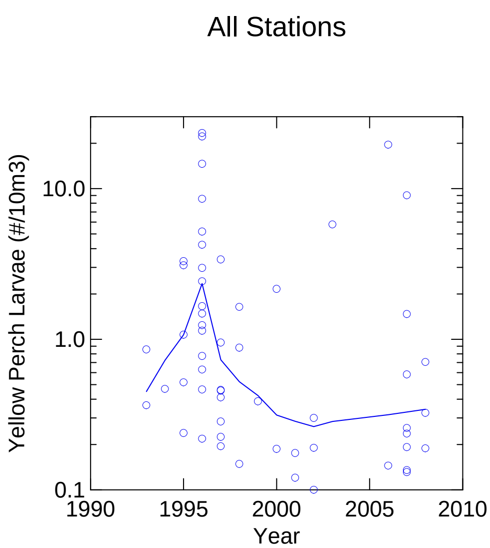


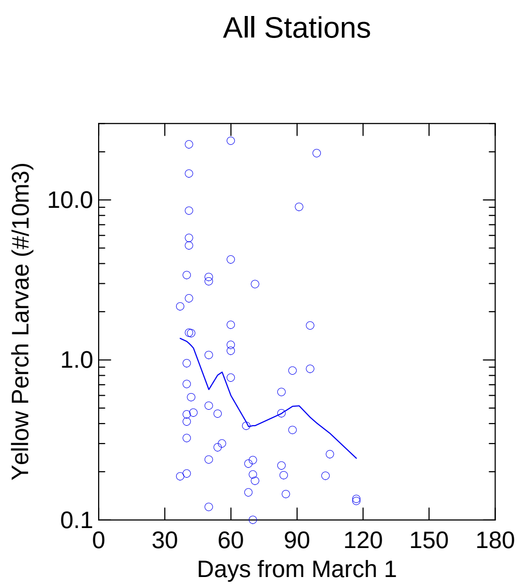
Figure 150. Seasonal pattern in Atherinid Larvae.

The seasonal occurrence of atherinid larvae per $10m^3$ is shown in a LOWESS graph in Figure 150. The pattern shows maximum density around 97 days after March 1, or around the first or second week of June. However, the peak is not pronounced, and the density persists at a slightly lower level into the fall.



The LOWESS graph in Figure 151 gathers the trend in density of yellow perch since 1993. Following unusually high densities in 1996, the general trend is a decline to lower numbers although they were caught in many samples in 2007 and 2008.

Figure 151. Long term trend in Yellow Perch Larvae.



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

Figure 152. Long term trend in Yellow Perch Larvae.

E. Adult and Juvenile Fish Trends: 1984-2008

Trawls

Overall patterns

Annual abundance of juvenile fishes inside Gunston Cove is indexed by mean catch per trawl at stations 7 and 10 combined (Table 14, Figure 153a). Since 1984, this index has fluctuated by over an order of magnitude, and the pattern was predominately due to changes in the catch rate of white perch (Figure 153a). Consequently, the catch rates of white perch and all species combined has exhibited a continuous declining trend across this entire period (Figure 153b). On average, catch rates of fishes within the cove were approximately one-third of what was recorded in the first few years of the survey (Figure 153b). The overall catch rate for the inner cove in 2008 was one of the 5 lowest on record for the survey (the lowest inner cove catch rate occurred in 2006). Of the most typically captured species only, 2 showed a modest increase from 2007: gizzard shad and brown bullhead. At station 9 in the main stem of the river, catch rate trends for individual species were similar to the inner cove with a decline for most species relative to 2007. Notably, catch of bay anchovy countered this pattern with the highest catch rate on record for this station, and for all stations combined, catch of bay anchovy was the second highest on record. 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 153a). With the exception of 2007 which had the highest catch rate on the survey, white perch catch rates at station 9 have demonstrated a flat or slightly increasing trend. By comparison, the importance of other species in the catches is apparent via a more moderate increasing trend in catch rate of all species combined at station 9 (Figure 153b,c).

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

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

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

Year	all species	white perch	blueback herring	alewife	gizzard shad	bay anchovy	spottail shiner	brown bullhead	pumpkin-seed
2008	70.7	16.2	0.0	0.1	4.0	0.3	2.6	0.6	7.0
2007	227.3	141.4	23.6	8.8	0.2	15.8	20.1	0.2	2.6
2006	23.4	8.6	1.4	0.6	0.2	2.0	2.7	0.4	1.6
2005	64.4	19.9	10.6	15.2	0.9	0.0	6.1	0.4	1.4
2004	340.3	19.5	281.3	27.5	0.7	0.5	6.7	0.1	0.4
2003	50.3	9.6	18.8	3.5	0.0	7.4	2.8	1.3	0.5
2002	81.0	15.5	9.9	27.7	0.1	16.2	0.7	0.9	1.7
2001	143.5	47.0	40.5	9.9	0.3	35.1	2.8	3.3	1.4
2000	70.0	54.9	3.6	1.9	2.4	1.7	1.3	2.0	0.6
1999	86.9	63.2	4.2	0.5	1.0	5.4	4.8	2.4	1.8
1998	83.2	63.9	2.2	0.5	0.6	3.7	6.8	1.0	1.7
1997	81.4	61.7	1.9	1.0	5.0	2.6	2.9	1.5	1.2
1996	48.0	35.4	2.5	1.6	0.5	0.2	2.6	0.5	2.1
1995	88.6	69.7	4.1	2.1	0.4	3.0	3.0	1.9	1.8
1994	92.2	66.9	0.8	0.1	0.1	0.5	6.2	3.2	2.7
1993	232.1	203.3	1.3	0.5	1.3	0.6	6.9	4.3	3.2
1992	112.8	81.6	0.2	0	0.9	0.8	2.4	11.5	5.1
1991	123.7	90.9	1.0	0.5	8.1	2.6	2.9	12.4	1.7
1990	72.8	33.3	21.9	3.2	0.1	1.1	1.1	10.0	0.5
1989	78.4	14.9	16.1	0.2	42.4	0.2	0.5	3.0	0.6
1988	96.0	45.1	11.2	8.8	12.7	8.3	1.8	5.3	0.9
1987	106.7	54.3	16.0	3.5	5.6	8.8	0.7	15.0	1.4
1986	124.6	65.4	1.9	24.0	4.1	4.2	0.5	18.4	0.6
1985	134.4	43.2	13.5	12.4	2.9	48.1	0.9	9.6	0
1984	167.8	99.5	7.5	0.7	13.8	8.1	1.7	33.3	0.2

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

Year	all species	white perch	American eel	bay anchovy	spottail shiner	brown bullhead	channel cat	tessellated darter	hog-choker
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	0.2
2005	91.1	36.5	0.0	12.1	1.8	2.2	4.7	0.1	0.1
2004	41.9	20.4	0.0	0.0	1.1	2.2	6.6	0.0	0.9
2003	62.5	29.9	0.1	0.0	0.6	2.1	14.1	1.2	6.6
2002	52.9	27.2	0.1	0.5	0	2.2	10.2	0.8	1.9
2001	77.1	40.1	0.2	22.2	0.1	0.9	5.5	0.8	1.3
2000	52.4	43.4	0.1	0	0.1	2.2	0.9	0	2.2
1999	23.1	19.1	0.1	0.2	0	0.2	3.2	0	0.9
1998	22.1	12.8	0.1	0.4	0.1	0.2	4.5	2.0	0.2
1997	49.6	37.2	0.2	0	1.1	0.3	2.3	0.4	0.3
1996	14.0	7.0	0.1	0	0.1	0.1	1.7	0.8	0
1995	31.9	17.4	0.3	0.2	0.2	4.3	2.0	0.1	0.5
1994	31.9	13.4	3.1	0.1	0	2.4	4.2	3.5	2.4
1993	31.2	6.8	1.6	0	6.6	1.3	6.8	7.9	1.2
1992	27.5	14.2	2.6	0	0	1.2	1.7	0.8	6.6
1991	67.9	42.4	0.4	1.9	0.1	1.0	1.9	0.4	6.3
1990	101.5	50.6	1.0	0	0.1	5.2	0.8	0.1	4.0
1989	14.3	7.9	0.2	0.4	0	1.5	0.3	0.3	0.2
1988	19.2	5.2	0	11.5	0	0	1.6	0	0.5

