An Ecological Study of Gunston Cove

2003-2004

FINAL REPORT

June 10, 2005

by

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Executive Summary

The year 2003 was characterized by below normal temperatures and abnormally high precipitation. Temperatures greatly below normal characterized the period from April through July. Precipitation was well above normal for May through December. This combination resulted in stream and river flows that were well above normal throughout the year. Sampling dates in mid June, mid July, mid September, and mid November were immediately preceded by over 1 inch of rainfall which affected water quality in the cove. The mid September sampling was immediately preceded by Hurricane Isabel which also brought strong winds and storm surges to the area.

Specific conductance was similar at both sites with no evidence of brackish water intrusion as was observed in the low flow year 2002. The high flows in mid June, mid September, and mid November were reflected in declines in conductance as ions in the cove were diluted by stream flow. Chloride was higher in the cove than in the river, another indication that brackish water was not moving from downstream and declines in chloride were similar to those in conductance.

Dissolved oxygen was near saturation in the river, but exhibited significant supersaturation in the cove in late April, late June, and late August, probably corresponding to peaks in phytoplankton activity. Field pH displayed a similar temporal pattern in the cove and was generally less variable in the river. Total alkalinity was generally higher in the river than in the cove and showed similar seasonal patterns in each area. Secchi depth was similar in the cove and in the river with most readings between 50 and 80 cm. Major declines were observed after major discharge events in September and November. Storm surge and strong winds from Hurricane Isabel also contributed to the decline in Secchi depth in September. Light attenuation coefficient and turbidity showed similar seasonal patterns.

Ammonia nitrogen was higher in the river (generally above 0.05 mg/L) than in the cove (generally below 0.05 mg/L). In the river summer values were typically higher than in spring or fall while in the cove there was little systematic difference. Un-ionized ammonia nitrogen increased rather markedly during the summer especially in the cove, but concentrations remained at least an order of magnitude below toxic thresholds. Nitrate nitrogen underwent similar patterns in cove and river with river concentrations running somewhat higher. A clear drawdown in nitrate was observed in the cove during the growing season, probably due to phytoplankton uptake. Nitrite was generally present at low levels with increases in late summer corresponding with somewhat elevated ammonia concentrations. Organic nitrogen was generally higher in the cove and showed a marked seasonal buildup related to algal uptake and incorporation.

Total phosphorus levels were fairly low in 2003 with most samples in cove and river below 0.1 mg/L. There was evidence for a gradual seasonal increase in the cove reflecting algal uptake topped off by a major spike in late November associated with a high flow event. Soluble reactive phosphorus exhibited a seasonal decline in the cove

which also may be tied to algal growth. Values in the river were generally higher, perhaps indicating that P was not limiting so much there. N:P ratio was generally higher in the cove with some values approaching N limitation in late summer in the river. BOD was generally higher in the cove than the river with a seasonal increase due to algal growth and an November spike in the cove related to flow. TSS was generally between 10 and 30 mg/L in both cove and river with a spike from the November flow event. VSS was higher in the cove due to phytoplankton growth during the summer and the flow spike in November.

Chlorophyll *a* exhibited a distinct seasonal pattern in both cove and river. In the cove values generally increased through early September reaching about 80 ug/L before dropping sharply with Hurricane Isabel. In the river the increase took longer to develop and started to decline before Isabel. Photosynthetic rate revealed a similar pattern. Phytoplankton density also showed a strong surge in late summer in cove and river. Phytoplankton biovolume surged earlier in both areas, but remained strong through early September.

Cyanobacteria dominated phytoplankton density due to their small cell size, but diatoms were clearly most important in terms of phytoplankton biovolume (and probably biomass). Bloom forming *Microcystis* was detected, but only in small quantities in late July and early August. The dominant diatom in both cove and river was *Melosira*, a filamentous centric. Discoid centrics were also important in early spring and mid-summer.

Rotifers were the most abundant zooplankton and followed a typical seasonal pattern of much elevated summer abundances. In the cove elevated abundances began in late spring and extended through early fall, while in the river they were mainly restricted to the summer. *Brachionus* and *Keratella* were the most abundant with Conochilidae important in the river in the summer and *Filinia* in the cove. Cladocerans were present at substantial numbers, but only during restricted periods. They were generally much more abundant in the cove than the river except for *Leptodora*. This may have been due to the higher flow conditions in 2003. Copepod nauplii were more abundant in the river than in the cove with a peak in mid summer. The calanoid copepod *Eurytemora* exhibited a strong spring peak in abundance in both river and cove. *Diaptomus* and other calanoids were most common in the early summer and were more common in the cove.

Clupeids (herring and shad) were the dominant ichthyoplankton as in previous years, making up almost 90% of the total fish larvae collected. *Morone* spp. (white perch and striped bass) and *Perca flavescens* (yellow perch) made up almost all of the rest. Peak density of clupeids and *Morone* sp. occurred in late May, while yellow perch peaked in early April.

White perch was the most common fish collected in trawls comprising 30% of the total. Blueback herring (23.2%), channel cat (9.8%), and bay anchovy (9.1%) rounded out the group of most common species. In an unusual reversal, blueback herring were actually more common than white perch at both cove trawl sites. Most of the blueback herring were collected on three sample dates while the white perch were more evenly distributed through the year.

Banded killifish was the most common species collected at seine sites comprising 44% of the total catch. Other common species were bay anchovy (12.4%), white perch (6.9%), and spottail shiner (6.8%). Banded killifish were the most abundant species at all seining sites and on most sampling dates.

Oligochaetes were the most abundant macrobenthic organisms in 2003 with similar densities observed in both river and cove. Chronomids were a close second in the cove while amphipods (scuds) and the Asiatic clam Corbicula were subdominant in the river. Isopods, spherid clams, and gastropods were also present in the river. Small populations of gastropods and chaoborids (phantom midges) were found in the cove.

Long-term trends were examined for a wide range of water quality and biological parameters. The analysis of water quality parameters focused on growing season values (June to September). Both LOWESS trend lines and linear regressions were exmined to allow detection of long-term trends. In the cove chlorophyll a, photosynthetic rate, BOD, VSS, total phosphorus, and organic nitrogen had significant regression coefficients indicating a net decrease over the study period (1983/4-2003). Nitrate nitrogen and TSS have also exhibited significant declines over the whole study period. Ammonia nitrogen has clearly declined since 1989. These results are consistent with a significant decline in phytoplankton biomass in the cove over the study period. Phytoplankton cell densities have also declined in the past two years. Secchi disc, a measure of water clarity, has demonstrated a steady and significant increase due to lower chlorophyll a and TSS. Water clarity is improving to the point that light levels in the cove are becoming more suitable for submersed aquatic vegetation (SAV).

In the river most indicators of phytoplankton do not exhibit a significant change over the study period. Chlorophyll a has shown a slight decline in the trend line over the past three years and phytoplankton density has declined over the past two years. However, major and substantial decreases have been observed in all forms of nitrogen. Dissolved oxygen has also shown an increase over the study period.

All zooplankton groups in the cove and most in the river have demonstrated a significant linear increase since 1990. The cladocerans and copepod nauplii have shown the greatest rates of increase. These may indicate an improvement in the quality of algae for food and/or a decline in planktivorous fish densities.

Clupeid larvae continued to be found in high abundance in the cove. Increased values since 2000 may be due to gizzard shad. *Morone* larvae (white perch and striped bass) continued a multiyear decline which began in 1996.

Oligochaetes remained the most abundant benthic macroinvertebrates at both sites. Chironomids have declined somewhat in the river, but remain abundant in the cove. Amphipods have been declining in recent years in the river, while isopods have been increasing. *Corbicula* is having a comeback after a major dieback during the early to mid 1990's.

In the cove trawl catches continued a decline begun in 2002 led by decreases in adult and juvenile white perch which began to decrease in 2001. For the last two years, white perch were substantially below half of the trawl collection, a condition unseen since 1990. This condition may be an actual decrease in the white perch stocks or merely a shift in their location since the population is not confined to the cove. The mean catch per trawl of blueback herring was high in 2003 while alewife was lower.

In the river trawl catches were actually somewhat higher than in 2002 and above the median value over the course of the study. White perch made up about half of the total catch, similar to recent years. Larger numbers of brown bullhead, channel catfish, tessellated darter, and hogchoker have been caught since 2000. All are known to feed on benthic animals which may have increased with dredge spoil placement.

In seine samples, the catch of banded killifish remained strong and dominated all other species. Blueback herring, alewife, and spottail shiner were caught in numbers comparable to most previous years. The abundance of white perch was very low, primarily due to fewer young-of-year in the catch. The catch of inland silverside was also low.

The occurrence of both adults and larvae in the creek was clear evidence of spawning by alewife in Pohick Creek in 2003. Alewife larvae were collected in early to mid April in the creek just below the outfall from the Noman M. Cole Pollution Control Plant. The adults were observed there and about a kilometer upstream at the base of a series of low waterfalls. Since 1996, we have collected either adult alewife or alosine larvae in Pohick Creek every year except 2002. Alewife adults were also observed in the creek in 2004, though identification of larvae caught there is still in progress. No blueback herring adults were caught in Pohick Creek in either 2003 or 2004 continuing the record since 1988.

Gizzard shad adults were caught in Pohick Creek in both 2003 and 2004. Larval gizzard shad were also caught in 2003, and spawning certainly occurred in the creek in 2003 and probably in 2004, too.

Water quality in Pohick Creek remains good enough to support spawning by alewife and gizzard shad. Perhaps consideration should be given to modifying the creek environment to encourage more spawning or better survival of the young larvae and to protect the adult fishes from fishermen..

The 20-year record of data from Gunston Cove and the nearby Potomac River is starting to reveal many interesting long-term trends that will aid in the continued management of the watershed and point source inputs.

We recommend that:

1. Long term monitoring should continue. The revised schedule initiated in 2004 which focuses sampling in April through September should capture the major trends affecting water quality and the biota.
2. Results of special mini-studies conducted during 2004 should be evaluated to determine if further changes in sampling or analysis are justified.
3. Efforts should be made to publish these results in the peer-reviewed literature.
4. The feasibility of continuous monitoring buoys in the river and cove should be explored.

THE ONGOING AQUATIC MONITORING PROGRAM

FOR THE GUNSTON COVE AREA

OF THE TIDAL FRESHWATER POTOMAC RIVER

2003

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INTRODUCTION

This section reports the results of the on-going aquatic monitoring program for Gunston Cove conducted by the Department of Environmental Science and Policy at George Mason University and supported by the Department of Public Works of Fairfax County, Virginia. This study is a continuation of work originated in 1984 at the request of the County's Environmental Quality Advisory Committee and the Department of Public Works. The original study design utilized 12 stations in Gunston Cove, the Potomac mainstem, and Dogue Creek. Due to budget limitations and data indicating that spatial heterogeneity was not severe, the study has evolved such that only two stations are sampled, but the sampling frequency has been maintained at semimonthly during the growing season. This sampling regime provides reliable data given the temporal variability of planktonic and other biological communities and is a better match to other biological sampling programs on the tidal Potomac including those conducted by the Maryland Department of Natural Resources and the District of Columbia.

The 1984 report entitled "An Ecological Study of Gunston Cove – 1984" (Kelso et al. 1985) contained a thorough discussion of the history and geography of the cove. The reader is referred to that document for further details.

This work's primary objective is to determine the status of biological communities and the physico-chemical environment in the Gunston Cove area of the tidal Potomac River for evaluation of long-term trends. This will facilitate the formulation of well-grounded management strategies for maintenance and improvement of water quality and biotic resources in the tidal Potomac. Important byproducts of this effort are the opportunities for faculty research and student training which are integral to the educational programs at GMU.

The authors wish to thank the numerous individuals and organizations whose cooperation, hard work, and encouragement have made this project successful. We wish to thank the Fairfax County Department of Public Works and Noman M. Cole, Jr. Pollution Control Plant, particularly Jimmie Jenkins, Elaine Schaeffer, and Shahran Moshsenin for their advice and cooperation during the study. The Northern Virginia Regional Park Authority facilitated access to the park and boat ramp. Without a dedicated group of field and laboratory workers this project would not have been possible. Thanks go to Tanya Amrhein, Gary Clarkson, Theresa Connor, Stephanie Coon, Leila Hamdan, Saiful Islam, Shannon Junior, Anita Marx, Andy Leslie Orzetti, Rebecca Robinson, and Ryan Albert. Claire Buchanan served as a voluntary consultant on plankton identification. Carol Lawrence and Roslyn Cress were vital in handling personnel and procurement functions.

METHODS

A. Profiles and Plankton: Sampling Day

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

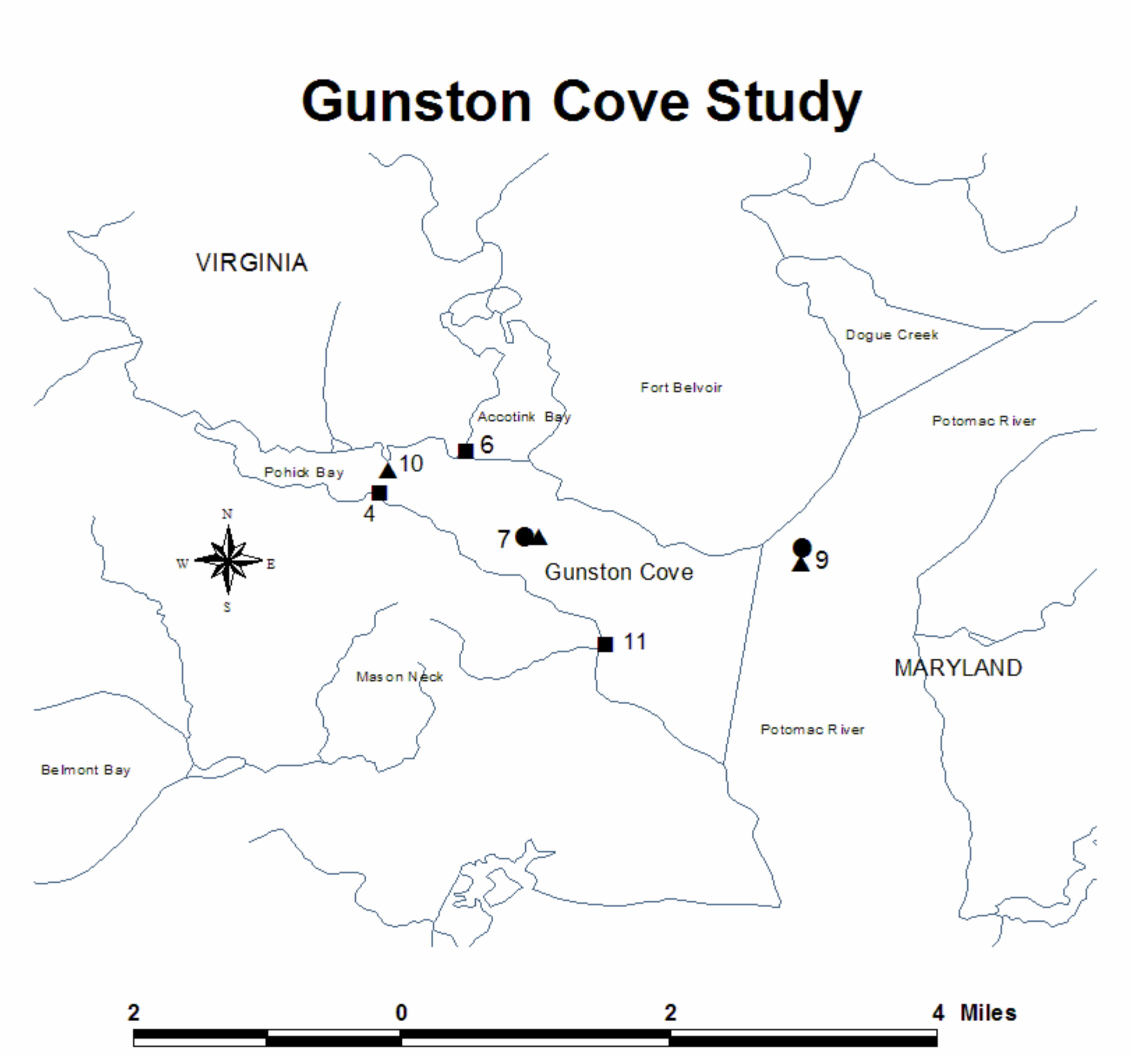


Figure 1. Gunston Cove area of the Tidal Potomac River showing sampling stations. Circles represent Plankton/Profile stations, triangles represent Fish Trawl stations, and squares represent Fish Seine stations.

Table 1
Sampling Dates and Weather Data for 2003

	Type of Sampling				Avg Daily Temp (^{o}C)		Precipitation (cm)	
Date	G	L	T	S	1-Day	3-Day	1-Day	3-Day
March 27	G	L	T	S	11.7	14.4	0	1.09
April 3		L*			19.4	15.2	0	T
April 10	G	L	T	S	8.3	5.9	0.18	1.49
April 29	G		T	S	19.4	17.4	T	T
May 15	G	L	T	S	17.8	16.5	0.33	0.33
May 29	G		T	S	16.1	15.7	0.13	1.02 (4.67-4 day)
June 11		L*			25.0	23.0	0.66	1.83
June 12	G	L	T	S	25.0	24.1	2.87	3.53
June 26	G		T	S	27.8	26.5	0	0
July 7			T	S	27.8	28.5	1.45	1.45
July 10	G				23.3	26.3	2.69	3.95
July 24	G	L	T	S	25.6	25.6	0	1.36
August 7	G	L			25.0	24.6	T	0.99
August 14		L*			28.9	27.8	0	0
August 21	G		T	S	27.2	26.3	0	0
September 4	G	L			23.3	24.8	0.30	1.55
September 18	Hurricane Isabelle				22.2	21.3	5.79	5.79
September 22	G**		T	S	23.3	23.3	1.98	1.98
September 25	G				21.1	20.2	0	4.24
October 1		L*			13.3	14.4	0	0
October 9	G	L	T	S	20.0	18.1	0	0
November 20	G	L?			10.6	12.6	0	3.73
November 24			T		11.7	12.6	0.81	0.81
December 10	G	L	T	S	7.8	4.6	0.71	0.71

Type of Sampling Key: G: GMU water quality profiles & plankton, L: Noman Cole Lab water quality profiles and plankton, T: GMU fish trawls, S: GMU fish seines
*Samples collected by Noman Cole Lab Personnel
**Hydrolab Profiles only

Sampling was initiated at 8-9 am. Four types of measurements or samples were obtained at each station : (1) depth profiles of temperature, conductivity, dissolved oxygen, and pH measured directly in the field; (2) water samples for GMU lab determination of pH, total alkalinity, chlorophyll *a*, photosynthetic rate, and phytoplankton species composition and abundance; (3) water samples for determination of nutrients, BOD, alkalinity, suspended solids, chloride, and pH by Lower Potomac Laboratory; (4) net sampling of zooplankton and ichthyoplankton.

Profiles of temperature, conductivity, and dissolved oxygen were conducted at each station using Hydrolab datasonde with temperature, conductivity, dissolved oxygen and pH probes. Measurements were taken at 0.3 m, 1.0 m, 1.5 m, and 2.0 m in the cove. In the river measurements were made with the Hydrolab at depths of 0.3 m, 2 m, 4 m, 6 m, 8 m, 10 m, and 12 m. Meters were checked for calibration before and after sampling.

A 2-liter depth-composited sample was constructed from equal volumes of water collected at each of three depths (0.3 m, middepth, and 0.3 m off bottom) using a submersible bilge pump. A 100-mL aliquot of this sample was preserved immediately with acid Lugol's iodine for later identification and enumeration of phytoplankton. The remainder of the sample was placed in an insulated cooler filled with river water to maintain *in situ* temperature until return to the lab. A 1-liter sample was collected from 0.3 m using the submersible bilge pump and placed in the insulated cooler with ice for lab analysis of surface chlorophyll a. A 4-liter sample was collected monthly made up of equal volumes of surface (0.3 m) and bottom (0.3 m off bottom) water at each site using the submersible pump for determination of nutrients and other parameters by Noman Cole Laboratory. This water was stored on ice and promptly delivered to the Noman Cole Laboratory.

Microzooplankton was collected by pumping 32 liters from each of three depths (0.3 m, middepth, and 0.3 m off the bottom) through a 44 µm mesh sieve. The sieve consisted of a 12-inch long cylinder of 6-inch diameter PVC pipe with a piece of 0.44 µm nitex net glued to one end. The 0.44 µm cloth was backed by a larger mesh cloth to protect it. The pumped water was passed through this sieve from each depth and then the collected microzooplankton was backflushed into the sample bottle. The resulting sample was preserved with formalin containing a small amount of rose bengal to a concentration of 5-10%.

Macrozooplankton was collected by towing a 202 µm net (0.3 m opening) for 1 minute at each of three depths (near surface, middepth, and near bottom). Ichthyoplankton was sampled by towing a 333 µm net (0.5 m opening) for 2 minutes at each of the same depths. Tows tended to follow an arc around the fixed profile site: macrozooplankton tows were about 250 m and ichthyoplankton tows about 500 m. Actual distance depended on specific wind conditions and tidal current intensity and direction, but an attempt was made to maintain a consistent slow forward speed through the water during the tow. The net was not towed directly in the wake of the engine. Each net was about 2 meters long with a 0.3 m opening into which a General Oceanics flowmeter was fitted. The depths were established by playing out rope equivalent to about 1.5-2 times the desired depth. Samples which had obviously scraped bottom were discarded and tow was repeated. Flowmeter readings taken before and after towing allowed precise determination of the distance towed which when multiplied by the area of the opening produced the volume of water filtered. Macrozooplanton and ichthyoplankton were preserved immediately with formalin to a concentration of 5-10%. Rose bengal formalin with carbonated water pretreatment was used for macrozooplankton, but not for ichthyoplankton. Macrozooplankton was collected on each sampling trip; ichthyoplankton collections ended after July because larval fish were normally not found after this time.

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

Photosynthetic rate was determined on the sample date by adding 100 µL of ^{14}C-labeled sodium bicarbonate (20 µCi/mL) to 50 mL of water from the depth-integrated sample. The 50 mL aliquot was split into two 20 mL glass scintillation vials that were placed at two light levels and incubated at river ambient temperature in a controlled temperature water bath. A total of four light levels, provided by a 1000 watt high pressure sodium bulb (Ceramalux), were used corresponding to roughly 1200, 600, 100, and 50 µmoles/m^2/sec of photons. (Full sun in summer is about 2000 µmoles/m^2/sec). Following a 1 hr incubation, 15-mL of vial contents were filtered through a 0.45 µm membrane filter (Gelman GN-6). Filters were frozen for later analysis.

pH and alkalinity were determined on 100 mL aliquots of the depth-integrated sample. pH was measured with a Hach EC-30 lab pH meter with Hach 1 electrode calibrated to 7 and 10. Alkalinity was determined by titration with 0.02 N H_2SO_4 to a pH of 4.6 (Standard Methods 1981). Acid titrant was calibrated with standard $NaCO_3$.

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

B. Profiles and Plankton: Followup Analyses

Chlorophyll *a* samples were extracted in a ground glass tissue grinder to which 4 mL dimethyl sulfoxide (DMSO) was added. The filter disintegrated in the DMSO and was ground for about 1 minute by rotating the grinder under moderate hand pressure. The ground suspension was transferred back to its scintillation vial by rinsing with 90% acetone. Ground samples were stored in the refrigerator overnight. Samples were removed from the refrigerator and centrifuged for 5 minutes to remove residual particulates.

Chlorophyll *a* concentration in the extracts was determined fluorometrically using a Turner Designs Model 10 field fluorometer configured for chlorophyll analysis as specified by the manufacturer. The instrument was calibrated using standards obtained from Turner Designs.

Fluorescence was determined before and after acidification with 2 drops of 10% HCl. Chlorophyll *a* was calculated from the following equation which corrects for pheophytin interference:

Chlorophyll *a* (µg/L) = $F_sR_s(R_b\text{-}R_a)/(R_s\text{-}1)$

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

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

To determine radiocarbon uptake, frozen filters were first placed in concentrated HCl fumes for 10 minutes to drive off residual inorganic carbon. Then, each filter was placed in a scintillation vial and scintillation cocktail was added. Vials were counted for 10 minutes each in a Packard Tricarb 2100TR liquid scintillation counter and corrected for efficiency by the external standard ratio method. Photosynthetic rate was determined from the following equation:

$$PhotosyntheticRate(mgC/L/hr) = \frac{(DPM)(ALK)(CF)(1.06)}{(DPMwat)(TIME)}$$

where DPM=^{14}C activity on filter (algae), (DPM/L)
ALK=Total alkalinity, (mg/L as $CaCO_3$)
CF=conversion factor from total alkalinity to dissolved inorganic carbon (Wetzel and Likens 1991)
DPMwat=^{14}C activity in incubation water (DPM/L)
1.06=isotopic discrimination factor
TIME=incubation time, (hr)

All filters were counted within one month of sample collection.

Phytoplankton species composition and abundance was determined using the inverted microscope-settling chamber technique (Lund et al. 1958). Ten milliliters of well-mixed algal sample were added to a settling chamber and allowed to stand for several hours. The chamber was then placed on an inverted microscope and random fields were enumerated. At least two hundred cells were identified to species and enumerated on each slide. Counts were converted to number per mL by dividing number counted by the volume counted.

Microzooplankton and macrozooplankton samples were rinsed by sieving a well-mixed subsample of known volume and resuspending it in tap water. This allowed subsample volume to be adjusted to obtain an appropriate number of organisms for counting and for formalin preservative to be purged to avoid fume inhalation during counting. A one mL subsample was placed in a Sedgewick-Rafter counting cell and whole slides were analyzed until at least 200 animals had been identified and enumerated. A minimum of two slides was examined for each sample. References for identification were: Ward and Whipple (1959), Pennak (1978), and Rutner-Kolisko (1974). Zooplankton counts were converted to number per liter with the following formula:

$$Zooplankton = \frac{(N)(V_s)}{(V_c)(V_f)}$$

where N=number of individuals counted
V_s=volume of reconstituted sample, (mL)
V_c=volume of reconstituted sample counted sample counted, (mL)
V_f=volume of water sieved, (L), normally 96 L

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

$$Ichthyoplankton = \frac{(N)(10)}{V}$$

ichthyoplankton in each sample was expressed as number per 10 m^3 using the following formula:
where N=number of ichthyoplankton in the sample
V=volume of water filtered, (m^3)

C. Adult and Juvenile Finfish

Fishes were sampled by trawling at Stations 7, 9, and 10 (Figure 1). A try-net bottom trawl with a 15-foot horizontal opening, a 3/4 inch square body mesh and a 1/4 inch square cod end mesh was used. The otter boards were 12 inches by 24 inches. Towing speed was 2-3 miles per hour and tow length was 5 minutes. In general, the trawl was towed across the axis of the cove at Stations 7 and 10 and parallel to the channel at Station 9, but most tows curved up to 90E from the initial heading and many turned enough to head in the opposite direction. The direction of tow should not be crucial. Dates of sampling and weather conditions are found in Table 1.

Shoreline fishes were sampled by seining at 3 stations: 4, 6, and 11 (Figure 1). The seine was 45-50 feet long, 4 feet high and made of knotted nylon with a 1/4 inch square mesh. The seining procedure was standardized as much as possible. The net was stretched out perpendicular to the shore with the shore end in water no more than a few inches deep. The net was then pulled parallel to the shore for a distance of 100 feet by a worker at each end moving at a slow walk. At the end of the prescribed distance the offshore end of the net was swung in an arc to the shore and the net pulled up on the beach to trap the fish. Dates for seine sampling were generally the same as those for trawl sampling.

After the net (trawl or seine) was hauled in, the fishes were measured for standard length to the nearest 0.5 cm. Standard length is the distance from the front tip of the head to the end of the vertebral column and base of the caudal fin. This is evident in a crease perpendicular to the axis of the body when the caudal fin is pulled to the side.

If the identification of the fish was not certain in the field, the specimen was preserved in 10% formalin and identified later in the lab. Identification was based on characters in dichotomous keys found in several books and articles, including Jenkins and Burkhead (1983), Hildebrand and Schroeder (1928), Loos et al. (1972), Dahlberg (1975), Scott and Crossman (1973), Bigelow and Schroeder (1953), and Eddy and Underhill (1978).

D. Macrobenthos

Macrobenthos was sampled at Stations 7 and 9. A petite ponar grab was used to collect three replicate samples at each station. Contents of the grab were sieved through a 0.5 mm stainless steel sieve in the field and the resulting animals and detritus were preserved in 5-10% formalin with rose bengal for later analysis. In the lab the formalin was rinsed from the samples and the entire sample was picked. Macroinvertebrates were identified and enumerated in each replicate. Keys for identification included Pennack (1978), Thorp and Covich (1991), and Merritt and Cummins (1984).

E. Data Analysis

Data for each parameter were entered into Quattro Pro spreadsheets for graphing of temporal and spatial patterns. Long term trend analysis was conducted by plotting data for a given variable by year and then constructing a trend line through the data. For water quality parameters the trend analysis was conducted on data from the warmer months (June-September) since this is the time of greatest microbial activity and greatest potential water quality impact. For zooplankton and fish all data for a given year were used. When graphs are shown with a log axis, zero values have been ignored in the trend analysis. Linear regression and standard parameteric (Pearson) correlation coefficients were conducted to determine the statistical significance of linear trends over the period of record.

RESULTS

A. Climate and Hydrological Factors

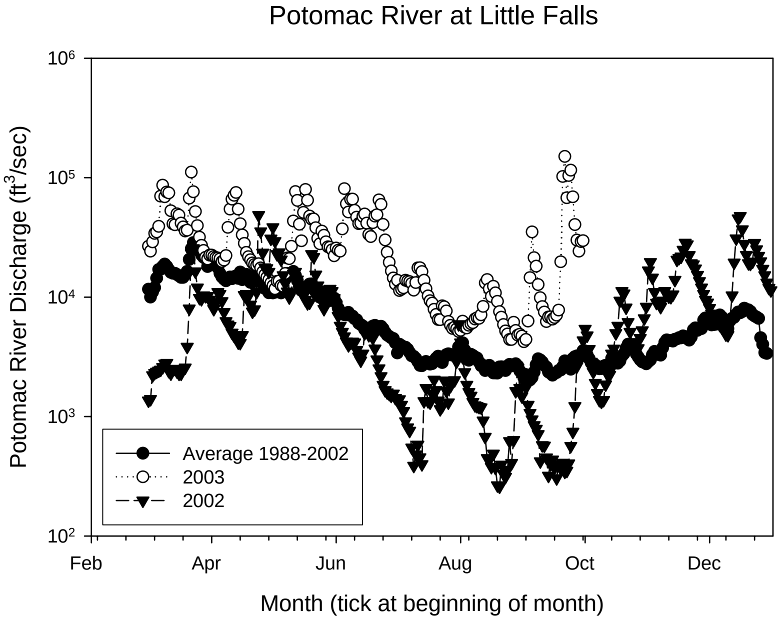
Air temperature was well below average for the period from February through June in 2003 (Table 2). July, August, and September were about normal. October was below normal and November above normal. Precipitation was well above normal for almost every month in 2003. June and September were over twice normal in precipitation. This was in contrast to above normal temperature and below normal rainfall characteristic of 2002.

Table 2
Meteorological Data for 2003. National Airport. Monthly Summary.

MONTH	Air Temp (^oC)		Precipitation (cm)	
February	0.9	(3.0)	13.8	(6.9)
March	8.4	(8.4)	10.7	(8.0)
April	12.8	(13.6)	6.5	(6.9)
May	16.5	(19.1)	17.9	(9.3)
June	21.8	(24.4)	20.0	(8.6)
July	25.4	(26.7)	14.6	(9.6)
August	26.0	(25.8)	11.8	(9.9)
September	21.4	(21.8)	17.4	(8.4)
October	14.1	(15.4)	10.0	(7.7)
November	11.7	(9.9)	10.7	(7.9)
December	4.0	(4.1)	11.0	(7.9)

Note: 2003 monthly averages or totals are shown accompanied by long-term monthly averages (1961-1990).

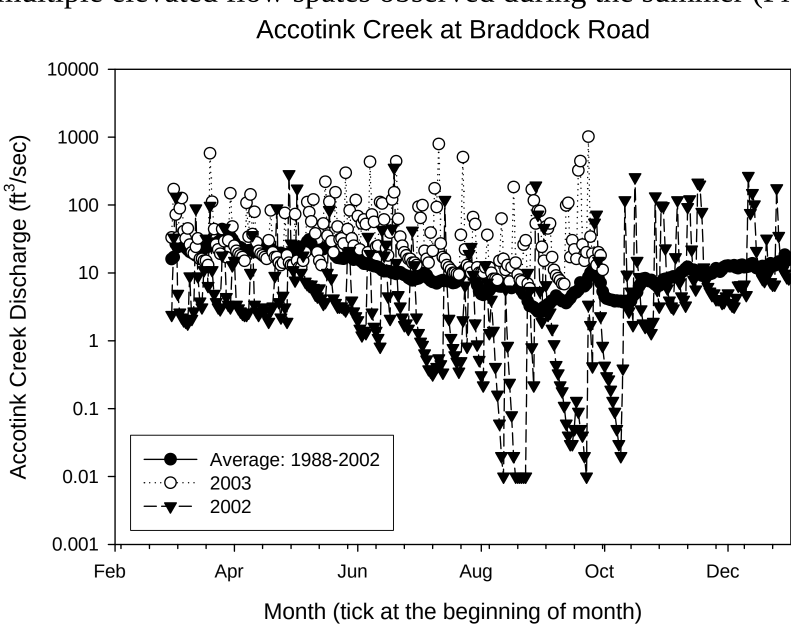
Source: National Climatic Data Center, National Oceanic and Atmospheric Administration for temperature and precipitation.



In a tidal freshwater system like the Potomac River, river flow entering from upstream is important in maintaining freshwater conditions and also serves to bring in dissolved and particulate substances from the watershed. High freshwater flows may also flush planktonic organisms downstream and bring in suspended sediments that decrease water clarity. The volume of river flow is referred to as "river discharge" by hydrologists.

Figure 2. Mean Daily Discharge: Potomac River at Little Falls (USGS Data).

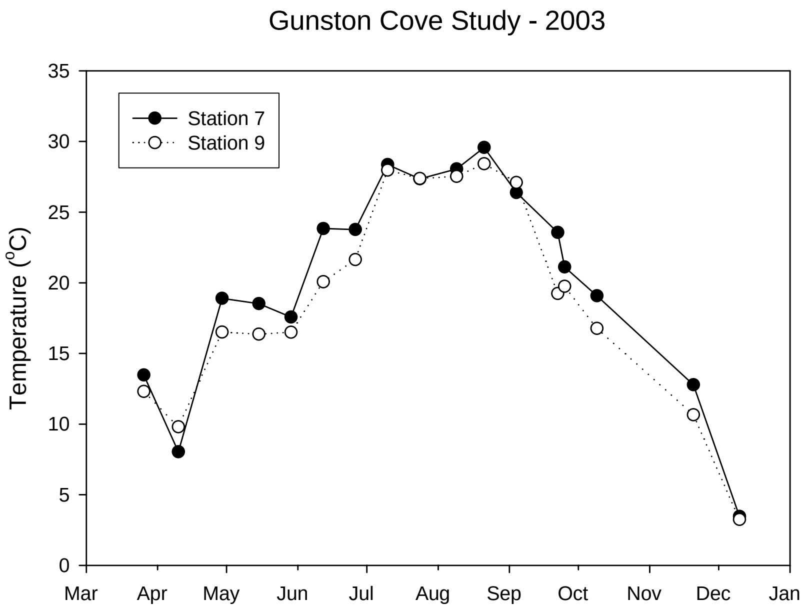
The year 2003 was much wetter than average and discharge observed at Little Falls reflected this (Figure 2). On virtually all dates, discharge at Little Falls was greater than a recent 15-year average and on many dates the flow was an order of magnitude (10x) greater than that average. Flow remained above 10,000 cfs well into July and then in August there was another peak. The 2003 flows in the river were especially striking when compared to the subaverage flows in 2002 when summer flows were often below 1000 cfs. Accotink Creek as Braddock Rd. also demonstrated higher flows with base flows generally at or above the long-term average with multiple elevated flow spates observed during the summer (Figure 2).



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

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

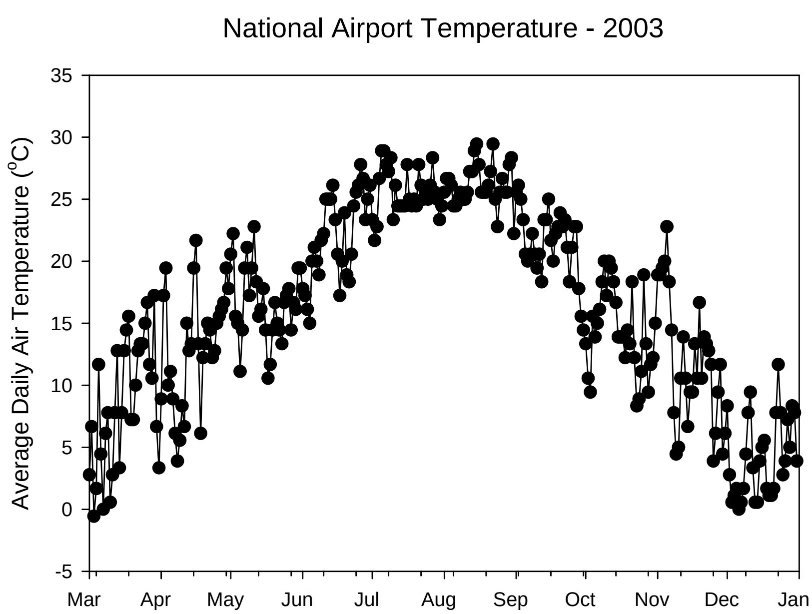
B. Physico-chemical Parameters: Embayment and River Stations



Water temperature is an important factor affecting both water quality and aquatic life. In a well-mixed system like the tidal Potomac, water temperatures are generally fairly uniform with depth. In a shallow mixed system such as the tidal Potomac, water temperature often closely tracks daily changes in air temperature.

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

Water temperature generally followed a typical seasonal pattern at both sites (Figure 4). Station 7 generally had higher temperatures because the shallower water there was more easily heated. Maximum was nearly 30°C in late August with a minimum below 5°C in December. Air temperature (Figure 5) was a good predictor of water temperature. The deviations from a smooth seasonal pattern observed in Figure 4 generally corresponded to short periods of especially warm or cold air temperatures.



Temperature controls the solubility of both ions and gases in water. Temperature regulates the metabolic activity of aquatic organisms including such processes as photosynthesis and respiration. Temperature is used as a cue by many organisms to migrate or to reproduce.

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

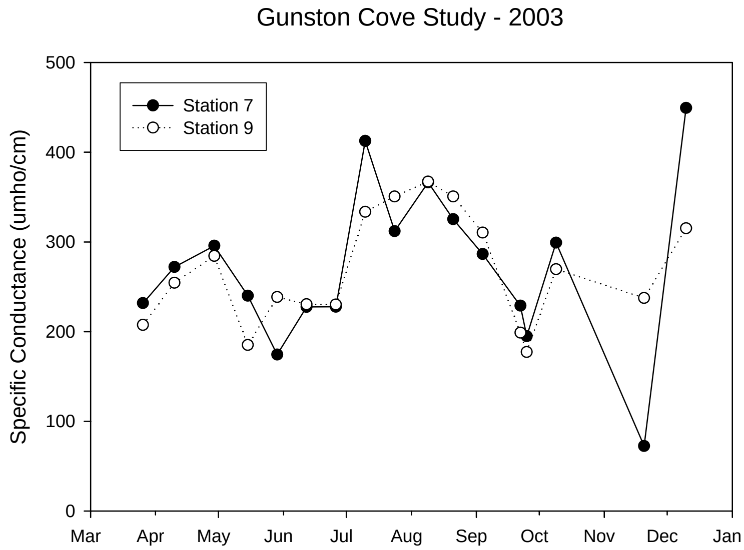
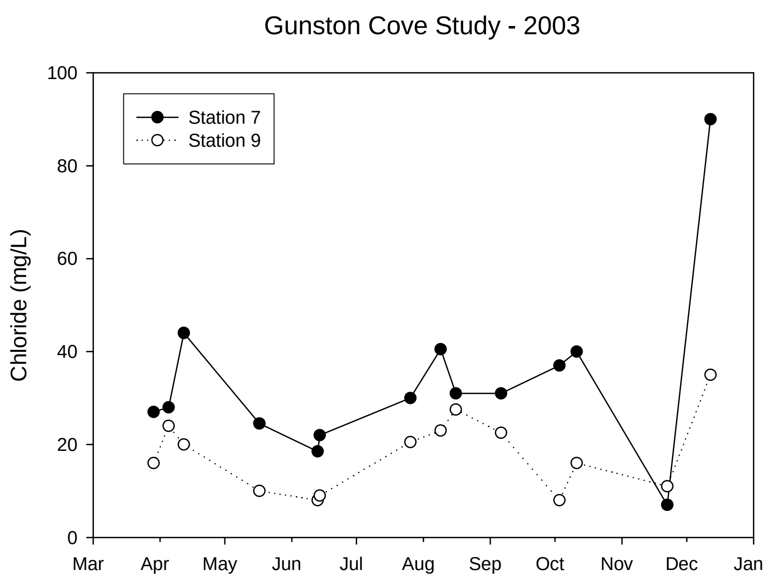


Figure 6. Specific Conductance (uS/cm). GMU Field Data. Month tick is at first day of month.

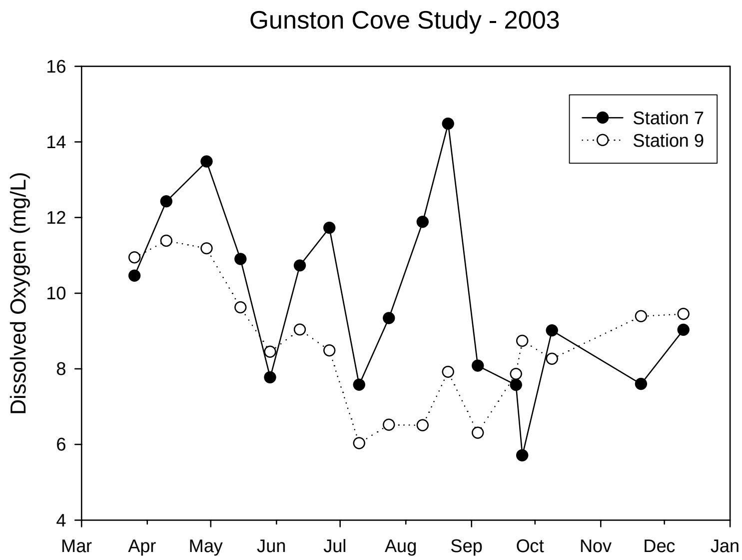
Specific conductance measures the capacity of the water to conduct electricity standardized to 25°C. This is a measure of the concentration of dissolved ions in the water. In freshwater systems, conductivity is relatively low. Ion concentration generally increases slowly during periods of low freshwater inflow and decreases during periods of high freshwater inflow. In years of low freshwater inflow during the summer and fall, conductance may increase dramatically if brackish water reaches the study area.