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

Year	all species	white perch	blueback herring	alewife	gizzard shad	bay anchovy	spottail shiner	brown bullhead	channel cat
2008	78.8	14.1	0.0	0.0	2.7	26.8	1.7	0.4	0.0
2007	236.1	159.5	16.6	11.6	0.1	10.7	13.8	0.1	0.0
2006	38.3	16.1	1.0	0.4	0.1	2.4	1.0	2.9	1.5
2005	114.8	26.4	7.5	15.8	0.6	4.3	4.6	1.0	1.8
2004	240.8	19.8	187.6	19.5	0.5	0.3	4.8	0.8	2.2
2003	54.4	16.4	12.6	2.3	0	4.9	2.0	1.6	5.3
2002	71.6	19.6	6.6	19.0	0.1	10.6	0.4	1.3	4.6
2001	122.3	45.8	27.6	6.8	0.3	31.0	1.9	2.6	1.8
2000	64.1	51.0	2.4	1.3	1.7	1.1	0.9	2.1	1.4
1999	65.6	48.4	2.8	0.3	0.7	3.7	3.2	1.7	0.8
1998	62.8	46.8	1.4	0.4	0.4	2.6	4.5	0.7	2.1
1997	70.8	53.5	1.3	0.7	3.3	1.7	2.3	1.1	3.1
1996	36.7	25.9	1.6	1.1	0.3	0.1	1.7	0.4	2.0
1995	69.7	52.3	2.7	1.5	0.2	2.1	2.0	2.7	2.9
1994	73.2	50.1	0.5	0	0.1	0.4	4.2	2.9	2.2
1993	167.8	140.4	0.9	0.4	0.9	0.4	6.8	3.3	1.8
1992	88.5	62.3	0.2	0	0.6	0.6	1.7	8.6	0.5
1991	103.8	73.6	0.6	0.4	5.2	2.4	1.9	8.4	4.7
1990	82.4	39.1	14.6	2.2	0.1	0.8	0.8	8.4	13.3
1989	57.0	12.6	11.0	0.2	28.4	0.3	0.3	2.5	0.7
1988	85.7	39.8	9.7	7.6	11.0	8.7	1.6	4.6	0.3
1987	106.7	54.3	16.0	3.5	5.6	8.8	0.7	15.0	0
1986	124.6	65.4	1.9	24.0	4.1	4.2	0.5	18.4	0
1985	134.4	43.2	13.5	12.4	2.9	48.1	0.9	9.6	0
1984	202.6	133.3	6.6	0.6	13.4	8.0	1.6	35.0	0.1

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

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

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

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

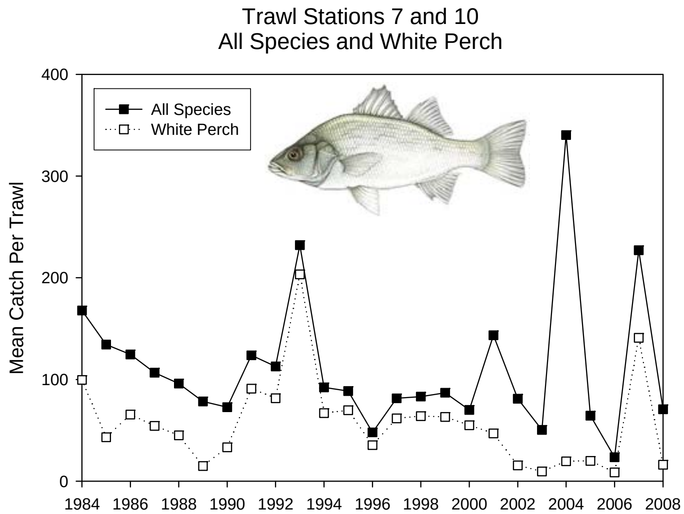


Figure 153a. Trawls. Annual Averages.
All Species and White Perch. Cove Stations 7 and 10.

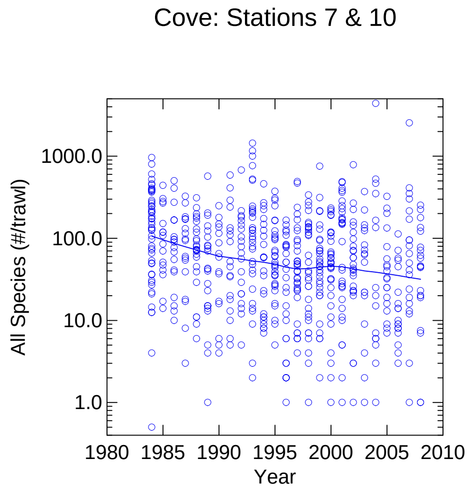


Figure 153b. Trawls. Long Term
Trend in Total Catch

Mean total number of fish per trawl sample exhibited a decline since the study began (Table 14 and Figure 153a, b), and this pattern was primarily a function of catches of white perch. The decline in white perch catch rates was punctuated by strong cohorts in 1993, 2007, and to a lesser degree 1984. 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 low catch rates between 2001 and 2008. For the remaining component of the catch, a complementary pattern is evident. Species other than white perch made up: a moderate to large proportion of the catch until 1990; a relative small part of the catch between 1991 and 2000; and, excepting 2006, a moderate to large proportion of the catch from 2001 to 2008.

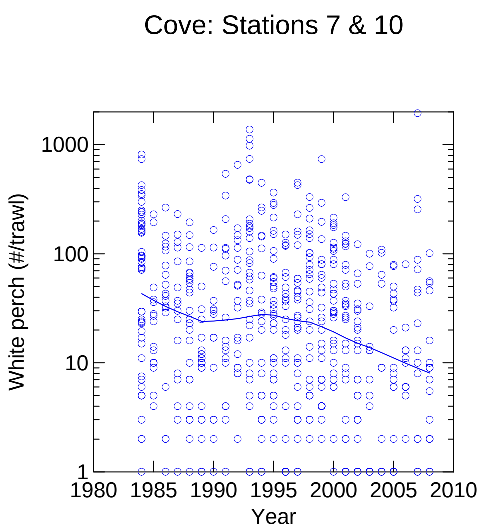


Figure 153c. Trawls. Long Term
Trend in White Perch. Sta 7 & 10.

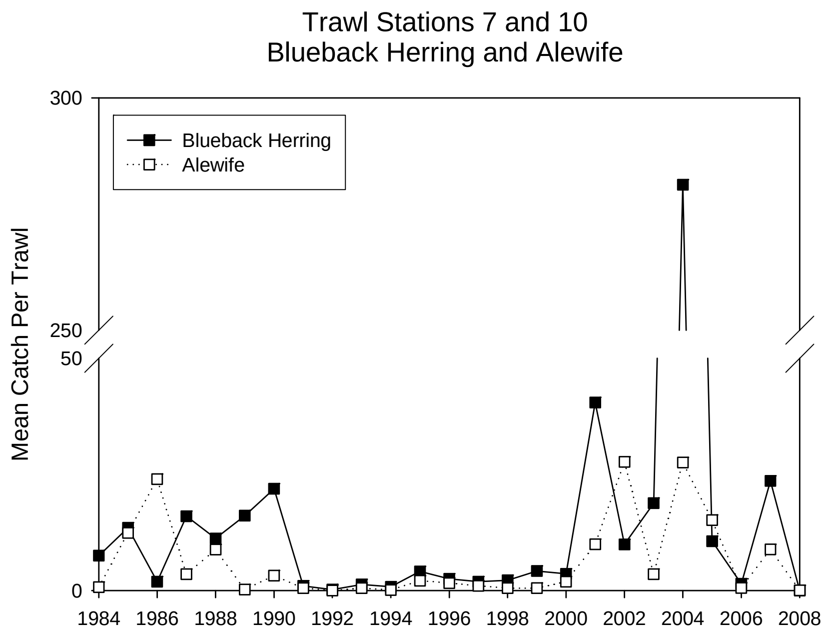


Figure 154a. Trawls. Annual Averages. Blueback Herring and Alewife. Cove Stations.

Although the strong year-class effects varied by species for the anadromous fishes, the same three phases of abundance for white perch were also evident for juvenile river herring (collectively, alewife and blueback herring). Moderate catch rates until 1990 were followed by a period of consistently low catch rates until 2000, after which catch rates have been moderate to high. It cannot be determined from these data whether low catch rates in 2006 and 2008 signify the start of a period of low catch rates, as time averaged trends still indicate the most recent period is higher than in any previous time during the survey (Figures 154 b & c).

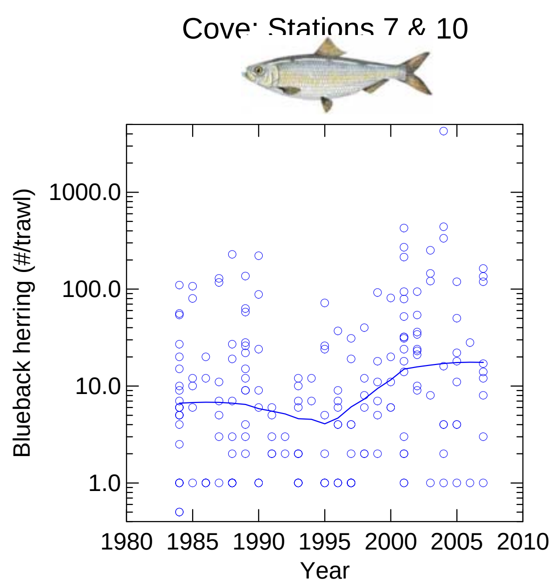


Figure 154b. Trawls. Long term trend in Blueback Herring (*Alosa aestivalis*). Cove Stations.

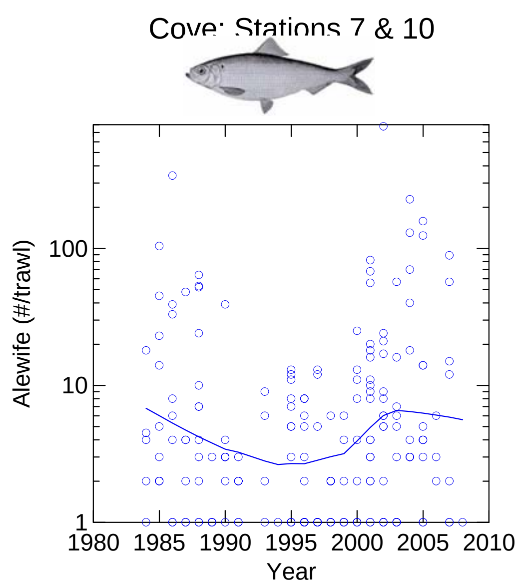


Figure 154c. Trawls. Long term trend in Alewife (*Alosa pseudoharengus*). Cove Stations.