During most of 2003, specific conductance exhibited similar patterns in the cove (Station 7) and the river (Station 9). River and tributary flows were generally high in 2003 keeping conductivity in the moderate range most of the year. The extreme low conductivity in November in the cove was a residual from the high flows of Isabel. Chloride followed similar patterns. Differences were that cove chloride was consistently greater than river chloride indicating that other ions were more important in the river than in the cove. The dramatic November drop and December rebound was also observed in chloride.



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

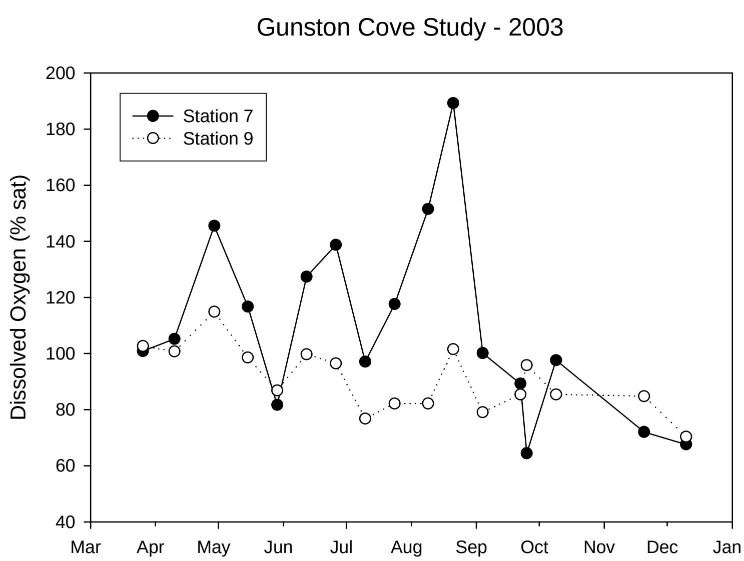
Figure 7. Chloride (mg/L). Noman Cole Lab Data. Month tick is at first day of month.



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

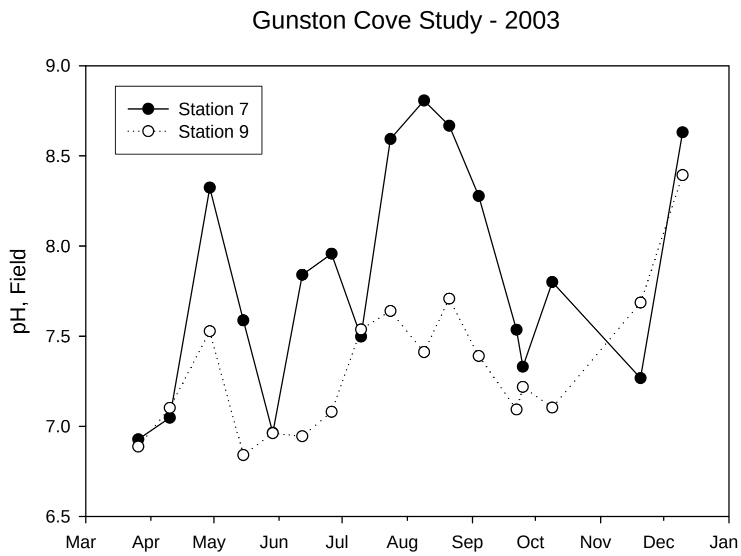
Figure 8. Dissolved Oxygen (mg/L). GMU Field Data. Month tick is at first day of month.

Dissolved oxygen in the cove was quite variable from month to month. Maxima were observed in early May and late August at about 14 mg/L (Figure 8). These high readings correspond to percent saturation values in excess of 140% (Figure 9) indicating high levels of photosynthesis. Another elevated reading was found in late June. The lowest reading in late September was found in the immediate aftermath of Hurricane Isabel at about 6 mg/L. Since this value corresponded with about 60% saturation this indicates low photosynthesis and high respiration. In the river dissolved oxygen readings followed a clear seasonal pattern with lower values in summer and higher values in spring and fall. Most readings in the river were in the 80-120% range indicating little change from saturation due to photosynthesis or respiration.



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

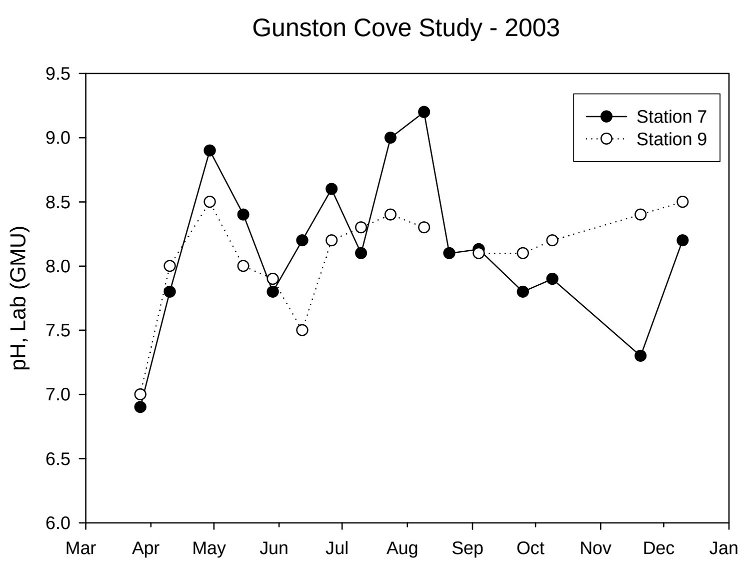
Figure 9. Dissolved Oxygen (% saturation). GMU Field Data. Month tick is at first day of month.



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

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

The Gunston Cove station showed more variability and generally higher values of pH during 2003 (Figure 10). Values above 8 were common observed in late April, late July and August. These generally corresponded to periods of higher dissolved oxygen saturation reinforcing the conclusion that photosynthesis was elevated at these times. In the river values were generally in the circumneutral range indicating lower levels of photosynthesis and perhaps higher respiration. GMU lab data was more similar between the two stations (Figure 11). Similar periods of elevated pH were found in the cove, but river values tended to be higher than in the field readings.



pH may be measured in the field or in the lab. Field pH is more reflective of in situ conditions while lab pH is done under more stable and controlled laboratory conditions and is less subject to error. Newer technologies such as the Hydrolab sonde used in GMU field data collection are more reliable than previous field pH meters and should give results that are most representative of values actually observed in the river.

Figure 11. pH. GMU Lab Data. Month tick is at the first day of the month.

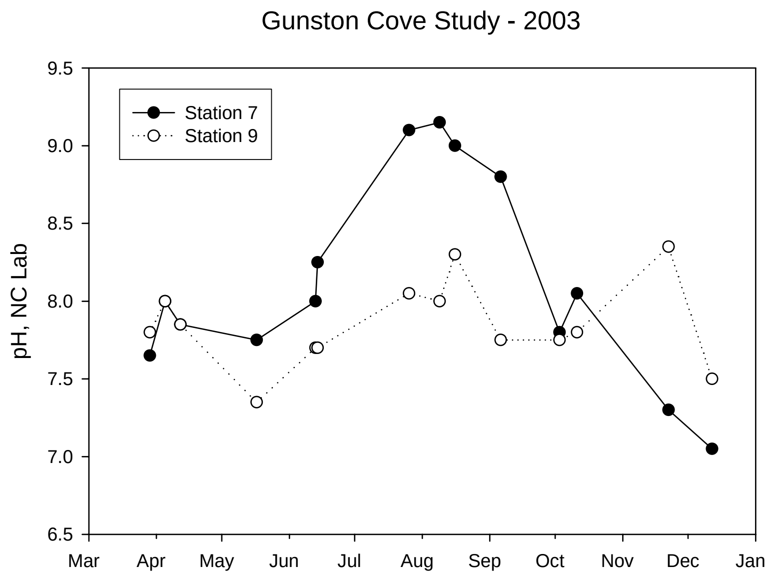
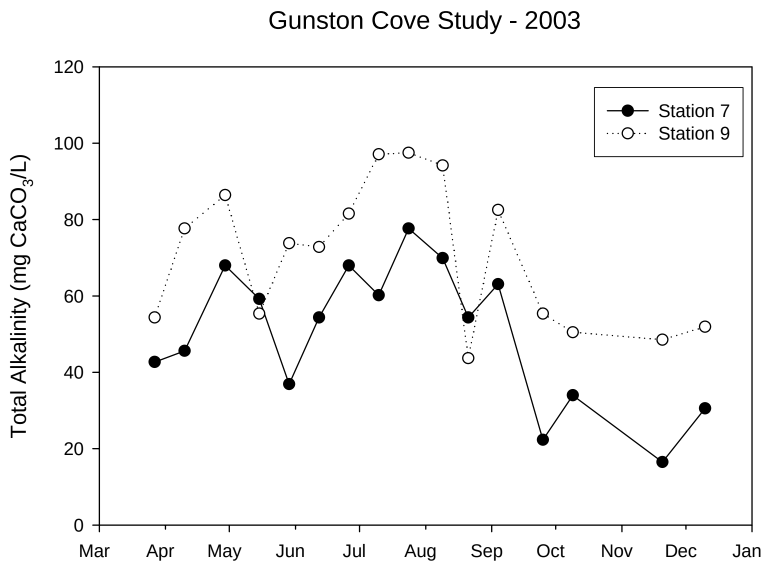


Figure 12. pH. Noman Cole Lab Data. Month tick is at first day of month.

The Noman Cole lab data indicated trends that were similar to GMU field data (Figure 12). Higher pH was found in the cove than in the river. Late August and September values indicated active photosynthesis in the cove. Values in the river were mostly circumneutral.



Alkalinity is a measure of the acid buffering capacity of water. In most freshwater systems, it is determined by the concentration of bicarbonate (HCO_3^-) and carbonate (CO_3^{-2}) ions dissolved in the water. Since rainfall is slightly acid, alkalinity tends to be lower when there is a lot of stream water inputs and tends to increase somewhat when stream inputs are less. Alkalinity can also be affected by treated sewage effluents and photosynthesis.

Figure 13. Total Alkalinity (mg/L as $CaCO_3$). George Mason Lab Data. Month tick is at first day of the month.

Total alkalinity as observed by GMU personnel was consistently higher in the river than in the cove (Figure 13). Two exceptions were late May and late August. Alkalinity was generally highest in the summer with a peak also observed in late April. Unusually low alkalinities observed in fall, especially in the cove, were probably due to Hurricane Isabel. Alkalinity data from the Noman Cole lab revealed a similar pattern with maxima in April and mid summer and a minimum in the fall as well as lower values overall in the cove (Figure 14).

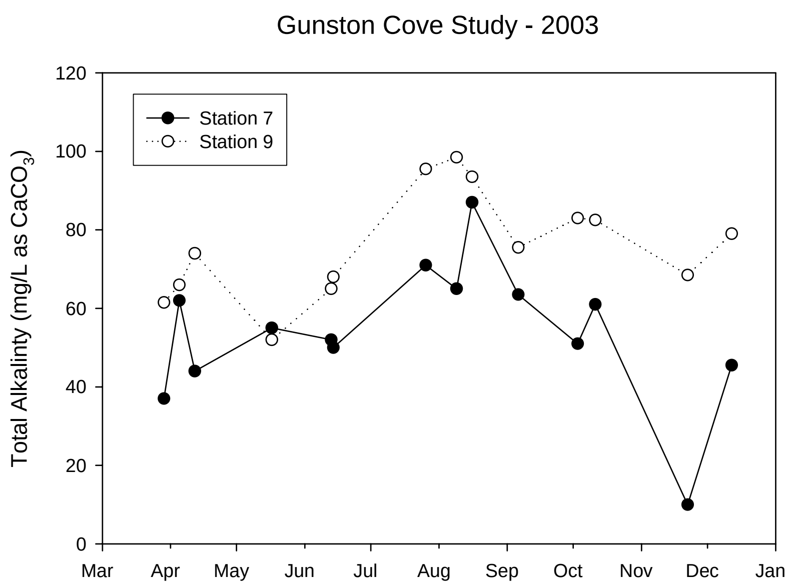
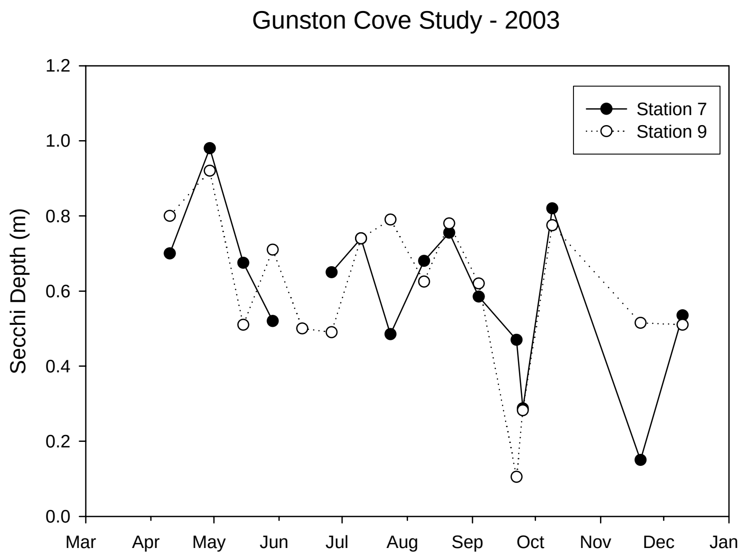


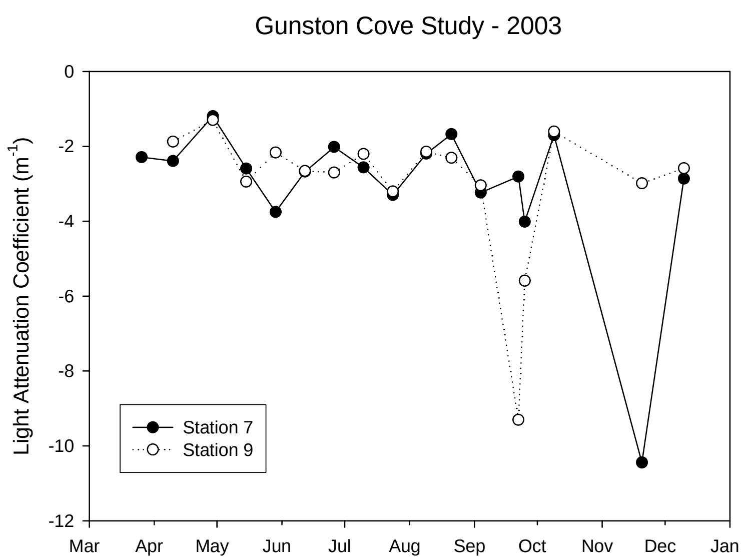
Figure 14. Total Alkalinity (mg/L as $CaCO_3$). Noman Cole Lab data. Month tick is at first day of month.



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

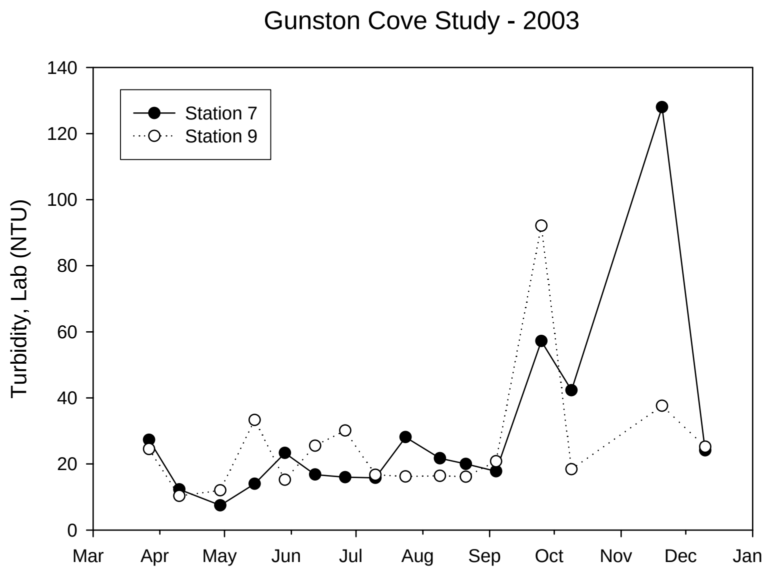
Figure 15. Secchi Disk Depth (m). GMU Field Data. Month tick is at first day of month.

Water clarity as reflected by Secchi disk depth was similar at both stations over most of the study period (Figure 15). The maximum Secchi depth observed at both stations was about 1 m in late April. For most of the summer Secchi depth varied from 0.5-0.8 m. A major decline was observed in late September in the wake of Hurricane Isabel when Secchi dropped to 10 cm in the river. In the cove the minimum was observed in November. Light attenuation coefficient was also highest (clearer water) in late April and was fairly constant in the summer (Figure 16). Major declines were observed in late September in the river and November in the cove.



Light Attenuation is another approach to measuring light penetration. This is determined by measuring light levels at a series of depths starting near the surface. The resulting relationship between depth and light is fit to a semi-logarithmic curve and the resulting slope is called the light attenuation coefficient. This relationship is called Beer's Law. It is analogous to absorbance on a spectrophotometer.

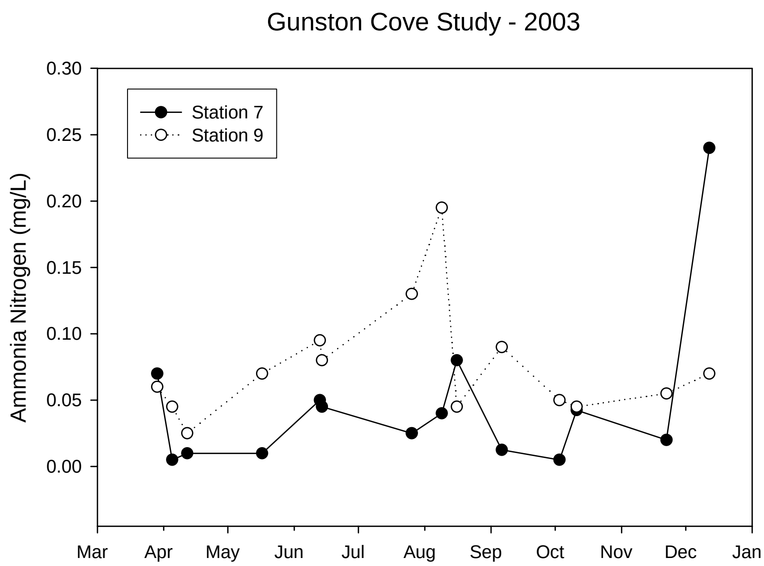
Figure 16. Light Attenuation Coefficient (m^{-1}). GMU Field Data. Month tick is at first day of month



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

Figure 17. Turbidity (NTU). GMU Lab Data.

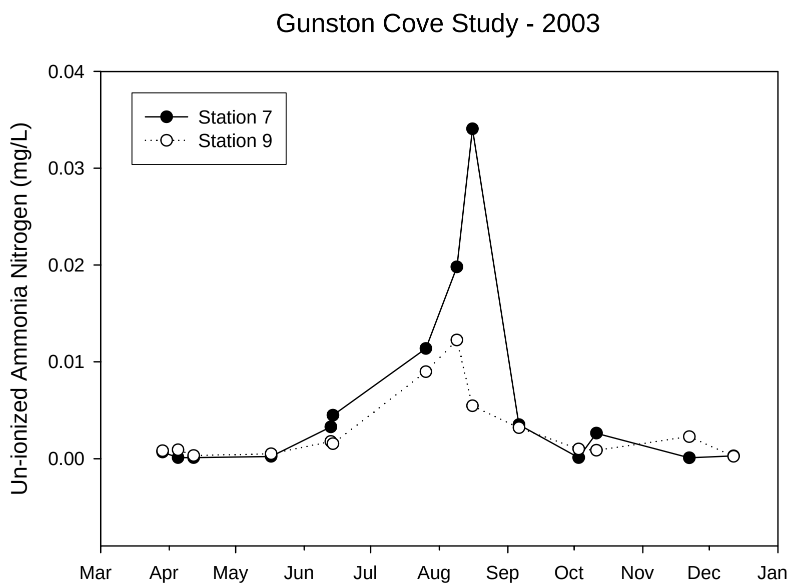
Turbidity reached a minimum in later April was fairly constant during the summer and then showed dramatic peaks in late September in the river and November in the cove (Figure 17). These patterns were very similar to those in Secchi depth and light attenuation coefficient.



Ammonia nitrogen measures the amount of ammonium ion (NH_4^+) and ammonia gas (NH_3) dissolved in the water. Ammonia nitrogen is readily available to algae and aquatic plants and acts to stimulate their growth. While phosphorus is normally the most limiting nutrient in freshwater, nitrogen is a close second. Ammonia nitrogen is rapidly oxidized to nitrate nitrogen when oxygen is present in the water. So, elevated levels of ammonia nitrogen (>0.5 mg/L) are generally associated with nearby discharge of wastewater.

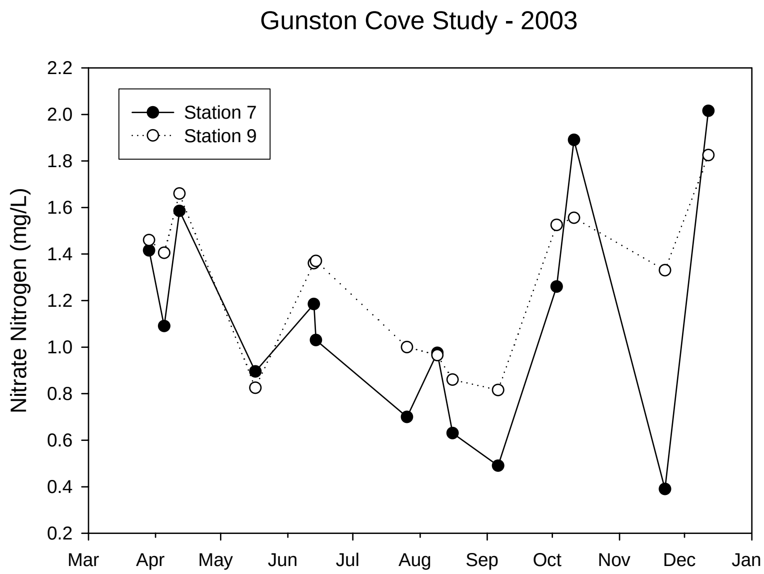
Figure 18. Ammonia Nitrogen (mg/L). GMU Field Data. Month tick is at first day of month.

Ammonia nitrogen was generally higher at the river station than in the cove (Figure 18). Cove values were generally in the range 0-0.05 for most of the year. A much higher reading of 0.25 mg/L was observed in December. Following a low in early April, river values increased steadily from below 0.05 mg/L in May to above 0.20 mg/L in early August. A decline in late August was followed by steady values of about 0.05 mg/L for the remainder of the year. Un-ionized ammonia exhibited a steady rise from March through early August in both river and cove, peaking at 0.035 mg/L in the cove and 0.01 mg/L in the river (Figure 19). Values were substantially lower for the remainder of the year.



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

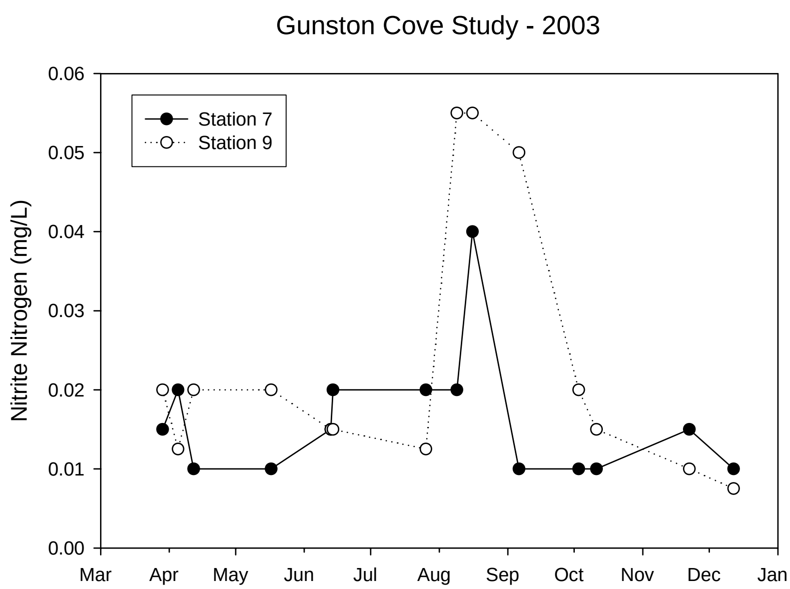
Figure 19. Un-ionized Ammonia Nitrogen (mg/L). Noman Cole Lab Data. Month tick is at first day of month.



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

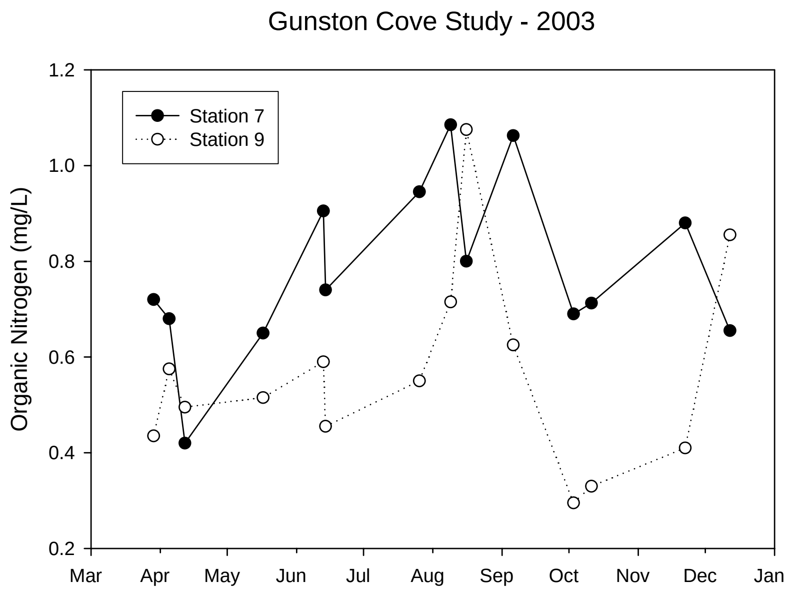
Figure 20. Nitrate Nitrogen (mg/L). Noman Cole Lab Data. Month tick is at first day of month.

Nitrate nitrogen followed similar trends in river and cove (Figure 20). Spring nitrates of about 1.5 mg/L gradually declined to about 0.9 mg/L in the river and 0.5 mg/L in the cove by early September. In late September nitrate exhibited a strong increase to above 1.5 mg/L. These higher values were sustained through the fall except for November in the cove when values dropped temporarily. Nitrite nitrogen was very low in the spring and then somewhat elevated in August before declining again in the fall (Figure 21).



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

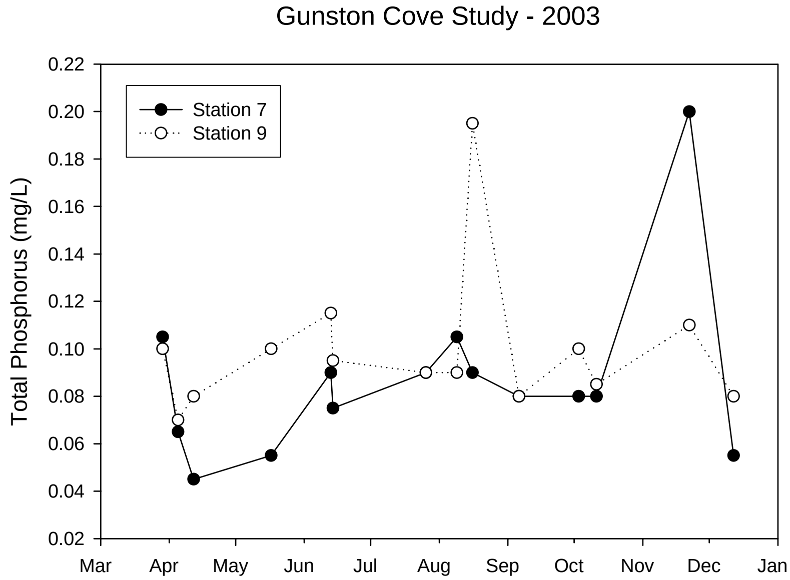
Figure 21. Nitrite Nitrogen (mg/L). Noman Cole Lab Data. Month tick is at first day of month.



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

Figure 22. Organic Nitrogen (mg/L). Noman Cole Lab Data. Month tick is at first day of month.

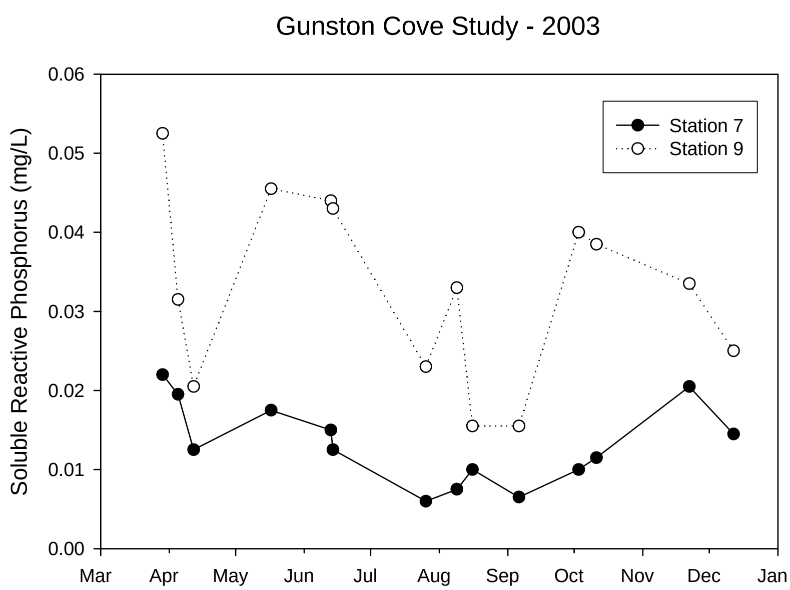
Organic nitrogen increased from low values in spring to higher levels in late summer in both cove and river (Figure 22). The increase occurred in the late spring-early summer in the cove and values were fairly constant through early September. In the river the increase was delayed through July and a sharper peak was found in late August. Also in the river, organic nitrogen declined strongly in the fall.



Phosphorus (P) is often the limiting nutrient in freshwater ecosystems. As such the concentration of P can set the upper limit for algal growth. Total phosphorus is the best measure of P availability in freshwater since much of the P is tied up in biological tissue such as algal cells. Total P includes phosphate ion (PO_4^{-3}) as well as phosphate inside cells and phosphate bound to inorganic particles such as clays.

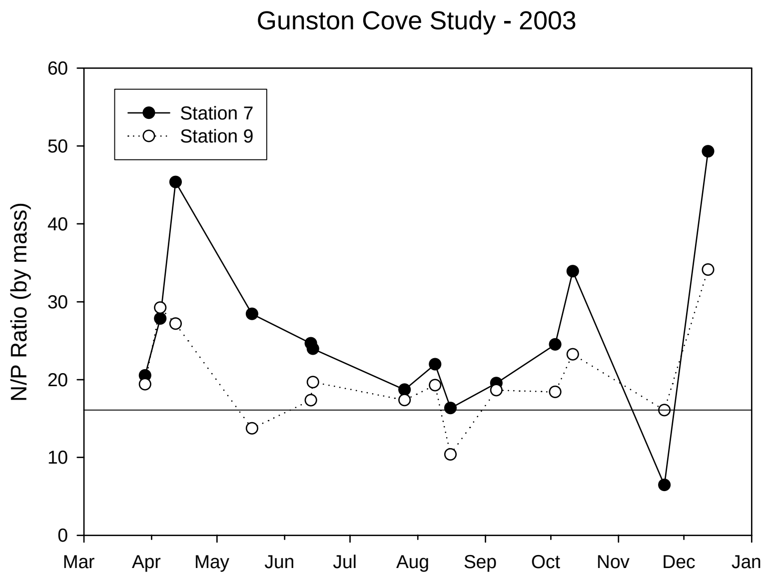
Figure 23. Total Phosphorus (mg/L). Noman Cole Lab Data. Month tick is at first day of month.

Total phosphorus was fairly constant through much of the year in the range of 0.06-0.12 mg/L at both stations (Figure 23). Exceptions were lower values in April and May in the cove and higher values in August in the river and November in the cove. Soluble reactive phosphorus was consistently higher in the river than in the cove (Figure 24). In both areas values were lowest during mid summer, the time of maximum utilization of SRP by algae. The decline in late April was also a time of high photosynthesis as suggested by DO and pH.



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

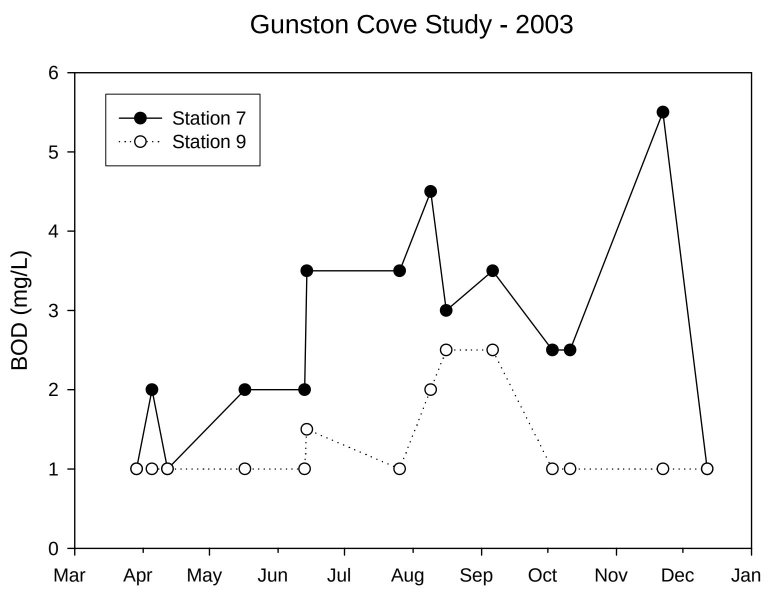
Figure 24. Soluble Reactive Phosphorus (mg/L). Noman Cole Lab Data. Month tick is at first day of month.



N:P ratio is determined by summing all of the components of N (ammonia, nitrate, nitrite, and organic nitrogen) and dividing by total P. This ratio gives an indication of whether N or P is more likely to be limiting primary production in a given freshwater system. Generally, values above 16 are considered indicative of P limitation while values below 16 suggest N limitation. N limitation could lead to dominance by cyanobacteria who can fix their own N from the atmosphere.

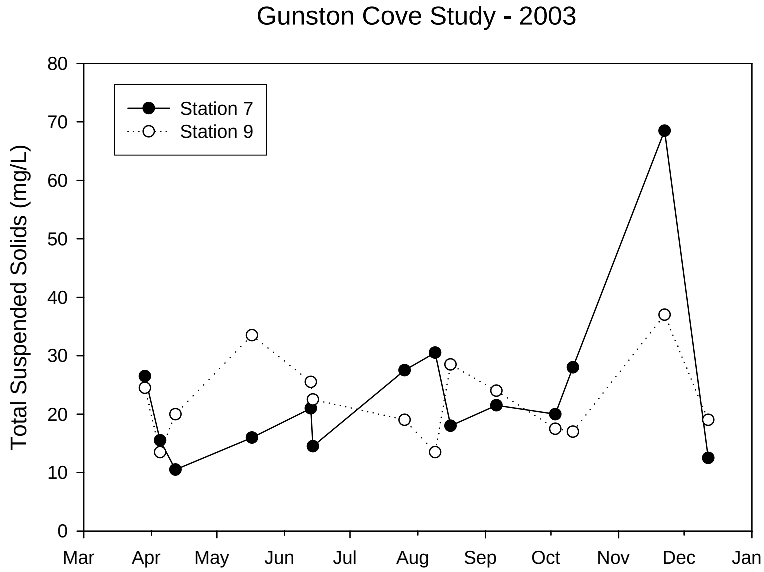
Figure 25. N/P Ratio (by mass). Noman Cole Lab Data. Month tick is at first day of month.

N/P ratio exhibited a familiar pattern with lowest values observed in late summer at both stations (Figure 25). Most of the readings were above 16 indicating P limitation, but the late summer value in the river was near 10 suggesting the possibility of N limitation. Biochemical oxygen demand (BOD) was consistently higher in the river than in the cove and was generally higher in summer than spring and fall. An outlier from this pattern was the peak in November in Gunston Cove (Figure 26).



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

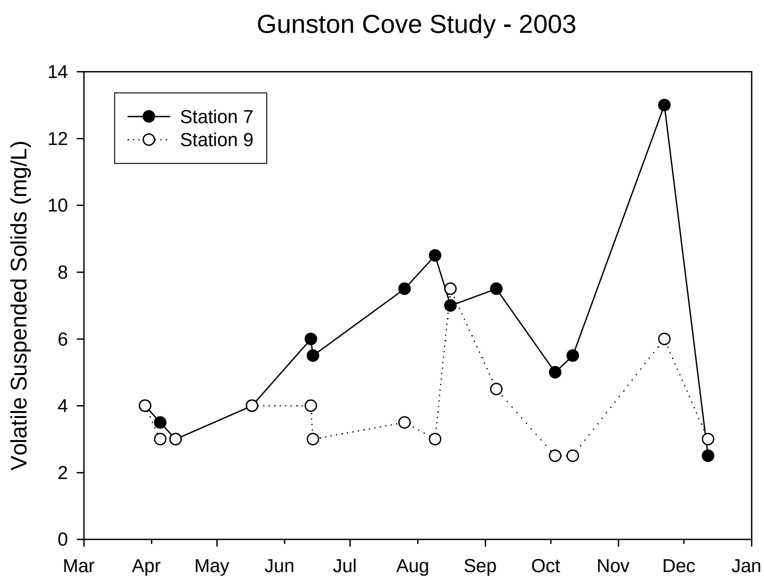
Figure 26. Biochemical Oxygen Demand (mg/L). Noman Cole Lab Data. Month tick is at first day of month.



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

Figure 27. Total Suspended Solids (mg/L). Noman Cole Lab Data. Month tick is at first day of month.

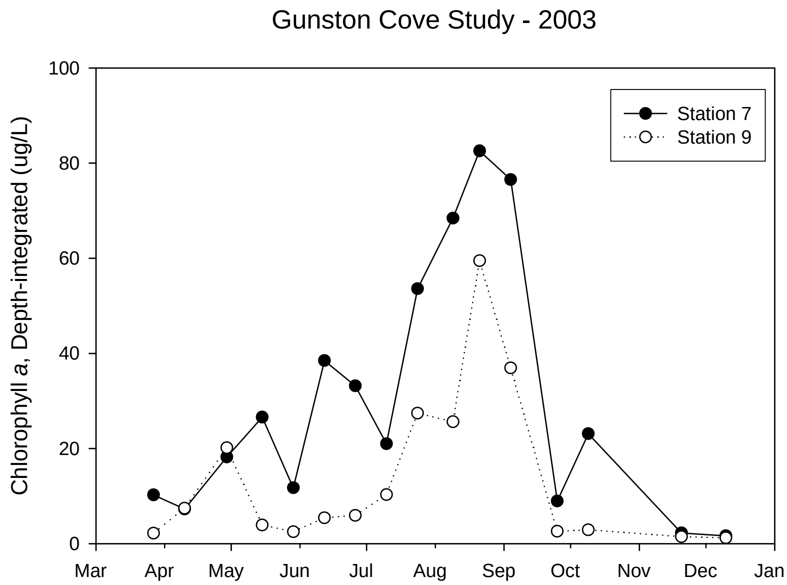
Total suspended solids were fairly constant and covered a similar range in the river and cove through most of the year (Figure 27). Values outside a general range of 10-30 mg/L were found in November with about 35 mg/L in the river and nearly 70 mg/L in the cove. Volatile suspended solids were typically greater in the cove than in the river (Figure 28). A seasonal pattern was clear in the cove with higher values in the summer except for the maximum in November. In the river lower levels were observed except in late August when river VSS was slightly higher than in the cove.



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

Figure 28. Volatile Suspended Solids (mg/L). Noman Cole Lab Data. Month tick is at first day of month.

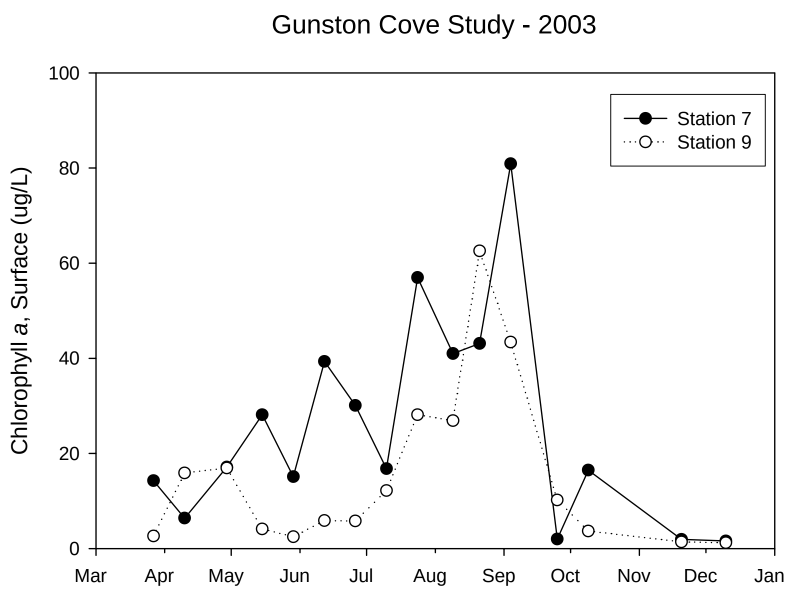
C. Phytoplankton



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

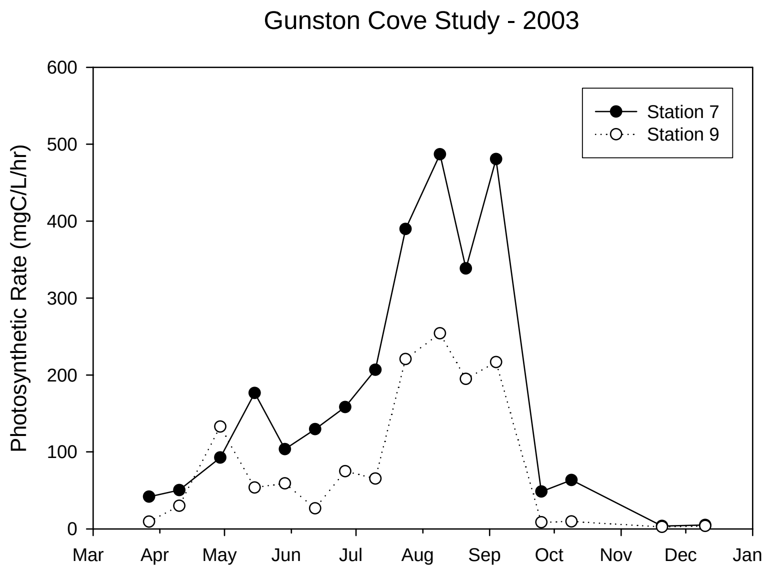
Figure 29. Chlorophyll *a* (ug/L). Depth-integrated. GMU Lab Data. Month tick is at the first day of month.