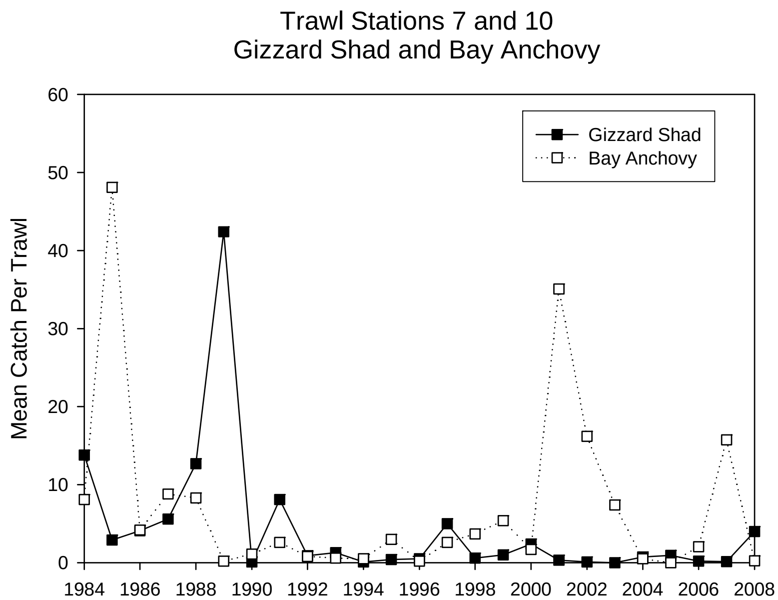


Figure 155a. Trawls. Annual Averages. Gizzard Shad and Bay Anchovy. Cove Stations.

Gizzard shad catch rates in trawls remained low in 2008, continuing a trend that began in 1990 (Figure 155a,b). Trend analysis with LOWESS emphasized declining gizzard shad catch rates for stations 7 and 10. Bay anchovy catch rates were also low in 2008 at inner cove stations. Although they are primarily resident in more saline portions of the estuary, their sporadic occurrence in tidal freshwater may represent significant transport of productivity from the lower regions of the Potomac. In addition, as they are an annual species, the parabolic trend in mean catch rates over the course of the survey (Figure 155c) is more indicative of prevailing environments (favorable versus unfavorable for early life stages and estuarine transport) than spawning stock abundance.

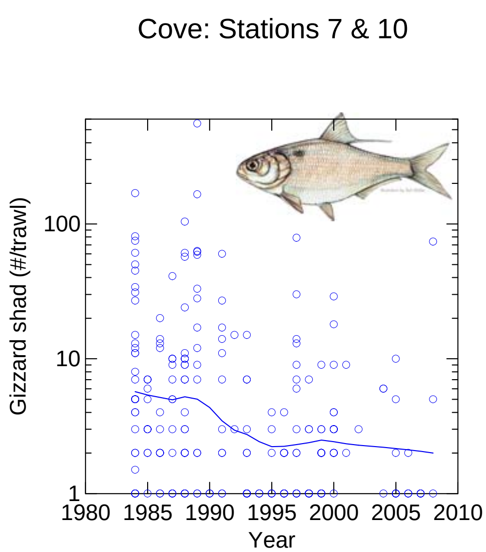


Figure 155b. Trawls. Long term trend in Gizzard Shad (*Dorosoma cepedianum*). Cove Stations.

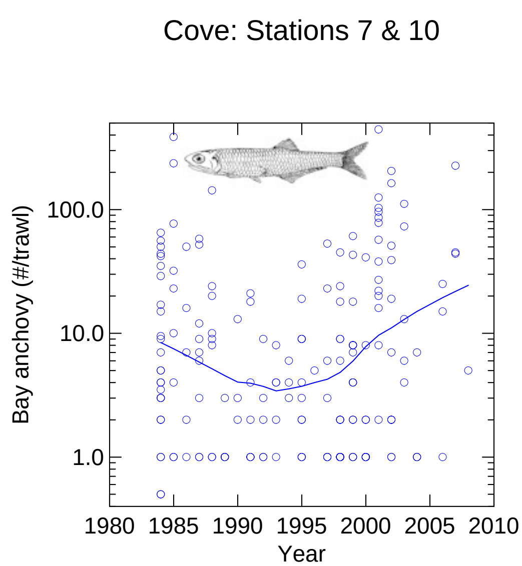
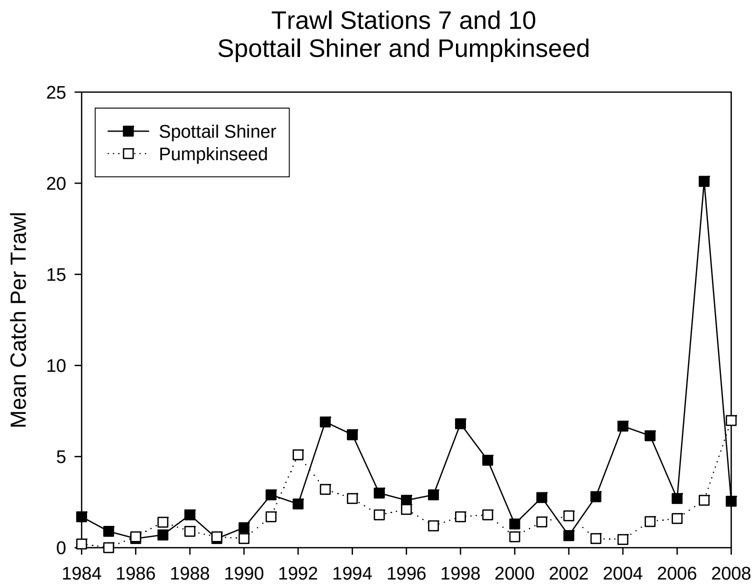


Figure 155c. Trawls. Long term trend in Bay Anchovy (*Anchoa mitchilli*). Cove Stations.



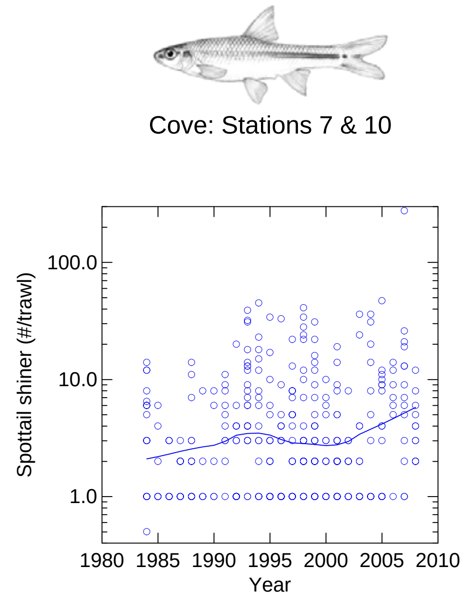


Figure 156a. Trawls. Annual Averages. Spottail Shiner and Pumpkinseed. Cove Stations.

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

Spottail shiner and sunfish (bluegill and pumpkinseed) are typically captured in low numbers relative to anadromous species, but they are consistently observed in the majority of all trawl and seine samples (Figure 156 a,b,c,d). In all three species, an increasing (albeit minor) trend has been observed since the beginning of the survey. In 2008, the most notable change was high catch rates of bluegill sunfish. These individuals were mostly juveniles, indicating unprecedented reproductive success of this species as measured by this survey.

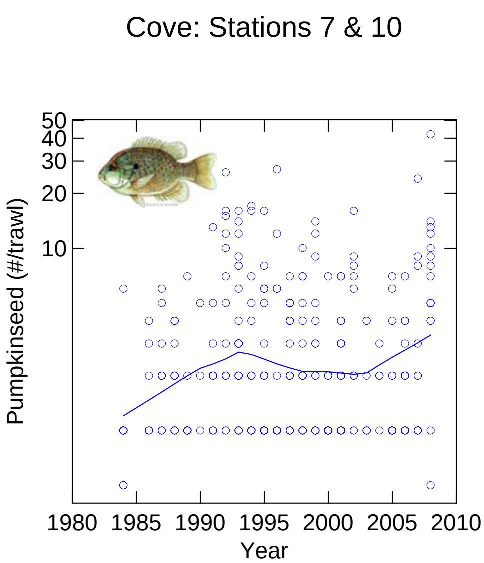


Figure 156c. Trawls. Long term trend in Pumpkinseed (*Lepomis gibbosus*). Cove Stations.

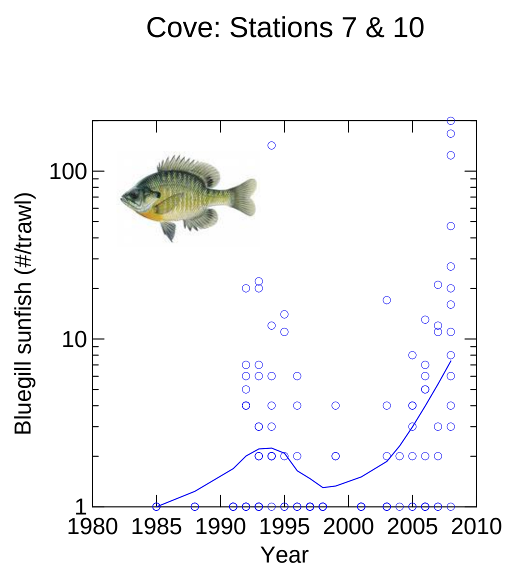


Figure 156d. Trawls. Long term trend in Bluegill (*Lepomis macrochirus*). Cove Stations.