Chlorophyll *a* exhibited a distinct seasonal pattern in both river and cove and the pattern was quite similar in both depth-integrated (Figure 29) and surface (Figure 30) samples. In the cove chlorophyll levels increased fairly steadily from early April to late August/early September. Two exceptions to this steady increase were low values in late May and in early August. A major decline in chlorophyll a was observed in late September corresponding with the passage of Hurricane Isabel. A recovery was observed in October, but November and December continued the seasonal decline. In the river a distinct peak was observed in late April followed by low chlorophyll a levels in May and June. Values increased in July and reached a distinct peak in late August.



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

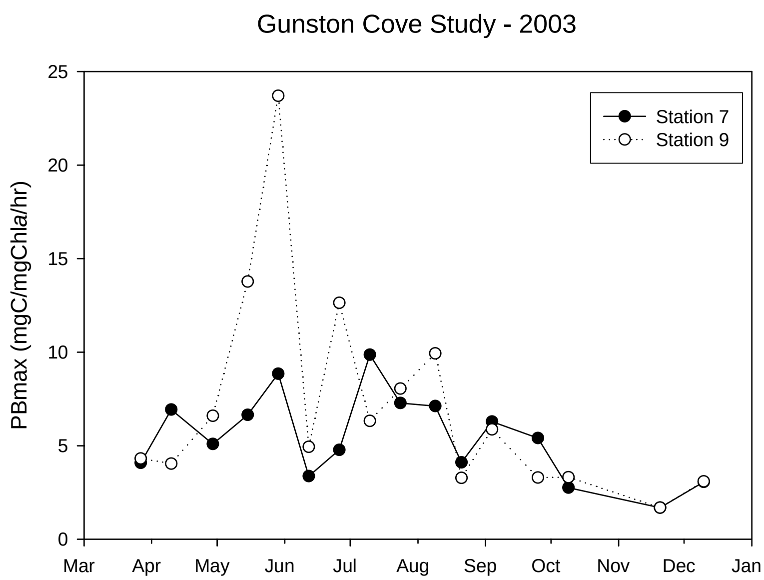
Figure 30. Chlorophyll *a* (ug/L). Surface. GMU Lab Data. Month tick is at first day of month.



Chlorophyll a measures the standing crop of phytoplankton while photosynthetic rate measures their productivity. Phytoplankton are primary producers meaning that they take CO_2 and sunlight and create living tissue by the process of photosynthesis. This can then serve as food for animals and other living things. Since light is a factor in photosynthesis and light varies in the environment, measurements are made in the lab under ideal light conditions so that these rates can be compared between samples.

Figure 31. Photosynthetic Rate at Light Saturation (ugC/L/hr). Month tick is at first day of month.

Photosynthetic rate followed patterns similar to those in chlorophyll *a* (Figure 31). In the cove there was a gradual increase reaching a seasonal peak in August and early September. A major decline was observed in late September with the passage of Hurricane Isabel. In the river the spring peak was apparent and the seasonal maximum occurred in August and early September followed by the Isabel decline. Photosynthetic rate per unit chlorophyll (P^B_{max}) was generally from 3-10 mgC/mgChl*a*/hr. Exceptions were several high values in the river in spring and early summer.



Photosynthetic rate is a function not only of light but of the amount of phytoplankton present. To get a measure of the rate that accounts for differences in the total amount of phytoplankton in the water, we can determine how much living tissue is created per unit of chlorophyll. This could be viewed as a measure of growth potential.

Figure 32. P^B_{max} (mgC/mgChl*a*/hr). Month tick is at first day of the month.

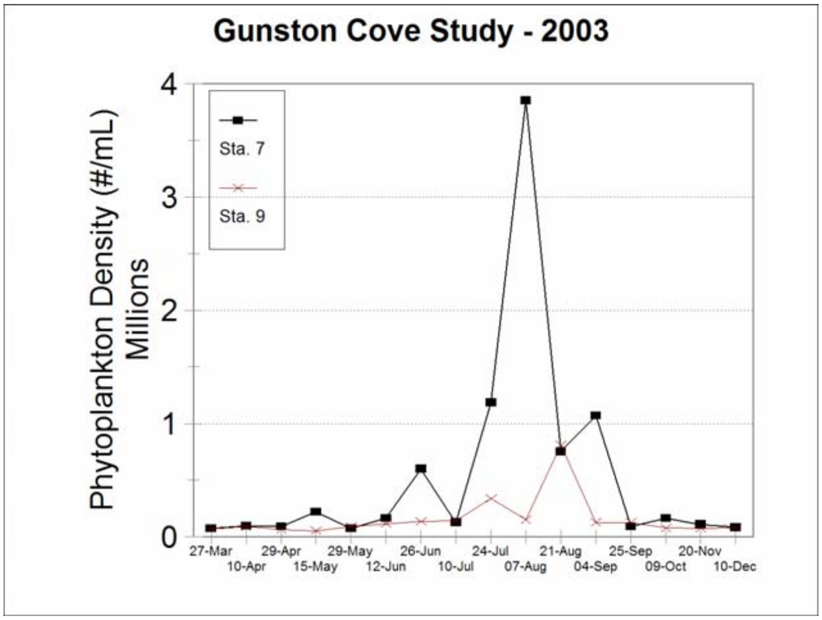


Figure 32. Phytoplankton Density (cells/mL).

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

Phytoplankton density was low in the spring in both cove and river, but in the summer cove values increased strongly (Figure 32). Maximum density attained in the cove was about 4 x 10^6 cells per mL in early August. The maximum observed in the river was about 0.8 x 10^6 cells per mL in early September. Total phytoplankton biovolume was also greater in the cove reaching maxima in late June and early August of about 450 x 10^6 um^3/mL. In the river the highest biovolume obtained was in early September at 200 x 10^6 um^3/mL. In both river and cove spring and late fall were times of low phytoplankton biovolume.

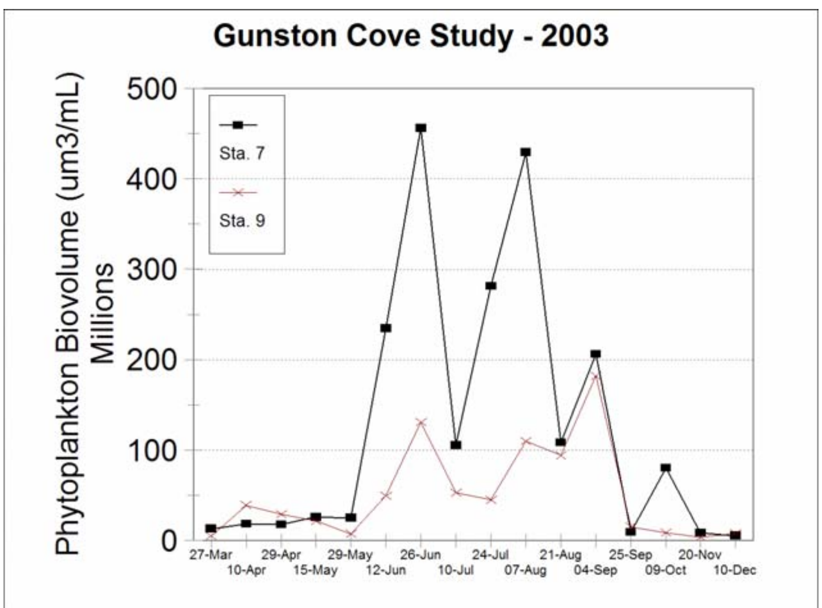
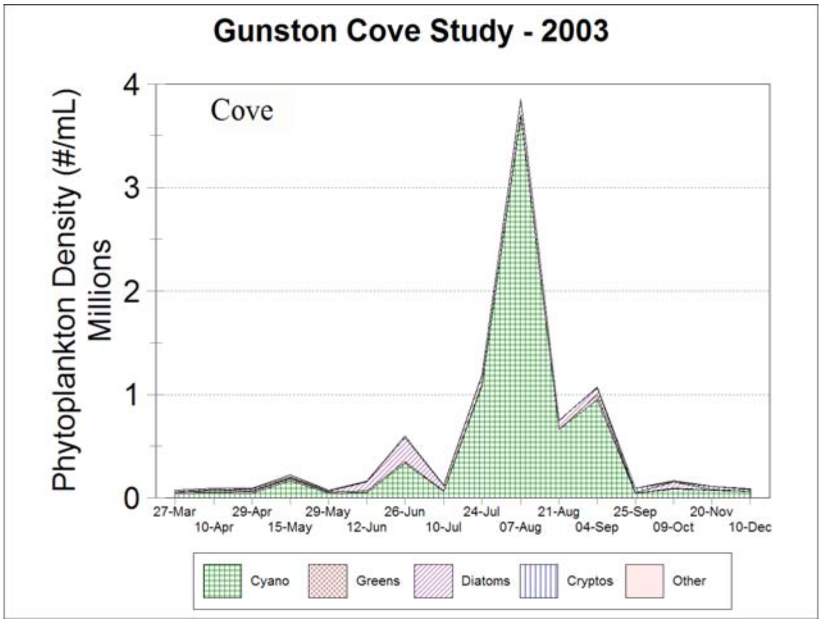


Figure 33. Phytoplankton Biovolume (um^3/mL).

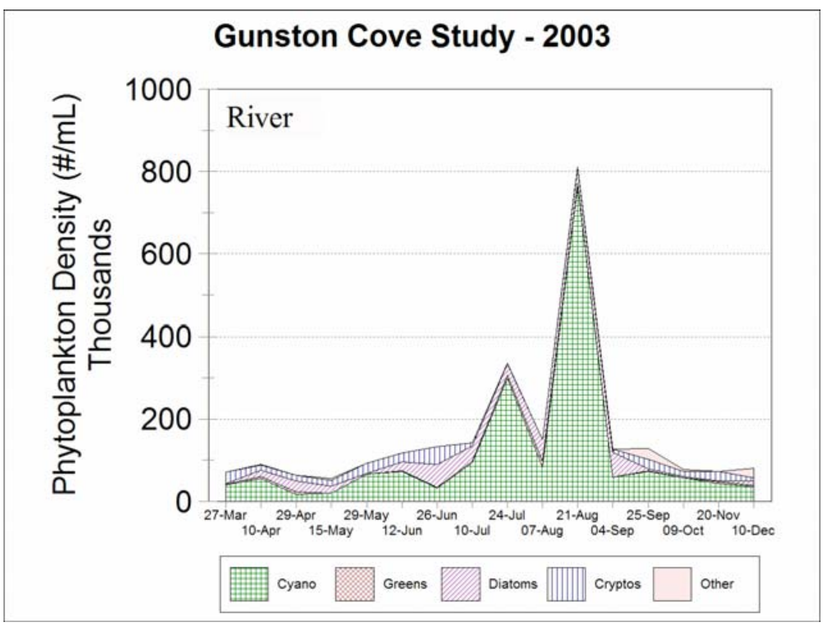
The volume of individual cells of each species is determined by approximating the cells of each species to an appropriate geometric shape (e.g. sphere, cylinder, cone, cube, etc.) and then making the measurements of the appropriate dimensions under the microscope. Total phytoplankton biovolume (shown here) is determined by multiplying the cell density of each species by the biovolume of each cell of that species. Biovolume accounts for the differing size of various phytoplankton cells and is probably a better measure of biomass. However, it does not account for the varying amount of water and other nonliving constituents in cells.



Total phytoplankton cell density can be broken down by major group. In this case **Cyano** refers to cyanobacteria (or "blue-green algae"), **Greens** refers to green algae, **Diatoms** is self-explanatory, **Cryptos** refers to cryptophytes, and **Other** includes euglenoids and dinoflagellates. Due to their small size cyanobacteria typically dominate cell density numbers. Their numbers are typically highest in the late summer reflecting an accumulation of cells during favorable summer growing conditions.

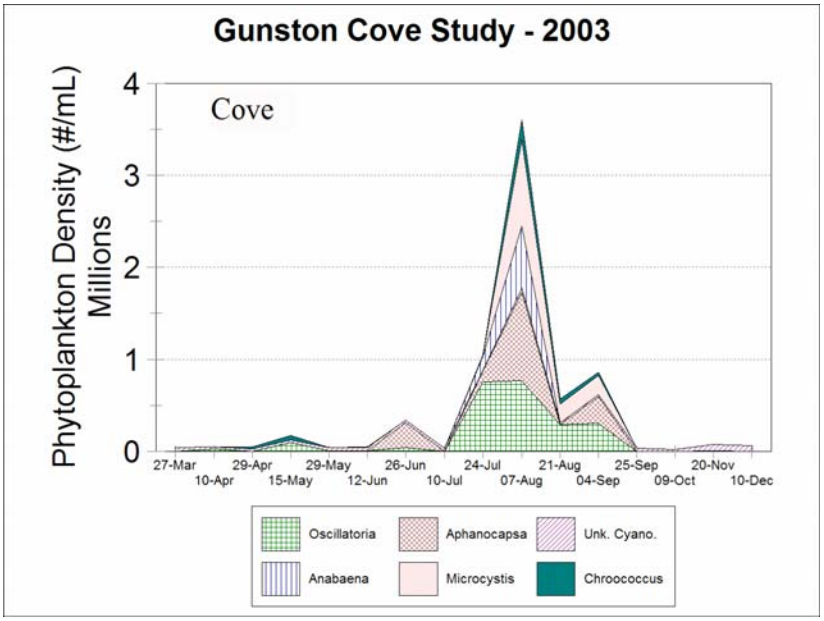
Figure 34. Phytoplankton Density by Major Group (cells/mL). Gunston Cove.

Phytoplankton density in the cove was overwhelmingly dominated by cyanobacteria (Figure 34). Diatoms contributed to the abundance total in June and in late August, early September and early October. In the river cyanobacteria were still generally dominant, but other groups made stronger and more frequent contributions (Figure 35). Diatoms were again important in spring and fall. Cryptophytes were also important during these periods in the river.



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

Figure 35. Phytoplankton Density by Major Group (cells/mL). River.

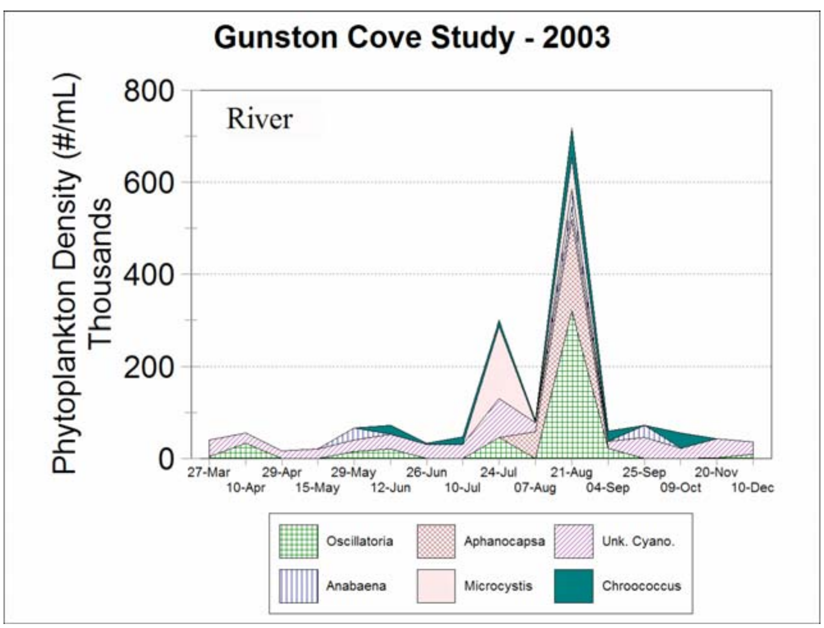


The dominant cyanobacteria on a numerical basis were:

- *Oscillatoria* – a filament
- *Aphanocapsa*- a small sphere
- Small spherical cells of unknown species
- *Anabaena* – a filament of spherical cells
- *Microcystis* – an irregular colony of spherical cells
- *Chroococcus* – individual spherical cells

Figure 36. Phytoplankton Density by Dominant Cyanobacteria (cells/mL). Gunston Cove.

In the spring *Oscillatoria* dominated cell density in the cove followed by early summer abundance of *Apahnocapsa* (Figure 36). The midsummer peak was notable in being a product of several taxa including *Oscillatoria*, *Aphanocapsa*, *Anabaena*, and *Microcystis*. In the river *Oscillatoria* shared dominance in the spring with unknown cyanobacteria (Figure 37). Their appeared to be two summer peaks: in late July *Microcystis* was most dominant with contributions from *Oscillatoria* and unknown cyanobacteria while in late August *Oscillatoria* alone made up about half the population.



Oscillatoria

Microcystis

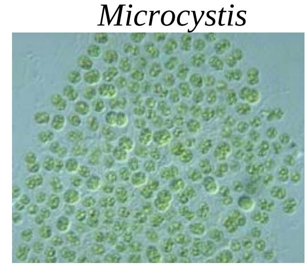
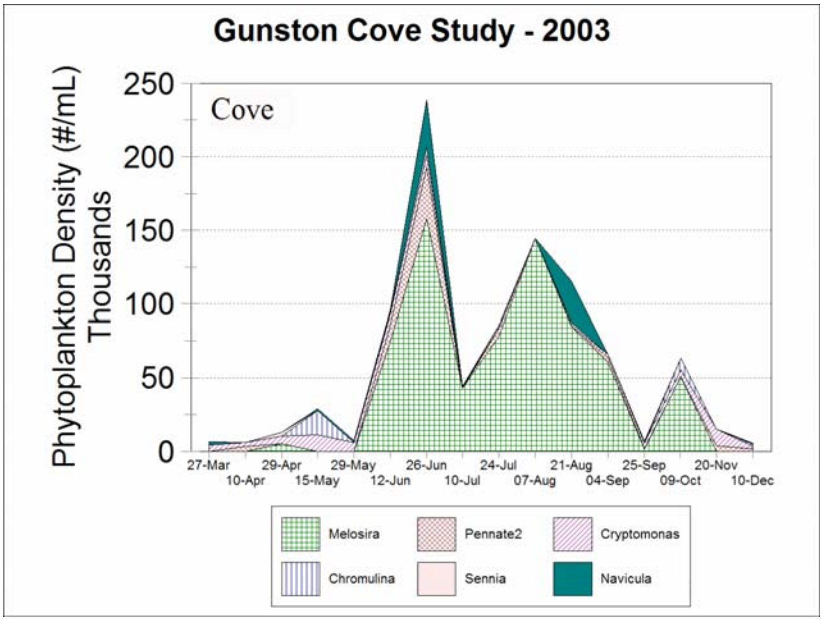


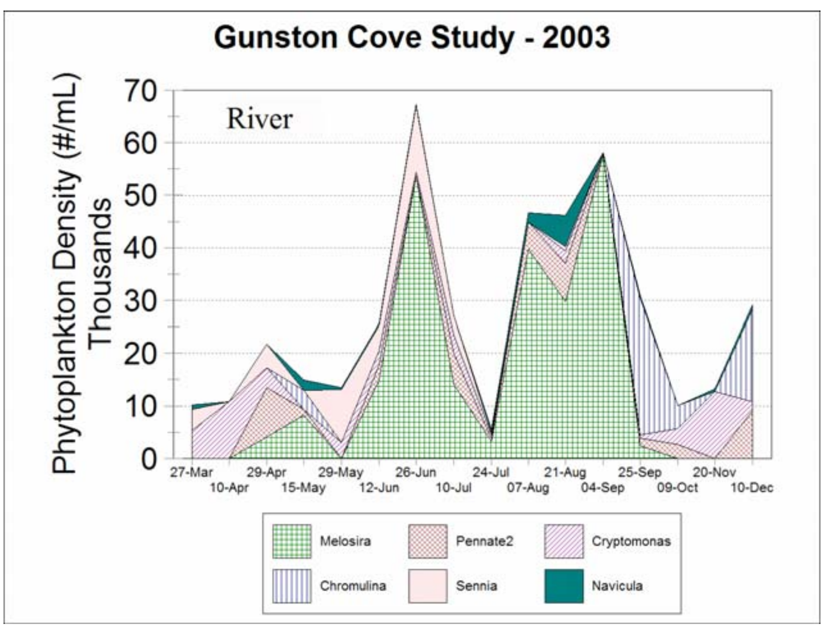
Figure 37. Phytoplankton Density by Dominant Cyanobacteria (cells/mL). River.



The most numerous non-cyanobacterial phyto-plankton were:
- *Melosira* – a filamentous centric diatom
- Pennate2 – an unidentified pinnate diatom
- *Cryptomonas* – an ellip-soidal flagellated unicell
- *Chromulina* – a flagellated chrysophyte unicell
- *Sennia* – a unicellular cryptophyte
- *Navicula* – a pinnate diatom

Figure 38. Phytoplankton Density (#/mL) by Dominant Noncyanobacterial Taxa. Gunston Cove.

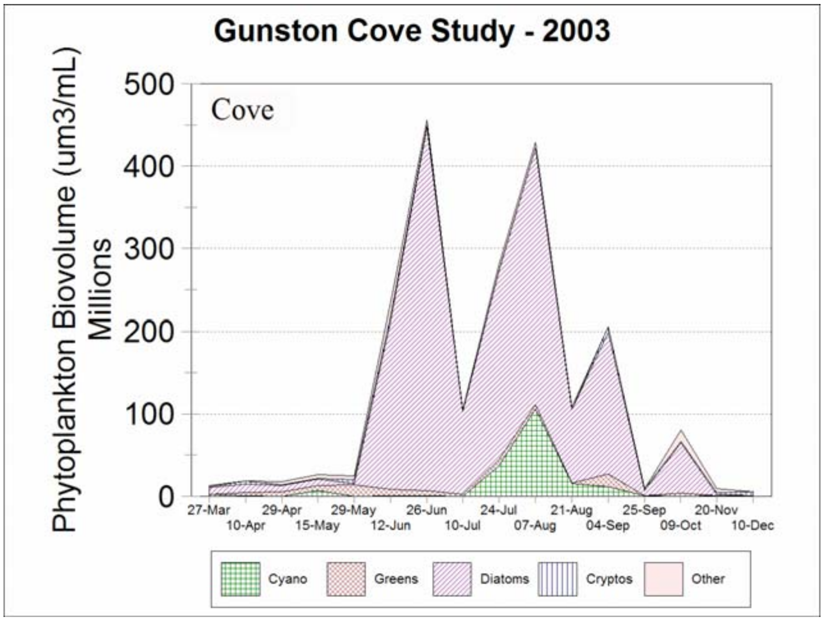
In the cove two flagellates, *Cryptomonas* and *Chromulina*, were the most numerous of the noncyanobacterial taxa during spring (Figure 38). However, in early June Melosira exhibited a dramatic increase and became the overwhelming dominant. While values went up and down, *Melosira* continued to be most numerous through October. During this time other diatoms such as *Navicul*a and an unknown pinnate (pennate2) made significant contributions to abundance. In the river densities were substantially lower, but *Melosira* assumed a leadership role sooner (Figure 39). *Cryptomonas* and pennates were dominant in spring and fall and *Chromulina* was dominant in fall.



Melosira

Cryptomonas

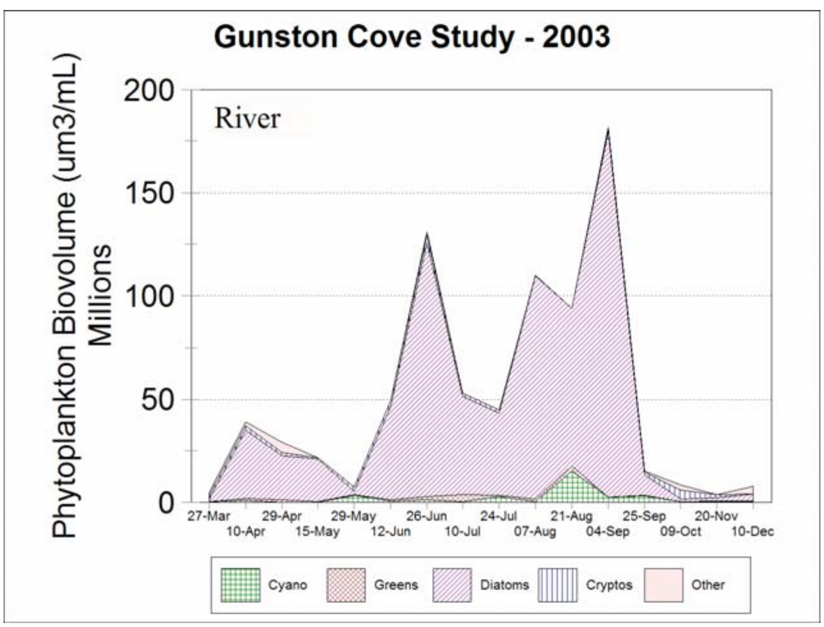
Figure 39. Phytoplankton Density (#/mL) by Dominant Taxa. Gunston Cove.



Total phytoplankton biovolume can be broken down into groups:
- **Cyano** – cyanobacteria ("blue-green" algae)
- **Greens** – green algae
- **Diatoms** – includes both centric and pinnate
- **Cryptos** – cryptophytes
- **Other** – includes euglenoids, crysophytes, and dinoflagellates

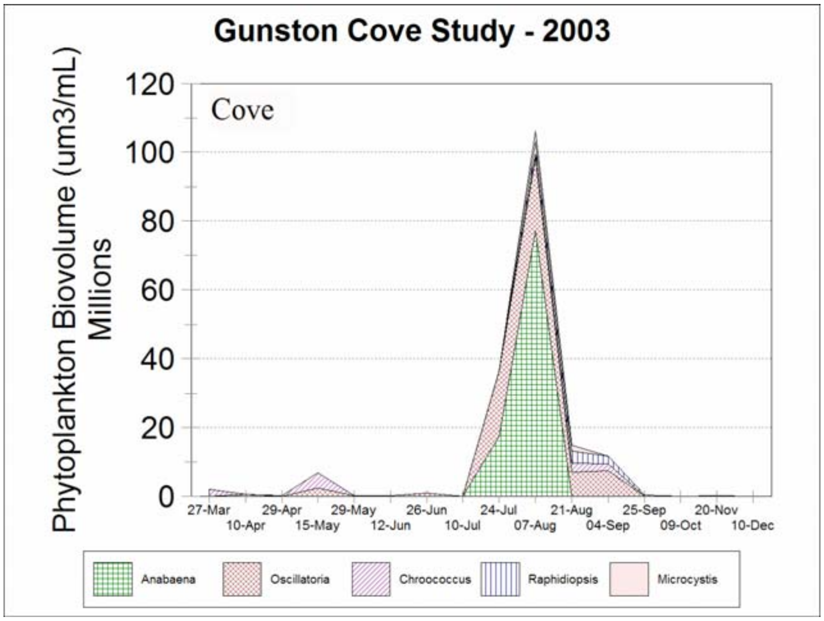
Figure 40. Phytoplankton Biovolume (um^3/mL) by Major Groups. Gunston Cove.

In the cove diatoms were the dominant contributor to total phytoplankton biovolume (Figure 40). Cyanobacteria became significant in late July and August. Other group made significant contributions to total phytoplankton biovolume only in the spring. A similar pattern was observed in the river (Figure 41). Diatoms were even more dominant than in the cove with cyanobacteria making a substantial showing only in late August. Peak summer phytoplankton biovolume in the river was less than half that found in the cove.



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

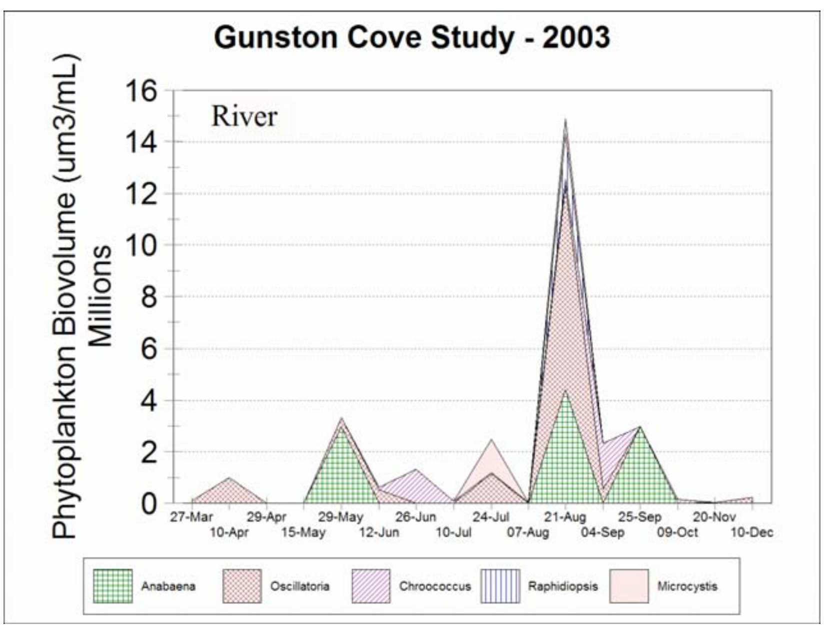
Figure 41. Phytoplankton Biovolume (um^3/mL) by Major Groups. River.



Cyanobacteria are generally most common in late summer and that is when they normally make the largest contribution to phytoplankton biovolume. *Anabaena*, the dominant summer cyanobacterium in 2003, is a nitrogen fixer meaning that it can take utilized N_2 gas dissolved in water as a N source. This would suggest possible N limitation in the summer.

Figure 42. Phytoplankton Biovolume (um^3/mL) by Cyanobacteria Taxa. Gunston Cove.

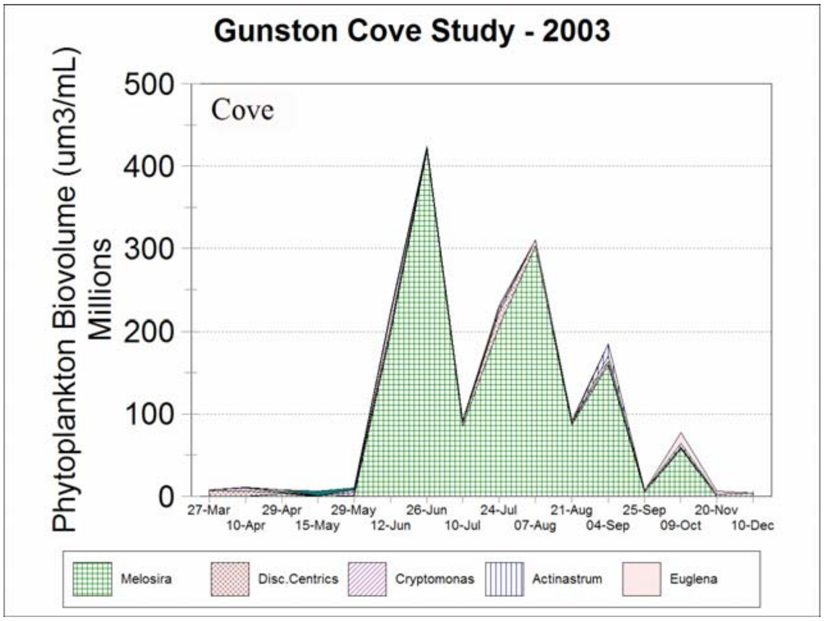
Cyanobacterial biovolume was most prominent in late July and early August in the cove (Figure 42). *Anabaena* was the major contributor to this peak. *Oscillatoria* was also prominent during this time and extended its abundance into early September. In the river cyanobacteria were present at much smaller levels and were more sporadic in their pattern (Figure 43). The largest peak was in late August with *Oscillatoria* and *Anabaena* being the dominants. *Microcystis* was co-dominant in late July.



Anabaena

Chroococcus

Figure 43. Phytoplankton Biovolume (um^3/mL) by Cyanobacterial Taxa. River.



Melosira

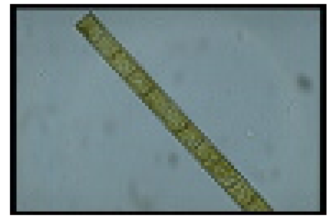
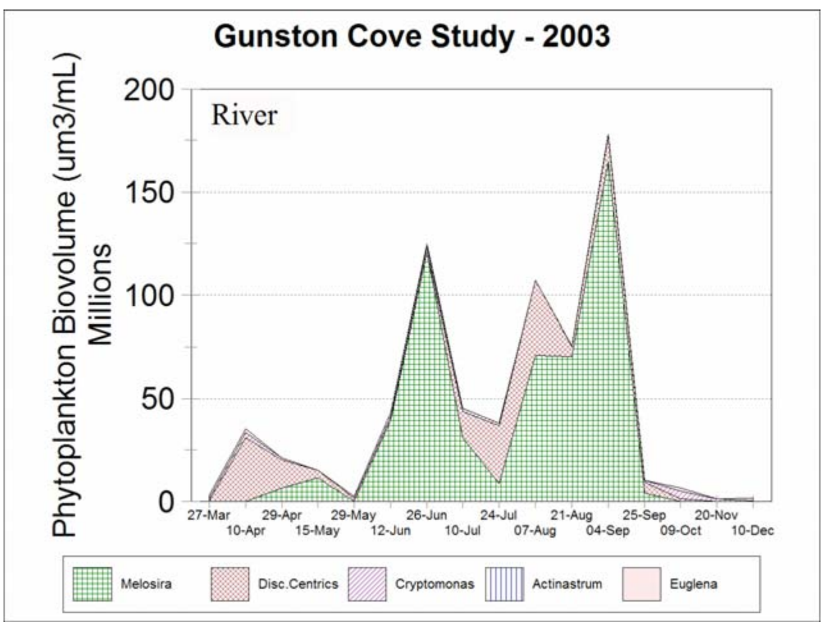


Figure 44. Phytoplankton Biovolume (um^3/mL) by Dominant Noncyanobacterial Taxa. Gunston Cove.

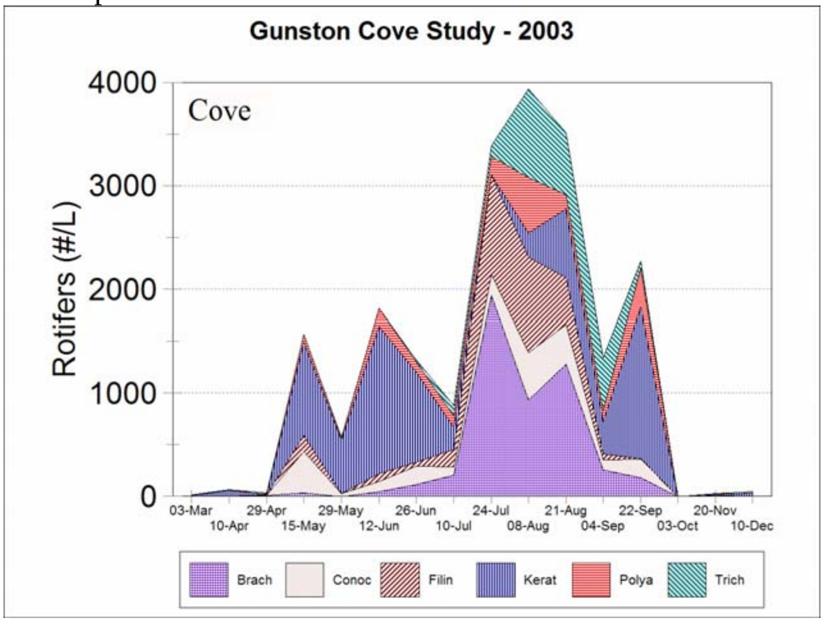
Biovolume of noncyanobacterial phytoplankton was dominated by the diatom *Melosira* throughout the year (Figure 44). It reached a peak in early June at over 400 x 10^6 um^3/ml and generally declined through the remainder of the year. In the river, discoid centrics were also common and dominated in early April and late July (Figure 45).



Discoid Centrics

Figure 45. Phytoplankton Biovolume (um^3/mL) by Dominant Taxon. River.

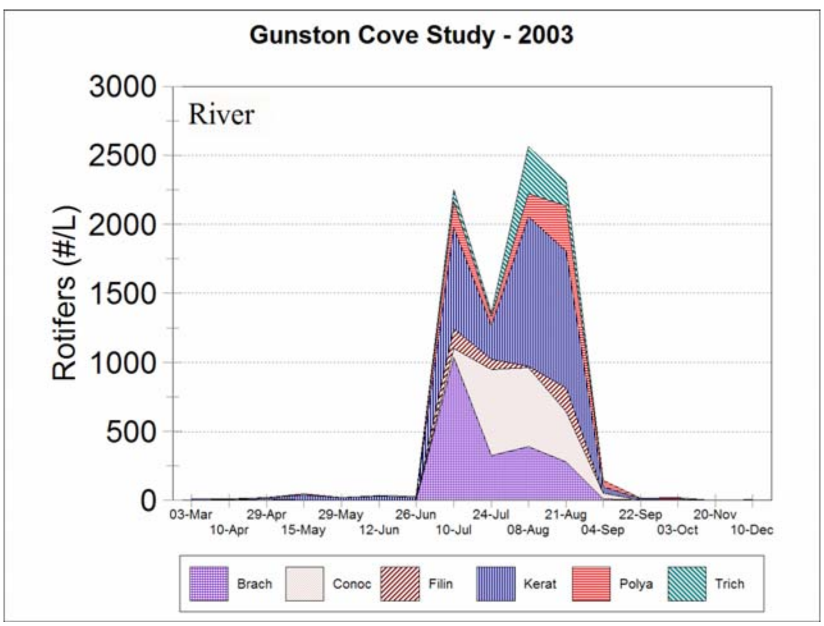
D. Zooplankton



Rotifers are the most smallest and most abundant metazoan zooplankton in most freshwater systems including the freshwater tidal Potomac River. Rotifers generally grow to maximum numbers in the summer and are scarce in the winter.
Dominant taxa in the cove and river in 2003 include:
Brachionus
Conochilidae
Filinia
Keratella
Polyarthra
Trichocerca
All of these taxa are common in freshwater systems.

Figure 44. Rotifer density by Dominant Taxa (#/L). Cove.

Rotifers increased rapidly in early May and then again in late July in the cove reaching a maximum of nearly 4000/L (Figure 44). *Keratella* was the dominant in spring with *Brachionus* becoming most important in the summer. *Filinia* and *Trichocerca* were also abundant in the summer bloom and *Keratella* resurged in late September. In the river the period of elevated rotifer abundance was more restricted. *Brachionus* and *Keratella* bloomed simultaneously in early June with Conochilidae becoming important in late July and early August. By late September all rotifers had declined substantially.



Brachionus (c. 50 um)

Conochilidae

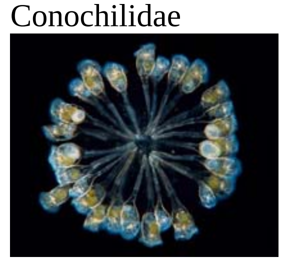
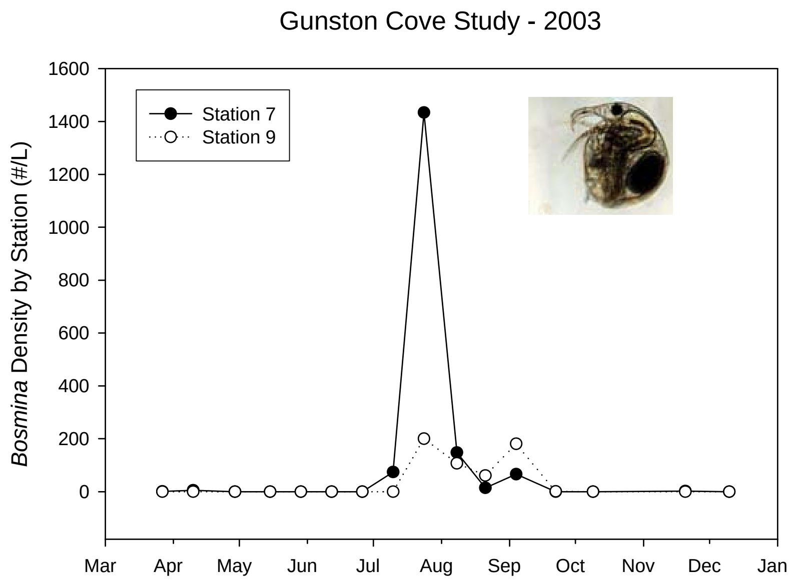


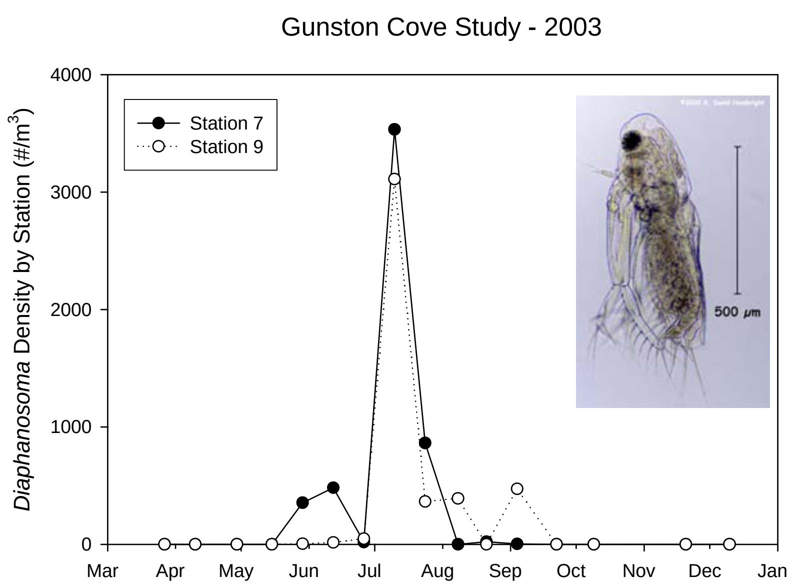
Figure 45. Rotifer Density by Dominant Taxa (#/L). River.