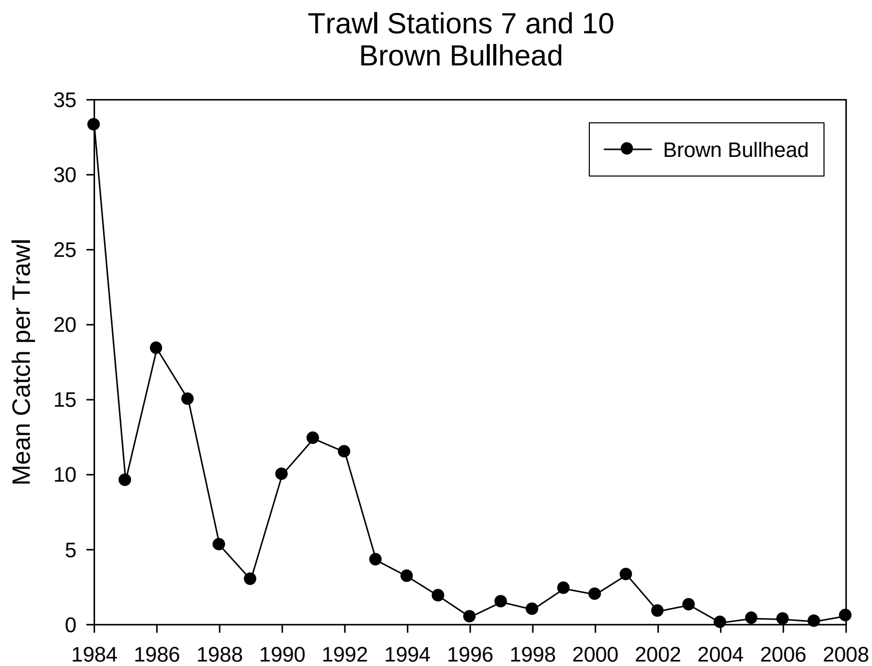


Figure 157a. Annual Averages. Brown Bullhead. Cove Stations.

Very few brown bullhead were captured during 2008, continuing a declining trend that has proceeded continuously since the start of the survey. This trend is evident both in the mean catch rate as well as the density of bullhead in non-zero catches (Figure 157a,b). Tessellated darter were consistently encountered at low abundance in trawl samples - at typical abundances of 1 to 2 individuals per trawl when observed at stations 7 and 10 (Figure 157c).

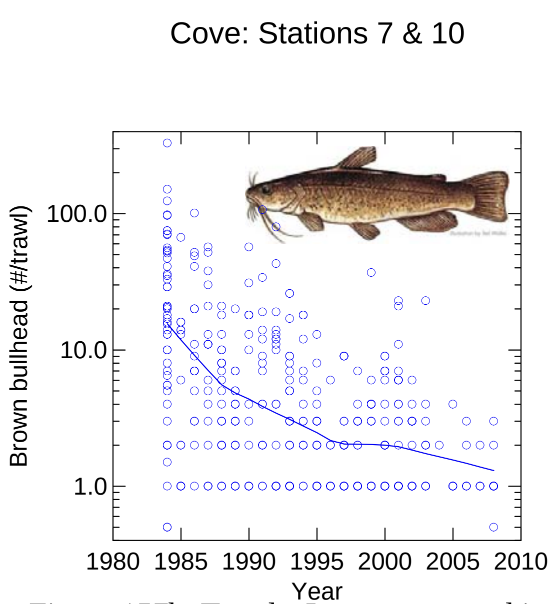


Figure 157b. Trawls. Long term trend in Brown Bullhead (*Ameirus nebulosus*). Cove Stations.

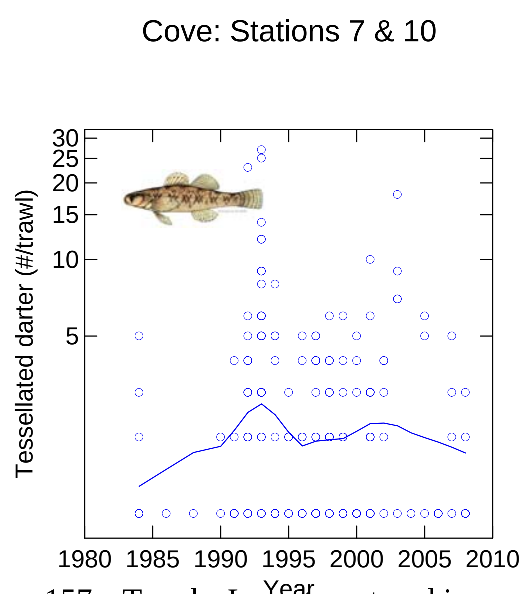


Figure 157c. Trawls. Long term trend in Tessellated Darter (*Etheostoma olmstedi*). Cove Stations.

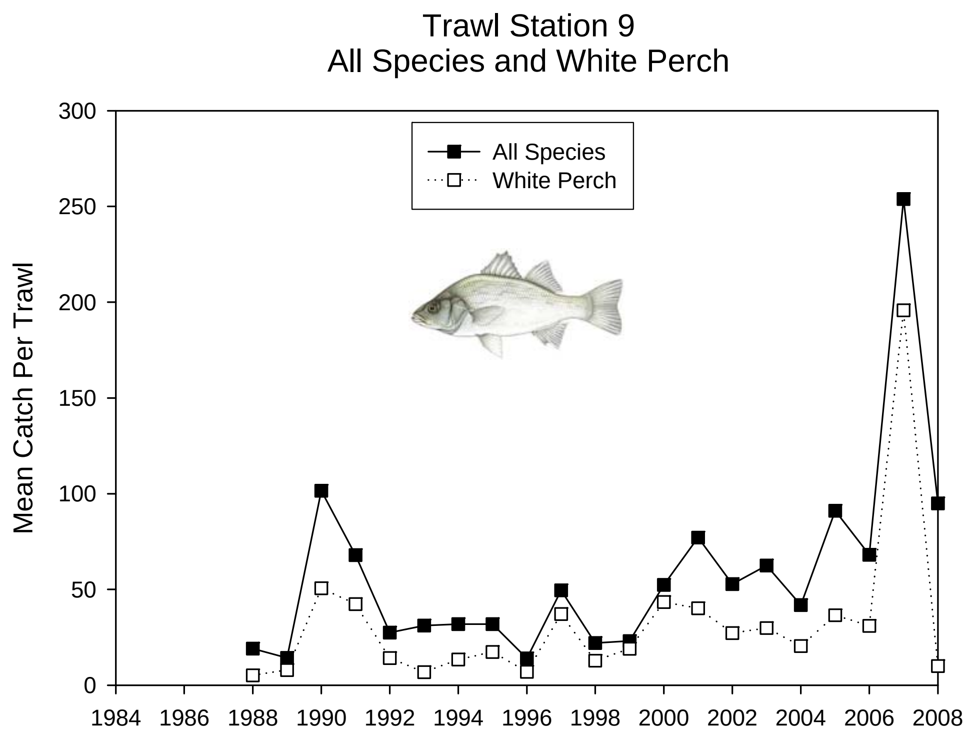


Figure 158a. Trawls. Annual Averages. All Species and White Perch. River Station.

At the river channel station (station 9), 2008 perpetuated an increasing trend in total fish catch rate (Figure 158a). Overall, catch rates of white perch and all species combined at station 9 were typically lower and less variable than at inner cove stations. Much of the variation at station 9 is directly attributable to the catch of white perch, but other species have become more important in recent years. These trends are not evident in the density of fish in positive catches, which has remained realatively constant around 11per trawl for all species combined and around 10 per trawl for white perch (Figures 158b,c). This indicates that the positive trend in mean catch rate trend is due to an increase in frequency of positive catches.

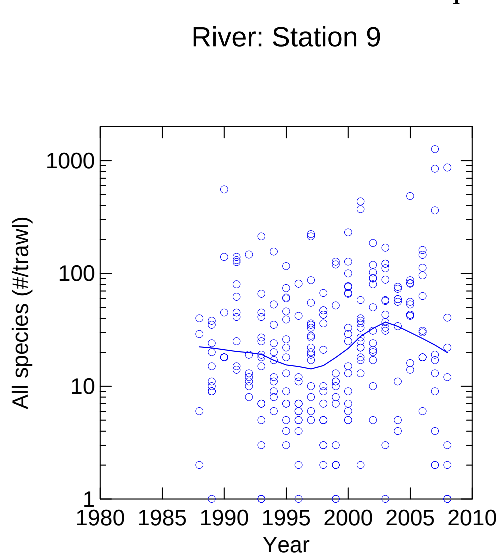


Figure 158b. Trawls. Long term trend in Total Catch. River Station.