Bosmina is a small-bodied (adults<0.3 mm) cladoceran, or "waterflea", which is common in lakes and freshwater tidal areas. It is typically the most abundant cladoceran with maximum numbers generally about 100-1000 animals per liter. Due to its small size and relatively high abundances, it is enumerated in the micro-zooplankton samples. *Bosmina* can graze on smaller phytoplankton cells, but can also utilize some cells from colonies by knocking them loose.

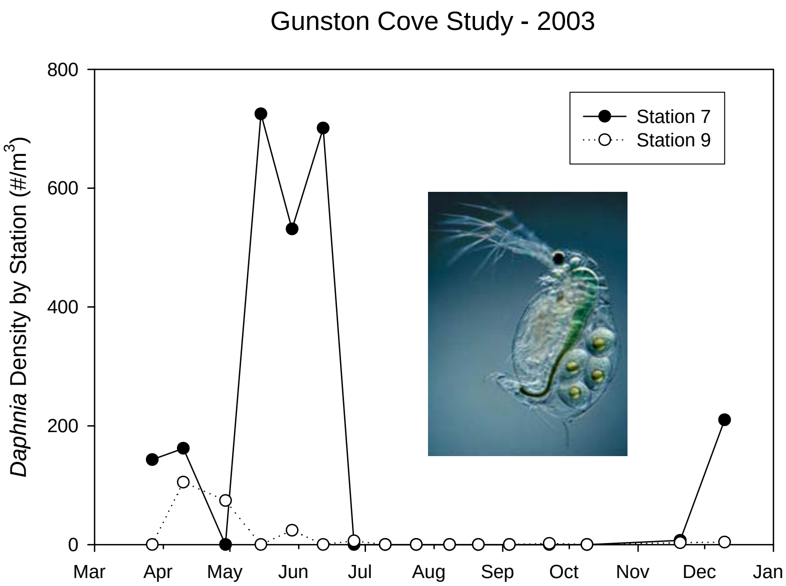
Figure 46. *Bosmina* density by Station (#/L).

Bosmina bloomed strongly in late July in the cove reaching nearly 1500/L (Figure 46) with densities dropping sharply thereafter. In the river two lesser peaks were observed, one in late July and the other in early Septemeber at about 200/L. *Diaphanosoma*, the most abundant larger cladoceran in Gunston Cove exhibited a strong peak of about 35,000/m^3 in early July (Figure 47). In the river this was preceded by some moderate densities and in the river some dates with moderated densities followed the peak.



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

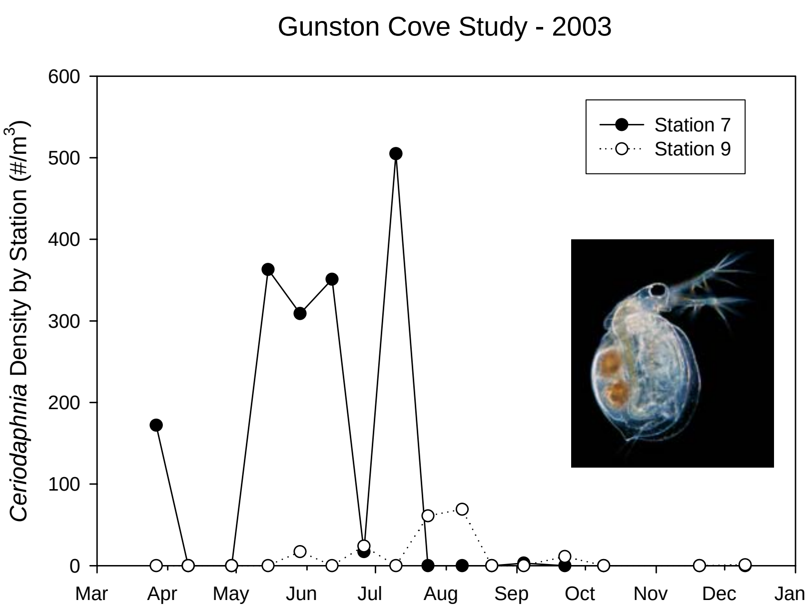
Figure 47. Diaphanosoma density by Station (#/m^3)



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

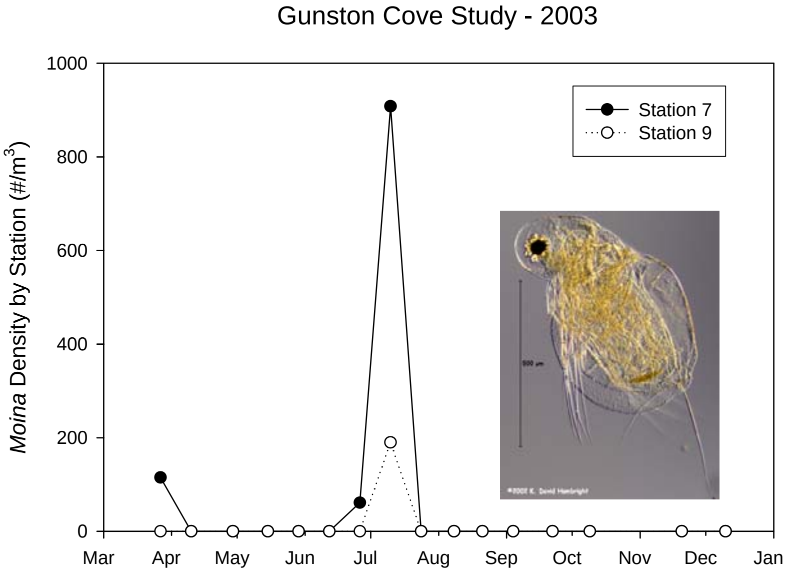
Figure 48. *Daphnia* Density by Station (#/m^3).

Daphnia reached highest densities in the cove during May and early June, but the densities were rather low (Figure 48). In the river an even more subdued peak was observed in the spring. *Ceriodaphnia* in the cove exhibited a similar May-June peak as *Daphnia* in the cove, but also had a maximum in early July (Figure 49). In the river, a very subdued peak was found in late July-early August.



Ceriodaphnia, another common large-bodied cladoceran, is usually present in numbers similar to *Daphnia*. Like all waterfleas, the juveniles look like miniature adults and grow through a series of molts to a larger size and finally reach reproductive maturity. Most reproduction is asexual except during stressful environmental conditions.

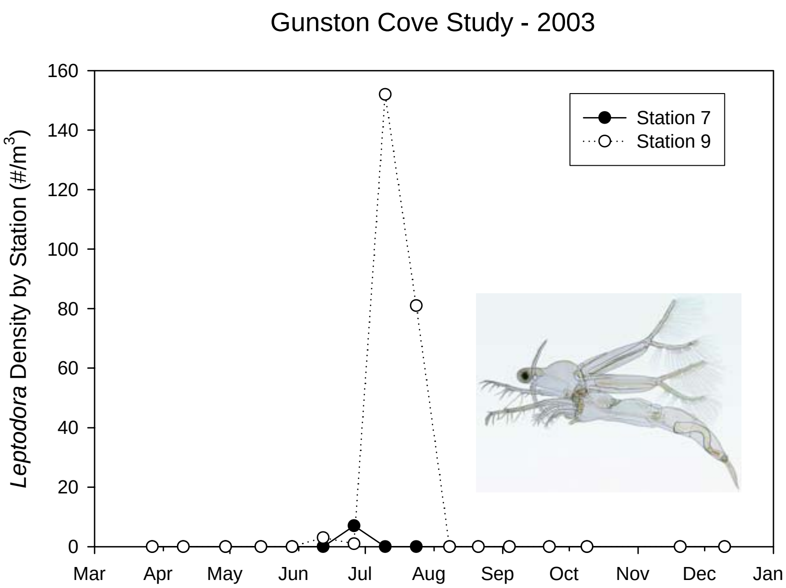
Figure 49. *Ceriodaphnia* Density by Station (#/m^3).



Moina is another waterflea that is often observed in the tidal Potomac River. Like the other cladocera mentioned so far, *Moina* grazes on phytoplankton to obtain its food supply.

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

Moina had a single distinct peak in abundance in early July in both Gunston Cove and the Potomac mainstem. The peak was about 900/m^3 in the cover while the river attained a lesser density of 200/m^3. *Leptodora*, the large cladoceran predator, was found at relatively high levels in the cove in early July. In the river the maximum was much lower and occurred in late June.



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

Figure 51. *Leptodora* Density by Station (#/m^3).

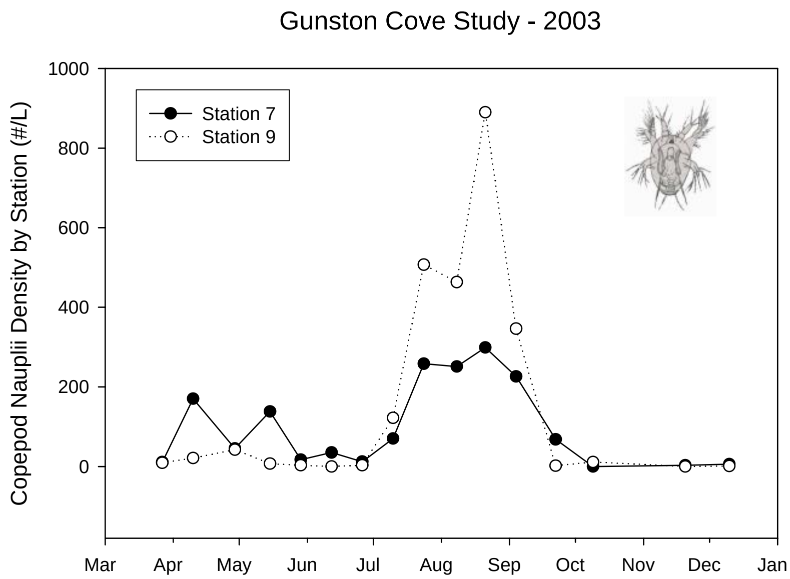


Figure 52. Copepod Nauplii Density by Station (#/L).

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

Copepod nauplii demonstrated a distinct seasonal pattern in 2003 with a substantial late summer-early fall maximum in both cove and river. In the cove nauplii densities approached 1000/L in late August. The maximum in the river was 300/L also in late August. In the river a secondary peak in nauplii was observed in the spring corresponding to the maximum in *Eurytemora*. *Eurytemora* exhibited a characteristic spring peak in both river and cove. A maximum of over 11,000/m^3 was observed in late April in the cove, while the river station peaked at about 10,000/m^3 in early April. A secondary peak was observed in both areas in early July at about 2000/m^3.

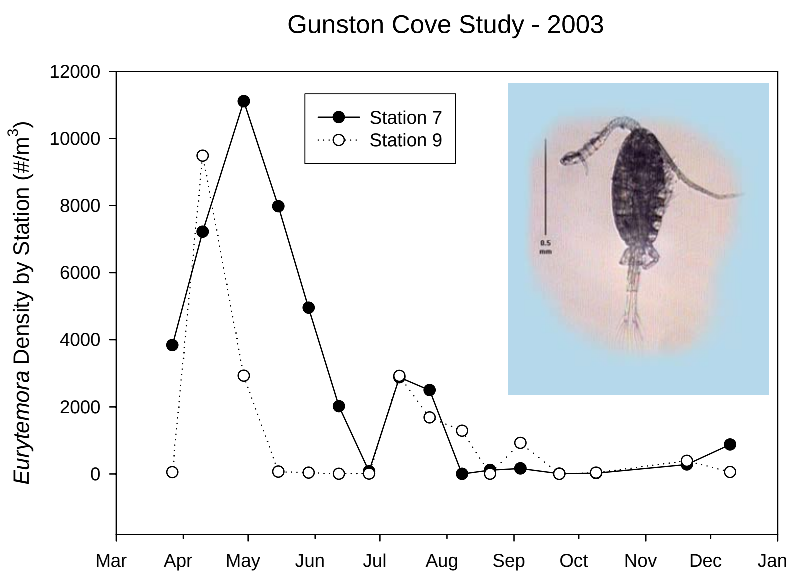
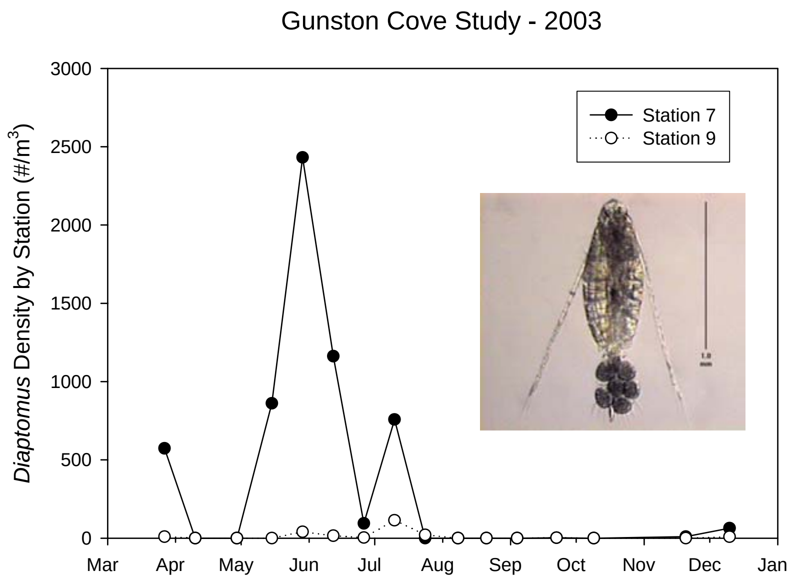


Figure 53. *Eurytemora* Density by Station (#/m^3).

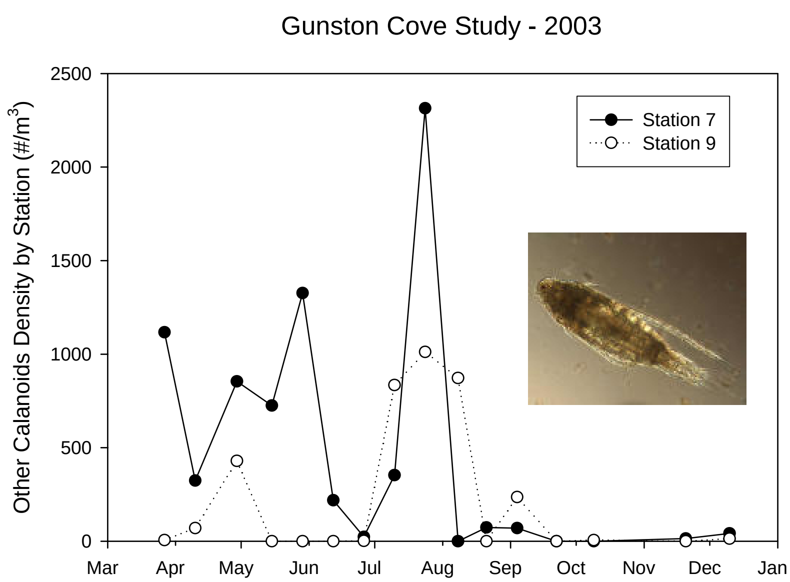
Eurytemora affinis is a large calanoid copepod characteristic of the freshwater and brackish areas of the Chesapeake Bay. *Eurytemora* is a cool water copepod which often reaches maximum abundance in the late winter or early spring. Included in this graph are adults and those copepodids that are recognizable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



Diaptomus pallidus is a calanoid copepod found in moderate densities in the Gunston Cove area. Diaptomus is an efficient grazer of algae, bacteria, and detrital particles in freshwater ecosystems Included in this graph are adults and those copepodids that are recognizable as *Diaptomus*.

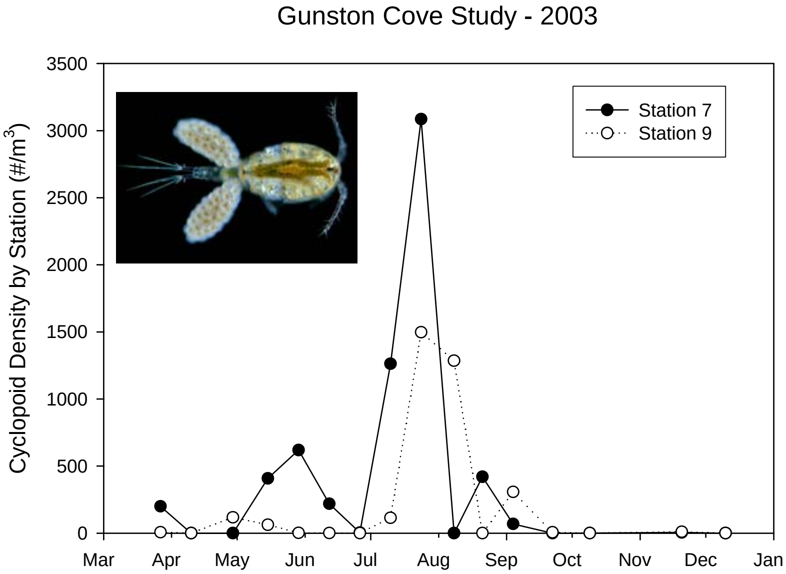
Figure 54. *Diaptomus* Density by Station (#/m^3).

Diaptomus was quite common in Gunston Cove in spring and early summer reaching a peak of nearly 2500/m^3 in late May. In the river few *Diaptomus* were observed. Other calanoid copepods occurred sporadically in the study area in spring and summer. Peak values were observed in late July of 2400/m^3 in the cove and 1000/m^3 in the river.



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

Figure 55. Other Calanoids Density by Station (#/m^3).



Cyclopoids are the other major group of planktonic copepods. Cyclopoids feed on individual particles suspended in the water including small zooplankton as well as phytoplankton. In this study we have lumped all copepodid and adult cyclopoids together.

Figure 56. Cyclopoid Copepods by Station (#/m^3).

Cyclopoid copepods reached their maximum abundance in the cove in late July at about 3000/m^3. In the river a similar late July maximum was observed reaching 1500/m^3. Few cyclopoids were observed at either station after early September.

E. Ichthoplankton

Larval fishes are transitional stages in the development of juvenile fishes. They range in development from newly hatched, embryonic fish to a juvenile fish with morphological features similar to those of an adult. After hatching from the egg, the larva draws nutrition from a yolk sack for a few days time. When the yolk sack diminishes to nothing, the fish begins a life of feeding on other organisms. This post yolk sack larva feeds on small planktonic organisms (mostly small zooplankton) for a period of several days. It continues to be a fragile, almost transparent, larva and suffers high mortality to predatory zooplankton and juvenile and adult fishes of many species, including its own. When it has fed enough, it changes into an opaque juvenile, with greatly enhanced swimming ability. It can no longer be caught with a slow-moving plankton net, but are soon susceptible to capture with the seine or trawl net.

In the 22 samples (11 at each Station), a total of 1544 individuals were caught. Of these, 479 were taken at Station 7 and 1065 at Station 9. The numbers of each taxon caught are shown in Table 3. The fish larvae are often difficult to distinguish at the species level, so many of the counts are only to the genera level.

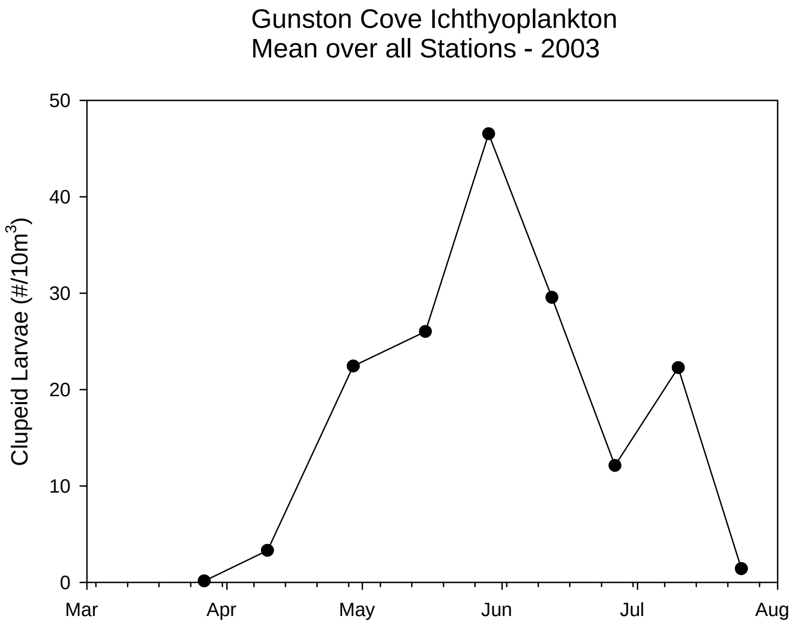
As is typical, the bulk of the catch (87.7 %) was members of the herring family. Most of these (41.65 %) were larvae of either gizzard shad or threadfin shad. Most, if not all, were probably gizzard shad, since threadfin shad never or almost never appear in our collections of juvenile and adult fishes. Larval *Alosa* sp. were second in rank (30.83 %). The larvae of *Morone* sp. accounted for 9.59 % of the total and were probably mostly white perch larvae.

The seasonal distribution of the catch per cubic meter of water of clupeid larvae is shown graphically in Figure 57 for all stations combined. That of white perch, inland silverside, and yellow perch are graphed separately in Figure 58.

Table 3. The larval fishes collected in Gunston Cove and the Potomac River in 2003.