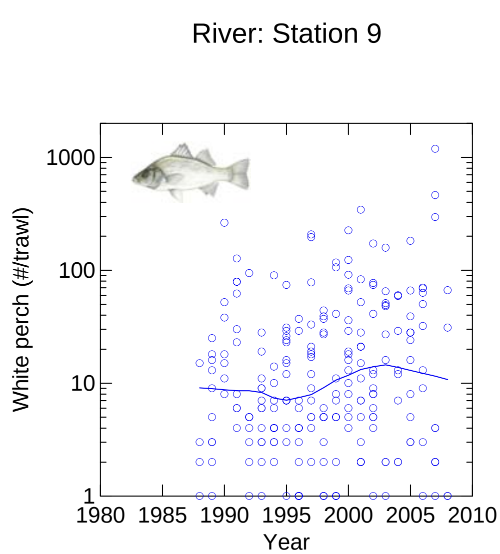


Figure 158c. Trawls. Long term trend in White Perch (*Morone americana*). River Sta.

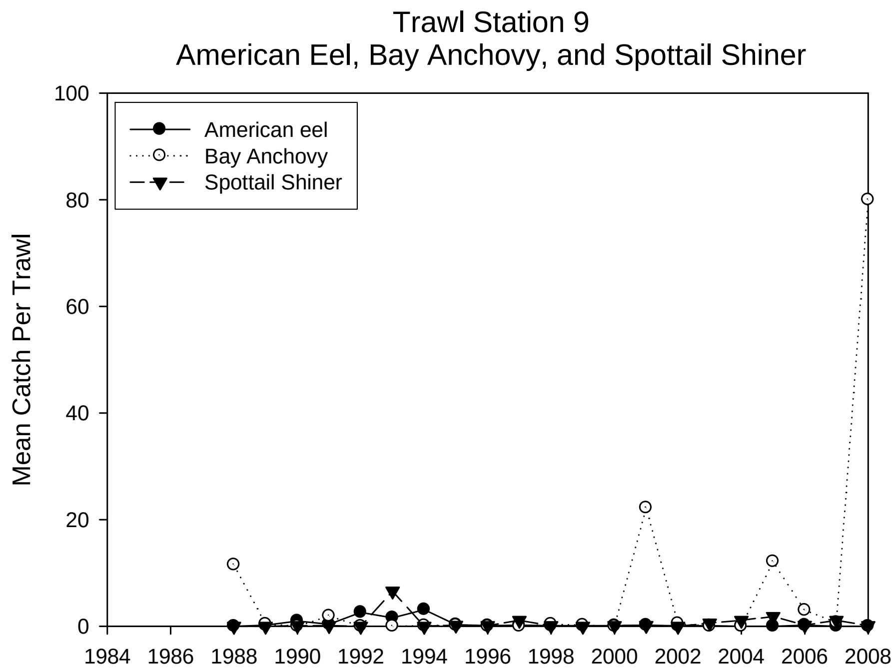


Figure 159a. Trawls. Annual Averages. Eel, Bay Anchovy, and Spottail Shiner. River Station.

Since 1988 when station 9 was incorporated as part of the survey, bay anchovy, spottail shiner, and American eel have occurred sporadically at station 9 (Figures 159a,b,c). Trends in mean catch rates for bay 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 2009 was the highest on record and indicates strong reproductive success and/or upstream transport.

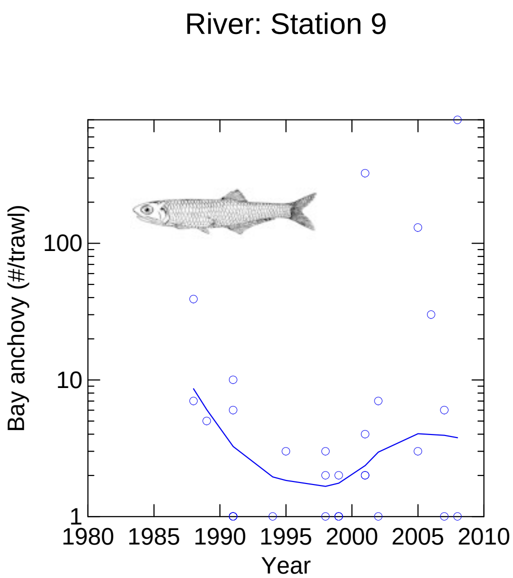


Figure 159b. Trawls. Long term trend in Bay Anchovy (*Anchoa mitchilli*). River Station.

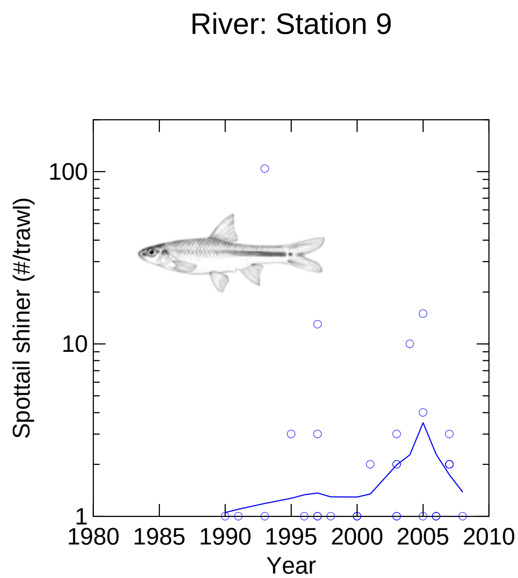
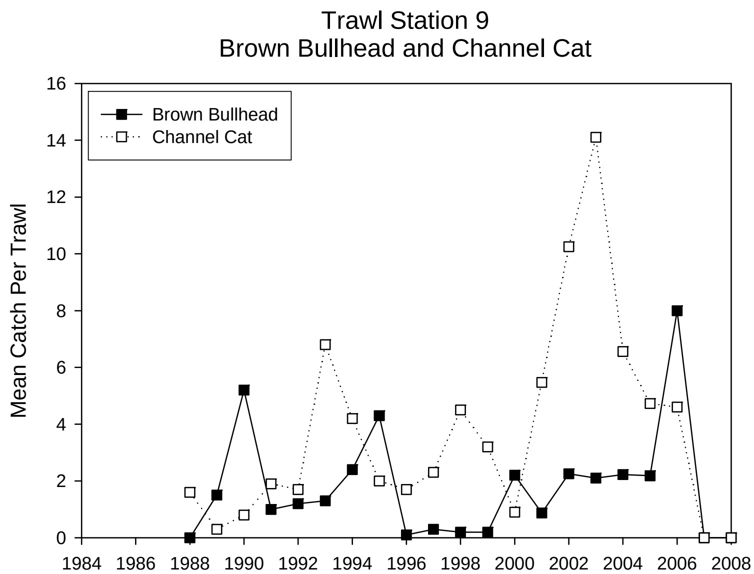


Figure 159c. Trawls. Long term trend in Spottail Shiner (*Notropis hudsonius*). River Station.



River: Station 9

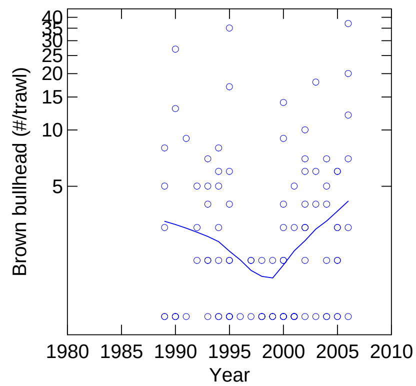


Figure 160a. Trawls. Annual Averages. Brown Bullhead and Channel Cat. River Station.

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

Overall, catch rates for all catfish species have been variable and at low levels (mean of 2 to 4 per trawl) compared to most other species that were observed (Figure 160a,b,c,d). In particular, 2008 ranked as one of the 5 lowest years in mean catch rate for all catfish species. Long-term mean trends were also variable and thus are difficult to characterize. One species that warrants close attention is the invasive, blue catfish, which was positively identified on the survey in 2001 and has been captured each year since then.

River: Station 9

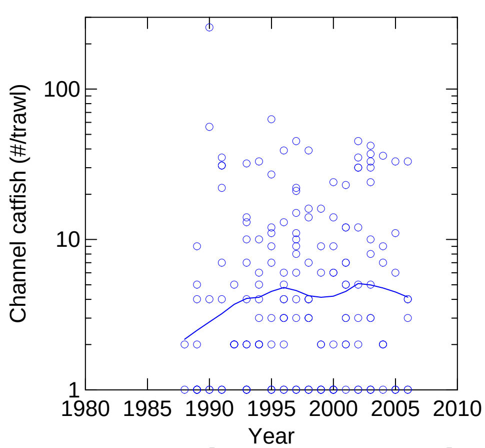


Figure 160c. Trawls. Long term trend in Channel Cat (*Ictalurus punctatus*). River Station.

River: Station 9

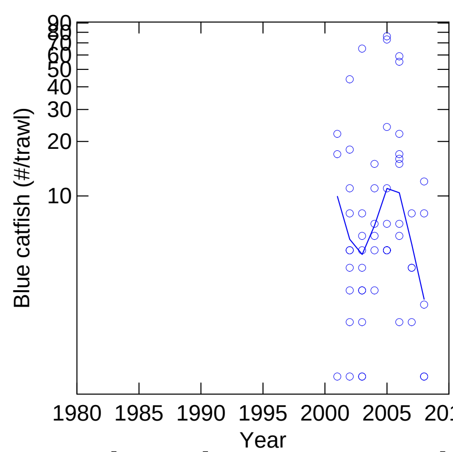


Figure 160d. Trawls. Long term trend in Blue Catfish (*Ictalurus furcatus*). River Station.

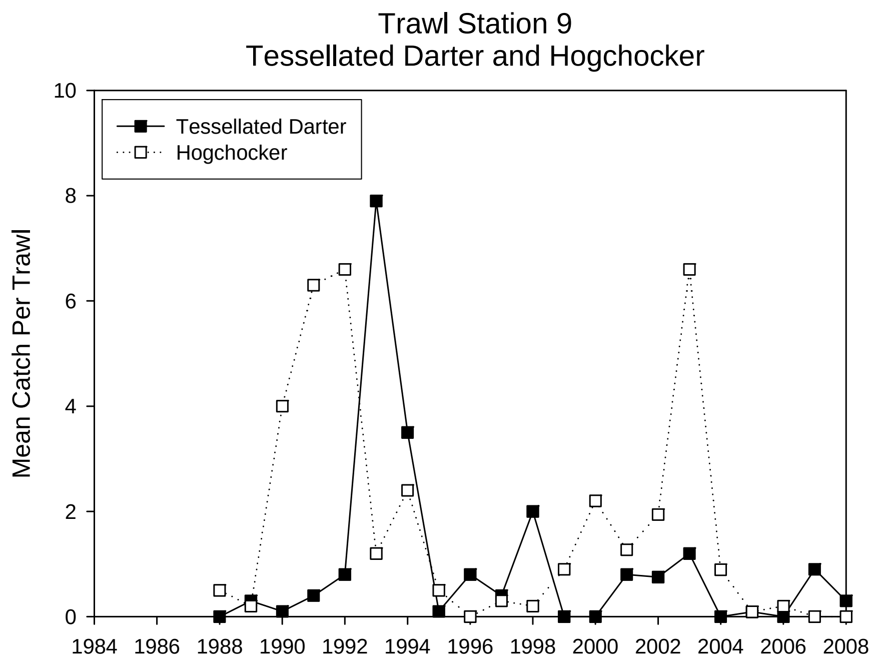


Figure 161a. Trawls. Annual Averages. Tessellated Darter and Hogchoker. River Station.

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

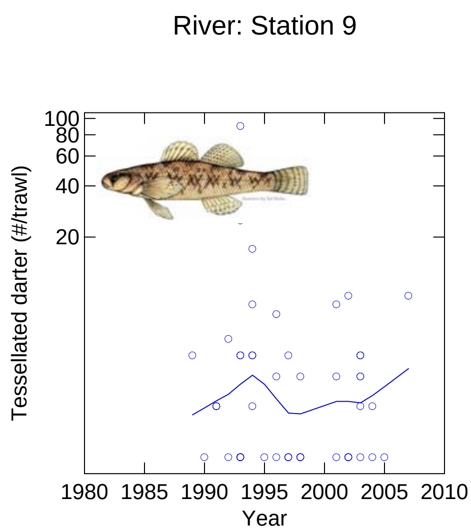


Figure 161b. Trawls. Long term trend in Tessellated Darter (*Etheostoma olmstedi*). River Station.

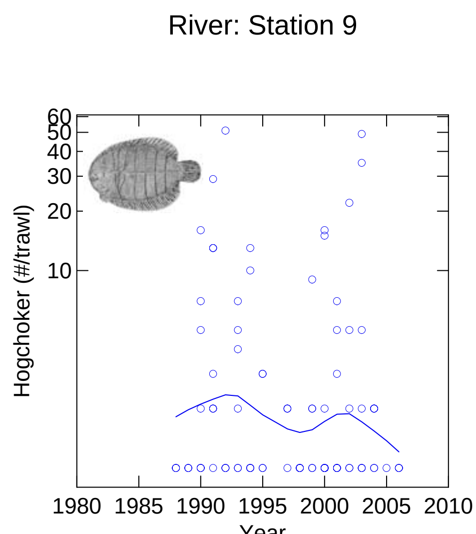


Figure 161c. Trawls. Long term trend in Hogchoker (*Trinectes maculatus*). River Station.

Seines

Mean annual seine catch rates were generally less variable than trawl catch rates, but the long-term trend with a period of lower catch rates during the mid-1990s is reflected in seine samples (Figures 162 and 163). The drop in the moving average (LOWESS trend) of catch rates during the middle of the series reflected a lower density of fish in non-zero catches (Figure 163) - a pattern that is only weakly evident from the lowest annual mean catch rates (zeros included) for 1993 and 1995 (Figure 162). Of the three most abundant years, 1994 was driven primarily by a single large catch of alewife, whereas high catch rates in 1991 and 2004 were a result of high catch rates of spottail shiner, blueback herring and (in 2004) alewife (Table 19). Overall, white perch and banded killifish have been the dominant species in seine samples throughout the survey, and this pattern also held in 2008.

Over the course of the survey mean annual seine catch rates of white perch have exhibited a gradual decline (Figures 164a), and the density of white perch in non-zero catches has declined at a faster rate over this period (Figure 164b). As this declining pattern is also reflected in the trawl data for the inner cove and there is an increasing trend for white perch at station 9, it appears that white perch distribution may have shifted towards the main stem of the Potomac. Another important factor is the recent pronounced increase in SAV, which is not effectively sampled but may represent a significant alternative habitat for white perch. Efforts to quantify gear efficiency and alternative methods to sample vegetated habitats are needed to understand the relative importance of these factors in explaining the observed trend and are addressed by the mini-study report (see “Development of a Drop-ring Sampling Protocol for Juvenile Fishes in Gunston Cove”, the third chapter in this annual report). In addition, mean annual catch rates of banded killifish have exhibited a long-term increasing trend (Figure 164a), and the density of banded killifish in non-zero catches has also increased by approximately five-fold (Figure 164c). Banded killifish have been the dominant species in seine samples during the past 8 years.

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

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

Year	all species	white perch	banded killifish	blueback herring	alewife	spottail shiner	inland silverside
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	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	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 & 2008 averages do not include Station 4A

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

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

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

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

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

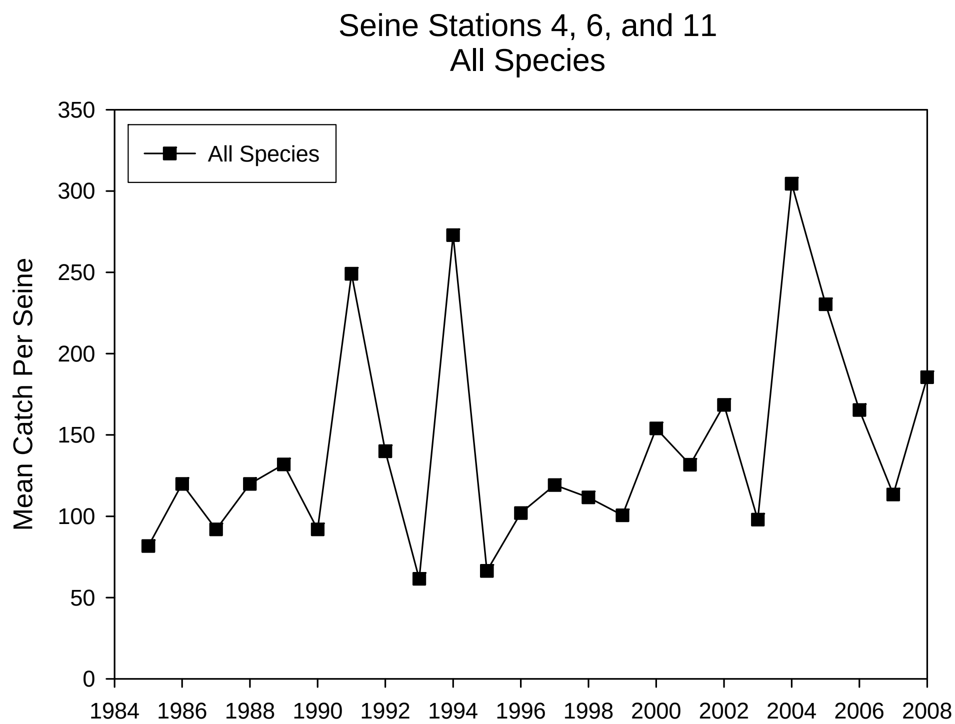


Figure 162. Seines. Annual Average over All Stations. All Species.

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

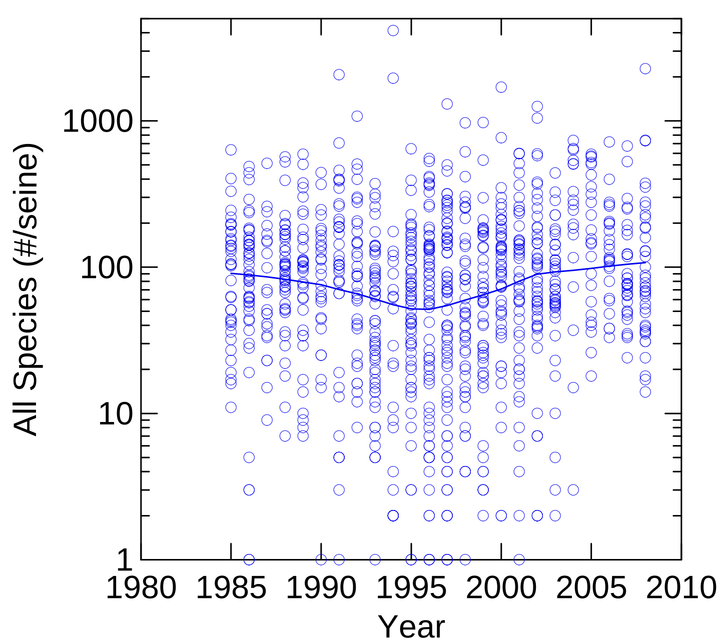


Figure 163. Seines. Long term trend in Total Seine Catch.

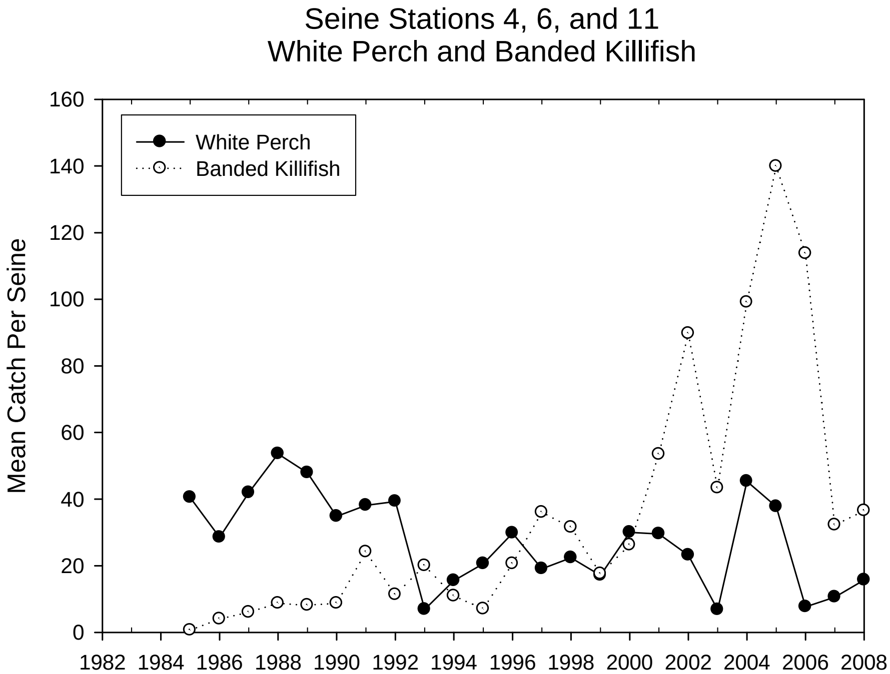
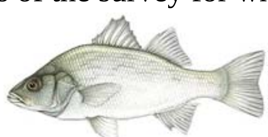


Figure 164a. Seines. Annual Average over All Stations. White Perch and Banded Killifish.

Long-term trends in mean annual catch rates (Figure 164a) and long-term densities in non-zero catches (Figures 164b,c) for the two dominant species in seine hauls have exhibited a negative association over the course of the survey (Figure 164). High initial numbers of white perch were followed by a prominent decline beginning around 1990 to less than half the average at the beginning of the survey. By comparison, banded killifish numbers were relatively low and constant until 1998 when a prominent increase began. In the most recent 2 years (2007 and 2008), mean annual catch rates were approximately one-quarter and 7-times the mean of the first five years of the survey for white perch and banded killifish, respectively.



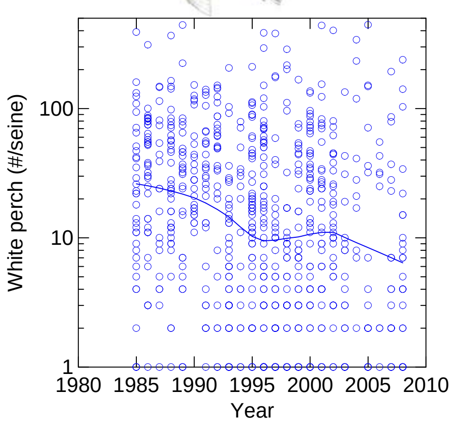


Figure 164b. Seines. Long term trend in White Perch (*Morone americana*). All Stations.

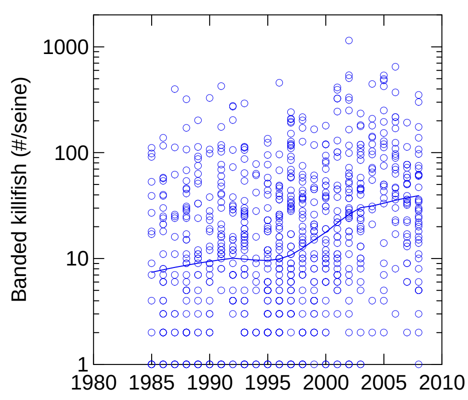


Figure 164c. Seines. Long term trend in Banded Killifish (*Fundulus diaphanus*). All Stations.

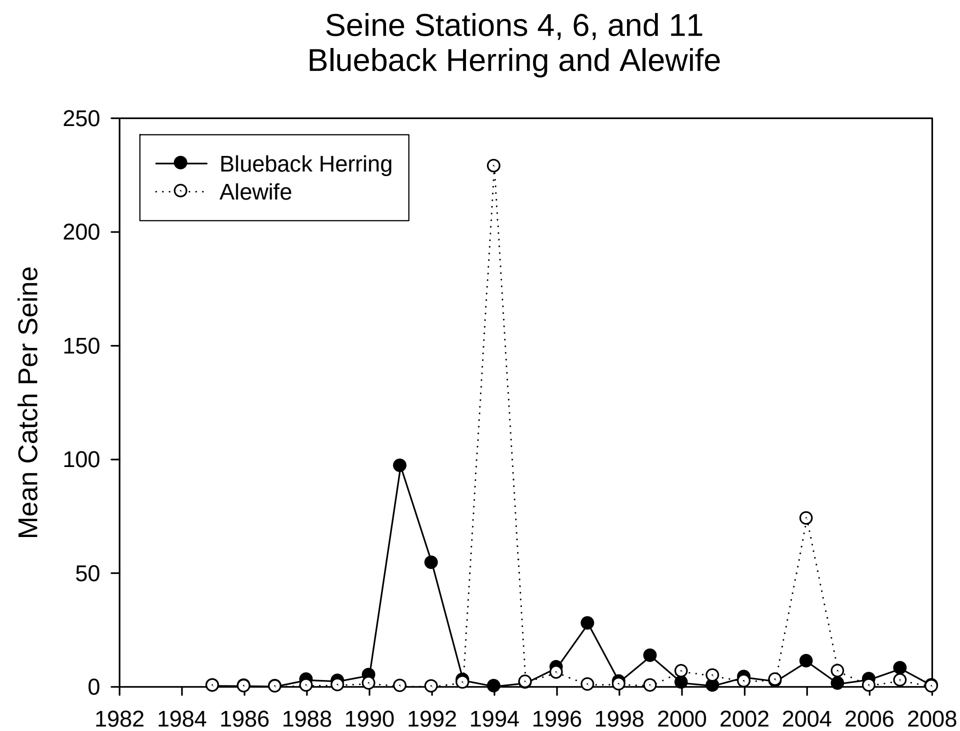


Figure 165a. Seines. Annual Average over All Stations. Blueback Herring and Alewife.

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

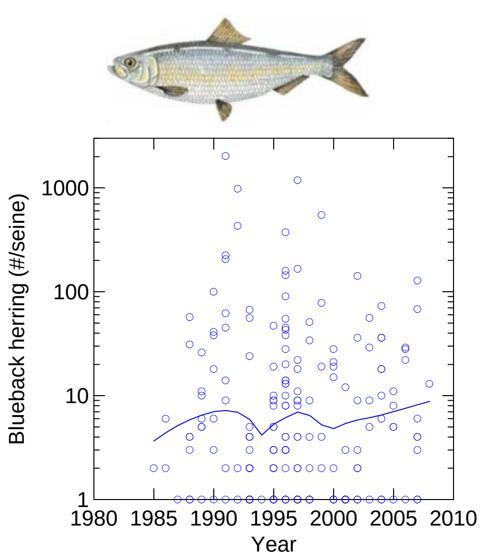


Figure 165b. Seines. Long term trend in Blueback Herring (*Alosa aestivalis*). All Stations.

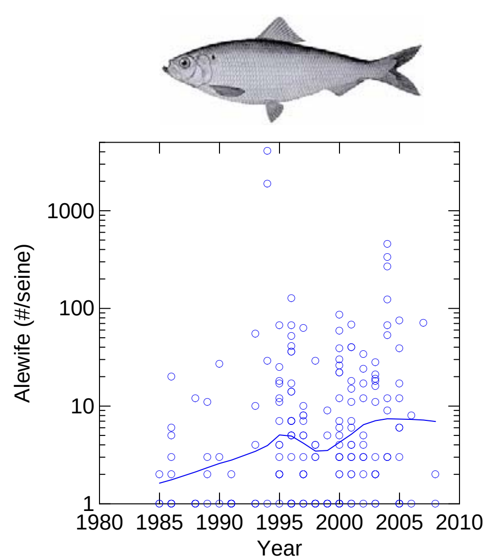


Figure 165c. Seines. Long term trend in Alewife (*Alosa pseudoharengus*). All Stations.

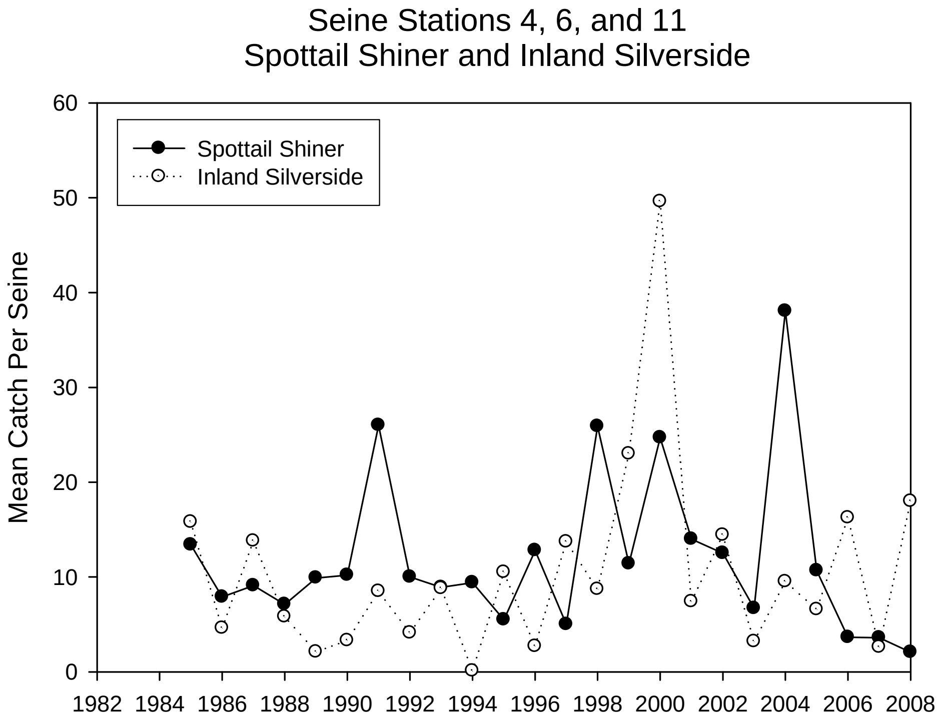


Figure 166a. Seines. Annual Average over All Stations. Spottail Shiner and Inland Silverside.

Owing to their affinity for marginal and littoral zone habitats, spottail shiner and inland silverside were consistently captured at moderate abundances throughout the course of the survey (Figure 166a). Although a few high abundance years (1991, 2000, and 2004) have occurred and a minor declining trend in density of spottail shiner in non-zero catches was present in the most recent 8 years of the survey (Figure 166b), the overall pattern of abundance indices in seines has been relatively unchanging during the course of monitoring.

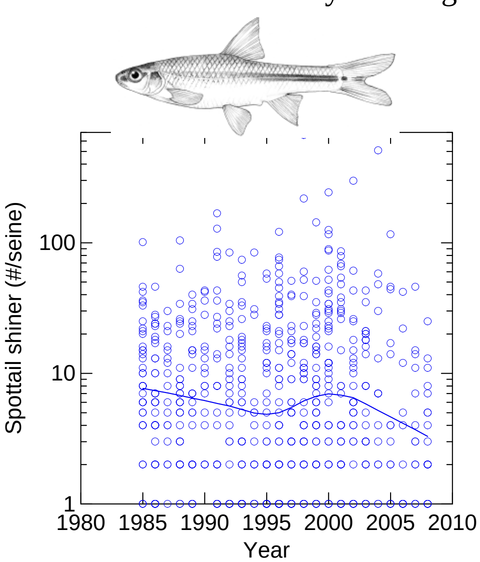


Figure 166b. Seines. Long term trend in Spottail Shiner (*Notropis hudsonius*). All Stations.

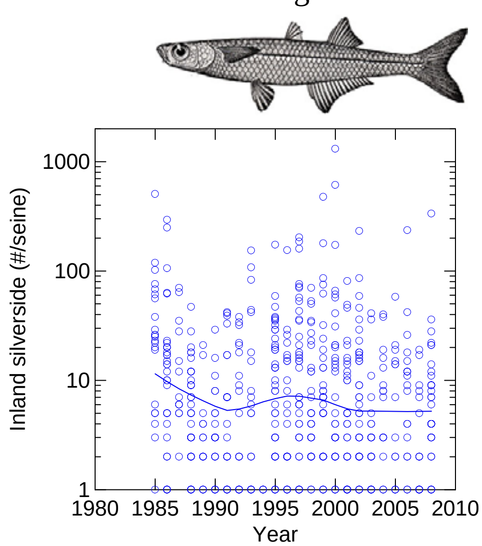


Figure 166c. Seines. Long term trend in Inland Silverside. (*Menidia beryllina*). All Stations.

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 8 years should be providing more favorable conditions for banded killifish, spottail shiner, inland silverside, and several species of sunfish (bluegill and pumpkinseed) and largemouth bass. Indeed, seine and trawl sampling has indicated a coincident and relative increase in many of these species. In addition, juvenile anadromous species continue to be an important component of the fish assemblage with more diverse catches (owing to the occurrence of American and hickory shad) and a slight indication of greater abundance of 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 develop alternative sampling approaches to quantify fishes in vegetated habitats and efforts to quantify catch efficiency should enhance the quality of the data and provide a more accurate picture of the fish assemblage and trends for the dominant species.

Drop ring sampling methodology was developed in a mini-study during 2007 and the approach was added to the routine monitoring activities in 2008. These data provide information on juvenile fish abundance from areas of Gunston Cove and habitats (SAV beds) that are not sampled (or not sampled well) by fixed station seine and trawl sampling. Consequently, drop ring data complement the fixed station sampling which provides information from shoreline and deeper non-vegetated habitats. The results demonstrated that the level of sampling effort is sufficiently precise 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).

Simply based upon the larger area represented by SAV beds compared with shallow shoreline habitats sampled with a seine, the drop ring sampling should provide a more synoptic view of changes in fish population size and relative recruitment strength. For example, both seines and drop ring samples provide information from shallow littoral areas, which represent the primary habitat for all life stages of banded killifish. The density of banded killifish was significantly higher in 2007 (5.2 per square meter) than in 2008 (2.2 per square meter), which when expanded by the representative area of the sampling domain (1.299 million square meters) gives total abundances of 6.759 and 2.859 million, respectively. By comparison (based upon geometric means, area, and catch efficiency estimates, see appendix), the abundance of banded killifish in 60,441 square meters of shoreline habitat was 32,421 and 33,480, respectively in 2007 and 2008. This leads to total abundance estimates (SAV plus shoreline) of 6,791,422 and 2,892,480 for banded killifish in these years, hence a change in population size of 57%. This contrasts with another abundant species on the survey that was only captured in seines during 2008. Although seine catch rate indices showed a modest increase in abundance of white perch from 2007 to 2008, the moderate density in SAV habitats in 2007 and absence of white perch from drop ring samples in 2008 leads to a different overall view. In 2008, white perch abundance declined by 99.5% from 447,863 in 2007. This result corresponds with an overall lower abundance of small-sized (i.e., young-of-the-year) white perch in 2008 (Kraus, pers. obs.). Therefore, the estimated change in abundance may be due to fluctuating recruitment success, which has been shown to vary by 1 to 2 orders of magnitude for white perch.

At this point, it is important to recognize that continued support of drop ring sampling in SAV beds will greatly enhance the overall knowledge of and ability to track trends in juvenile fish abundance in Gunston Cove, supporting the monitoring goals of this survey. With similar levels of sampling effort and precision, this can be accomplished with a budget similar to that in 2008.

F. Submersed Aquatic Vegetation (SAV) Trends: 1994-2008

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

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

The following scenario, based on prevailing concepts of SAV-phytoplankton-light interactions, seems most likely to explain these observations. Declining phytoplankton populations have led to an increase in water clarity which allows SAV to grow to greater depths and spread. The SAV coverage will tend to further inhibit phytoplankton by shading and further increase water clarity (Secchi depth). This will allow spread of SAV into even deeper areas.

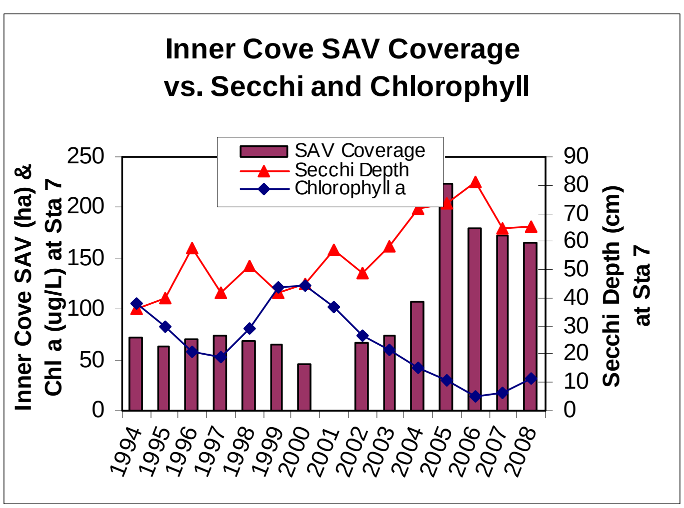


Figure 167. Inner Cove SAV Coverage. 1994-2008. Graphed with average summer (June-September) Depth-integrated Chlorophyll a (ug/L) and Secchi Depth (cm) measured at Station 7 in Gunston Cove.

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