Table 3
Larval Fishes Collected, by Taxon
Gunston Cove Study – 2003

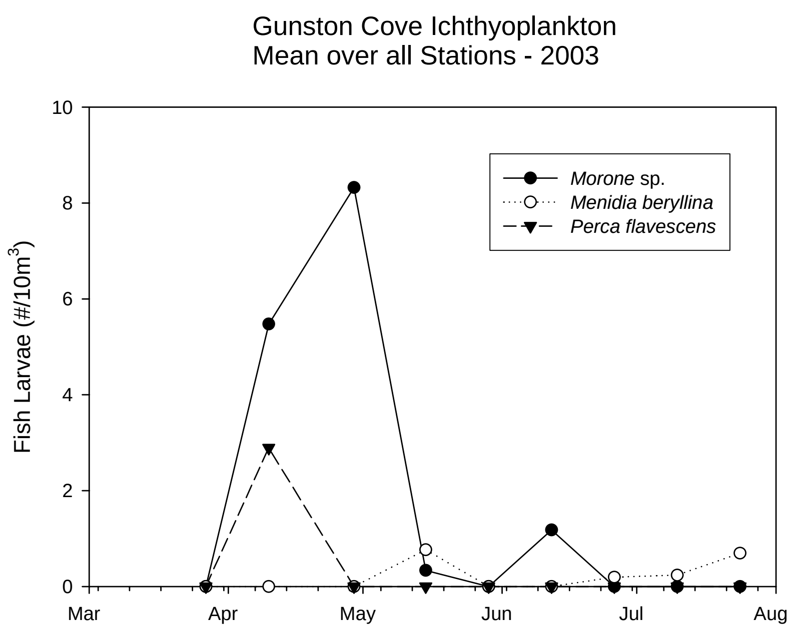
Taxon	Common Name	Number caught Total	Sta 7	Sta 9	% of total
Clupeidae	herring and shad family	216	11	205	13.99
Alosa sp.	American shad, alewife, hickory shad, or blueback herring	476	237	239	30.83
Alosa pseudoharengus	alewife	17	13	4	1.10
Alosa aestivalis	blueback herring	2	2		0.13
Dorosoma sp.	gizzard shad or threadfin shad	643	64	579	41.65
Morone sp.	white perch or striped bass	148	118	30	9.59
Morone saxatilis	striped bass	1	1		0.06
Perca flavescens	yellow perch	27	27		1.75
Menidia beryllina	inland silverside	14	6	8	0.91
Total		1544	479	1065	



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

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

Clupeid larvae include blueback herring, alewife, hickory shad, and gizzard shad. These are difficult to distinguish and have similar spawning patterns so they are lumped into one group for this analysis. Clupeids increased in the study areas through April and May attaining a maximum of nearly 50/10m^3. Numbers declined through June and July. *Morone* sp. (probably mostly white perch) during April reaching a peak of about 8/10m^3 in late April before declining strongly by mid-May. Yellow perch (*Perca flavescens*) was collected only in mid April while inland silverside (*Menidia beryllina*) was sporadically found throughout the summer.



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

Figure 58. Other Fish Larvae by Date. Month label is at the beginning of the month.

F. Adult and juvenile fishes

Trawls

Trawls for fishes were made at three stations in 2003: Stations 10, 7, and 9 (Figure 1). Beginning on March 27, trawl samples were collected on fourteen dates, with the last one on December 10. The total of 42 trawls collected 2,274 individuals, with representatives of 25 species. The list of species and the number of individuals of each species caught are presented in Table 4.

White perch were the most common catch (30.3% of the total), followed, in rank, by blueback herring (23.2%), channel cat (9.8%), bay anchovy (9.1%), alewife (4.3%), blue cat (4.3%), hogchoker (4.1%), spottail shiner (3.8%), brown bullhead (2.9%), tessellated darter (2.6%), hickory shad (2.1%), pumpkinseed (1.1%), and banded killifish (1.0%). A new species for the trawl catch was the silverjaw minnow.

The numbers of each species collected on each date are shown in Table 5A and Table 5B. White perch juveniles and adults, that were spawned in 2002 and earlier years, were caught in abundance at Station 9 in April 10. A similar collection of older and larger-sized white perch were caught at Station 7 on June 12 and at both Station 7 and Station 9 on June 26. Newly transformed young-of-the-year (YOY) white perch spawned in 2003 first appeared in the trawl catch on June 12 at Station 10 when only one was caught, and then on June 26 at Station 10, when 31 individuals were caught. On July 7 two were caught at Station 9 and one at Station 7. On July 24, 12 were caught at Station 7 and two at Station 9. On August 21, seven YOY white perch were collected at Station 7, and six were taken at Station 9. One was caught on September 22 at Station 10, and 13 probable YOY were caught at Station 9 on October 9. On November 24, a final 22 probable YOY were collected at Station 9. A total of only 98 individuals were caught. This is a very low annual catch of newly spawned white perch.

Newly spawned juvenile blueback herring began to be caught in large numbers on June 26 at Station 10 and continued to be caught through September 22 at Stations 7 and 10. Alewife young-of-the-year appeared on June 12 and were caught as late as October 9, but never in large numbers. It is difficult to distinguish hickory shad juveniles from alewife juveniles and blueback herring juveniles, and, thus, the identifications of all the alewife juveniles in this study are not certain, but most are probably correctly identified. Their catch totaled 47 YOY individuals. Bay anchovy juveniles from the 2003 spawning began to move into the Cove area in abundance in late August and remained numerous at Station 7 through September. Channel cat juveniles and adults were caught regularly at Station 9 in the channel, with most abundant catches in March, June, and November and December. Blue cat were most abundant on August 21. Brown bullhead were abundant in the trawl at Station 9 on June 26. Hogchoker were taken in the channel throughout the season, but larger numbers were caught on May 29 (all young juveniles) and September 22 (perhaps the same age cohort). Pumpkinseed and tessellated darter were fairly common from May 29 through July 7. One older juvenile and two YOY juvenile striped bass were caught.

Table 4

Adult and Juvenile Fish Collected by Trawling
Gunston Cove Study - 2003

Anguillidae	*Anguilla rostrata*	American eel	5
Clupeidae	*Alosa aestivalis*	blueback herring	528
	Alosa mediocris	hickory shad	47
	Alosa pseudoharengus	alewife	98
	Dorosoma cepedianum	gizzard shad	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	207
Cyprinidae	*Carassius auratus*	goldfish	2
	Cyprinus carpio	common carp	1
	Hybognathus regius	eastern silvery minnow	0
	Notemigonius crysoleucas	golden shiner	0
	Notropis buccatus	silverjaw minnow	1
	Notropis hudsonius	spottail shiner	86
Catostomidae	*Carpiodes cyprinus*	quillback	0
	Catostomus commersoni	white sucker	0
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	66
	Ameiurus catus	white catfish	1
	Ictalurus furcatus	blue catfish	98
	Ictalurus punctatus	channel catfish	222
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	22
	Fundulus heteroclitus	mummichog	1
Atherinidae	*Menidia beryllina*	inland silverside	6
Gobiidae	*Gobiosoma bosc*	naked goby	0
Percichthyidae	*Morone americana*	white perch	688
	Morone saxatilis	striped bass	4
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	0
	Lepomis auritus	redbreast sunfish	0
	Lepomis gibbosus	pumpkinseed	14
	Lepomis macrochirus	bluegill	26
	Micropterus salmoides	largemouth bass	2
	Pomoxis annularis	white crappie	1
Percidae	*Etheostoma olmstedi*	tessellated darter	59
	Perca flavescens	yellow perch	5
Sciaenidae	*Leiostomus xanthurus*	spot	0
	Micropogonias undulatus	Atlantic croaker	0
Soleidae	*Trinectes maculatus*	hogchoker	94
TOTAL			2284

Table 5A

Adult and Juvenile Fish Collected by Trawling
Gunston Cove Study - 2003

			27-Mar	10-Apr	29-Apr	15-May	29-May	12-Jun	26-Jun	7-Jul	24-Jul	21-Aug	22-Sep	9-Oct	24-Nov	10-Dec
Anguillidae	*Anguilla rostrata*	American eel	1	0	0	0	0	0	0	3	0	0	1	0	0	0
Clupeidae	*Alosa aestivalis*	blueback herring	0	0	0	0	0	0	251	0	122	8	147	0	0	0
	Alosa mediocris	hickory shad	0	0	0	0	0	2	0	1	3	0	1	40	0	0
	Alosa pseudoharengus	alewife	0	0	0	0	0	7	58	8	2	0	7	16	0	0
	Dorosoma cepedianum	gizzard shad	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	0	0	0	4	0	0	0	111	86	6	0	0
Cyprinidae	*Carassius auratus*	goldfish	0	0	0	0	0	0	0	0	0	0	0	0	2	0
	Cyprinus carpio	common carp	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Hybognathus regius	eastern silvery minnow	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Notemigonius crysoleucas	golden shiner	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Notropus buccatus	silverjaw minnow	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Notropis hudsonius	spottail shiner	0	2	0	0	3	3	1	29	4	4	1	3	36	0
Catostomidae	*Carpiodes cyprinus*	quillback	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Catostomus commersoni	white sucker	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	0	0	0	0	3	24	22	4	0	1	1	4	6	1
	Ameiurus catus	white catfish	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	Ictalurus furcatus	blue catfish	2	0	0	0	6	0	1	5	3	65	4	1	8	3
	Ictalurus punctatus	channel catfish	31	3	1	0	35	22	37	8	3	5	10	1	42	24
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	0	0	0	0	2	0	8	0	0	0	0	0	12	0
	Fundulus heteroclitus	mummichog	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Atherinidae	*Menidia beryllina*	inland silverside	0	0	0	0	0	0	0	0	6	0	0	0	0	0
Gobiidae	*Gobiosoma bosc*	naked gobi	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Percichthyidae	*Morone americana*	white perch	2	158	2	0	17	105	175	29	41	58	1	49	50	1
	Morone saxatilis	striped bass	0	0	0	0	1	0	0	2	0	0	0	0	0	1
Centrarchidae	*Ennacanthus gloriosus*	bluespotted sunfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lepomis auritus	redbreast sunfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lepomis gibbosus	pumpkinseed	0	1	0	0	4	1	2	5	0	0	1	0	0	0
	Lepomis macrochirus	bluegill	0	0	0	0	2	0	0	0	1	6	0	0	17	0
	Micropterus salmoides l	argemouth bass	0	0	0	0	0	0	0	0	0	0	0	0	2	0
	Pomoxis annularis	white crappie	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Percidae	*Etheostoma olmstedi*	tessellated darter	3	4	0	0	7	8	18	9	0	0	4	1	2	3
	Perca flavescens	yellow perch	0	0	0	0	1	0	1	2	0	0	0	0	1	0
Sciaenidae	*Leiostomus xanthurus*	spot	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Micropogonius undulatus	Atlantic croaker	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Soleidae	*Trinectes maculatus*	hogchoker	5	0	0	0	49	0	1	0	0	1	36	0	2	0
TOTAL			44	169	3	0	130	176	576	105	185	259	300	121	183	33

The abundance of each species in the trawls at each station is shown in Table 6. About the same quantity of fishes were caught at Station 7 (37.5%) and Station 9 (38,4%). White perch were most abundant at Station 9 and somewhat less abundant at Station 7. Blueback herring and bay anchovy were abundant at Station 7 and channel cat, blue cat, and hogchoker were abundant at Station 9. The catch at Station 10 was lower (24.0%), and was dominated by blueback herring and alewife. The growth of beds of submersed aquatic vegetation at Station 10 was noted as early as May 15, and may represent a major change in conditions in Pohick Bay. The number of species caught at each station was about the same: Station 7—16 sp., Station 9—15 sp., Station 10—17 sp..

Table 6

Adult and Juvenile Fish Collected by Trawling

Gunston Cove Study - 2003

			Station	7	9	10
Anguillidae	*Anguilla rostrata*	American eel		3	2	0
Clupeidae	*Alosa aestivalis*	blueback herring		274	2	252
	Alosa mediocris	hickory shad		43	1	3
	Alosa pseudoharengus	alewife		23	1	74
	Dorosoma cepedianum	gizzard shad		0	0	0
Engraulidae	*Anchoa mitchilli*	bay anchovy		190	0	17
Cyprinidae	*Carassius auratus*	goldfish		0	2	0
	Cyprinus carpio	common carp		0	1	0
	Hybognathus regius	eastern silvery minnow	0	0	0	
	Notemigonius crysoleucas	golden shiner		0	0	0
	Notropus buccatus	silverjaw minnow		0	0	1
	Notropis hudsonius	spottail shiner		33	9	44
Catostomidae	*Carpiodes cyprinus*	quillback		0	0	0
	Catostomus commersoni	white sucker		0	0	0
Ictaluridae	*Ameiurus nebulosus*	brown bullhead		12	29	25
	Ameiurus catus	white catfish		0	0	1
	Ictalurus furcatus	blue catfish		0	98	0
	Ictalurus punctatus	channel catfish		24	198	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish		0	0	22
	Fundulus heteroclitus	mummichog		0	0	1
Atherinidae	*Menidia beryllina*	inland silverside		6	0	0
Gobiidae	*Gobiosoma bosc*	naked goby		0	0	0
Percichthyidae	*Morone americana*	white perch		225	419	44
	Morone saxatilis	striped bass		2	2	0
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish		0	0	0
	Lepomis auritus	redbreast sunfish		0	0	0
	Lepomis gibbosus	pumpkinseed		6	1	7
	Lepomis macrochirus	bluegill		4	0	22
	Micropterus salmoides	largemouth bass		0	0	2
	Pomoxis annularis	white crappie		0	0	1
Percidae	*Etheostoma olmstedi*	tessellated darter		10	17	32
	Perca flavescens	yellow perch		2	0	3
Sciaenidae	*Leiostomus xanthurus*	spot		0	0	0
	Micropogonias undulatus	Atlantic croaker		0	0	0
Soleidae	*Trinectes maculatus*	hogchoker	1	93	0	
TOTAL				853	874	547

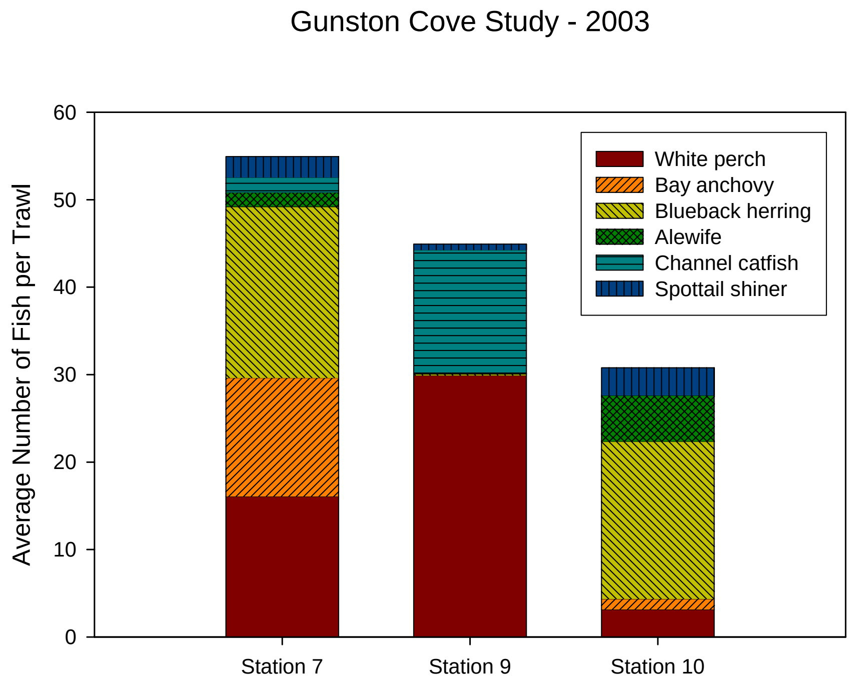


Figure 59. Adult and Juvenile Fishes Collected by Trawling. Dominant Species by Station.

Station 7, located in Gunston Cove, recorded the largest average number of fish per trawl with three species (white perch, bay anchovy, and blueback herring) making up most of the catch and being about evenly represented. Station 9, located in the Potomac mainstem, had a preponderance of white perch, with a substantial contribution from channel catfish. Other species were rare. Station 10, located in Pohick Bay, was dominated by the two members of the herring family, blueback herring and alewife. White perch and spottail shiner made significant contributions.

White perch (*Morone americana*), the most common fish in the open waters of Gunston Cove, continues to be an important commercial and popular game fish. Adults grow to over 30 cm long. Sexual maturity begins the second year at lengths greater than 9 cm. As juveniles they feed on zooplankton and macrobenthos, but as they get larger consume fish as well.

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

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

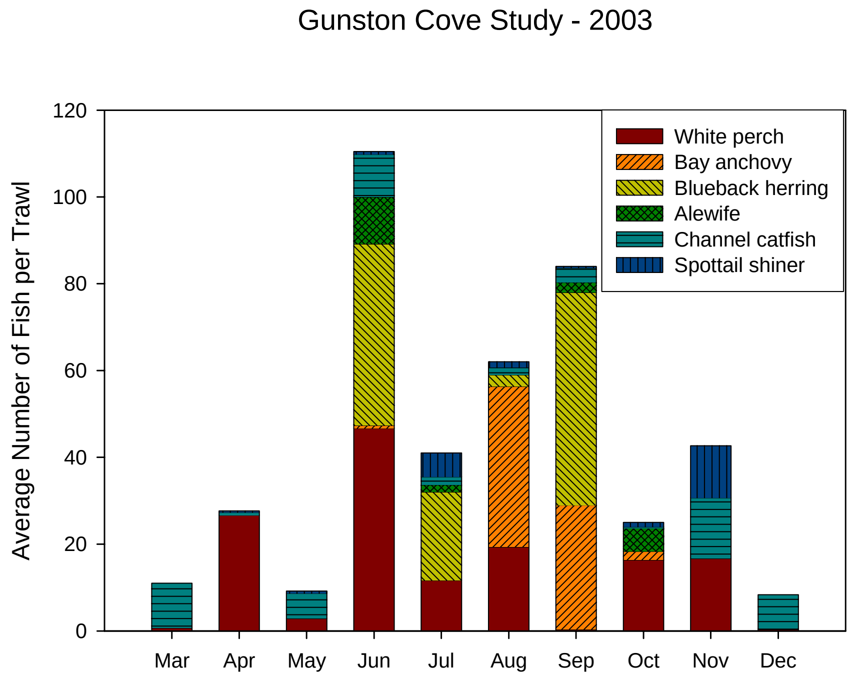


Figure 60. Adult and Juvenile Fishes Collected by Trawling. Dominant Species by Month.

White perch were observed at appreciable levels in most months from April through November. In the spring, most are returning adults, whereas in summer and fall young-of-the-year dominate trawl catches. Bay anchovy were mainly found in the late summer-early fall as they work their way up from further down in the estuary. Blueback herring and alewife juveniles were found in the warmer months. Channel cat and spottail shiner were collected sporadically throughout the year.

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

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

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

Seines

Seine collections of fishes were begun on March 27 and continued through December 10. Seines were made at three sites, Station 4 near the mouth of Pohick Creek, Station 6 near the mouth of Accotink Creek, and Station 11 about halfway between trawl Station 7 and trawl Station 9, on the south shore of Gunston Cove (Figure 1). Fourteen seines were done at each station, for a total of 42 seines. The species of fishes that were caught and the total numbers of each are shown in Table 7. A total of 27 species and 4,111 individuals were collected. The most numerous species caught was banded killifish, which represented 44.1% of the total . Other abundant species were bay anchovy (12.4% of the total catch), white perch (6.9%), spottail shiner (6.8%), mummichog (4.5%), bluegill (4.0%), inland silverside (3.2%), pumpkinseed (3.2%), alewife (3.1%), tessellated darter (2.9%), hickory shad (2.6%), blueback herring (2.4%), and yellow perch (1.0%).

The numbers of individuals of each species caught on each collection date are presented in Tables 8A and 8B. The abundance of banded killifish rose dramatically on April 29 and remained high through October 9. Bay anchovy appeared in large numbers on June 12 and in more moderate numbers on both September 22 and October 9. Young-of-the-year white perch were sparse in the early summer seines, but increased during the late summer and fall.. Two white perch YOY were taken on June 26, eight on July 24, 30 on August 21, 130 on October 9, and 37 on November 24. Three striped bass YOY were caught on June 26. Identifiable YOY alewife, hickory shad, began showing up on June 12 and persisted in catches through October 9. Spottail shiners were collected on all but one date, and yellow perches were collected from June 12 through August 21.

The numbers of individuals of each species caught at each station are shown in Table 9. The largest catch (40.5%) was at Station 6, Station 11 was next with 37.0%, and Station 4 had 22.5%. Submersed aquatic vegetation growing at Station 4 interfered with the seining process on October 9. The number of species collected at Station 4 was 22, at Station 6 was 19, and at Station 11 was 18. Less abundant species like goldfish, common carp, golden shiner, mummichog, bluespotted sunfish, pumpkinseed, bluegill, largemouth bass, and tessellated darter were more common at the inner Cove Stations 4 and 6. Abundant species such as bay anchovy, banded killifish, inland silverside, and white perch were collected in larger numbers at Stations 6 and 11. Blueback herring, hickory shad, alewife, spottail shiner, and striped bass were most numerous at Stations 4 and 11.

The mean catch per seine at each station for six abundant species is graphed in Fig. 61. The average catch per seine for each month is presented in Fig. 62.

Table 7

Adult and Juvenile Fish Collected by Seining
Gunston Cove Study - 2003

Lepisosteidae	*Lepisosteus osseus*	longnose gar	0
Anguillidae	*Anguilla rostrata*	American eel	0
Clupeidae	*Alosa aestivalis*	blueback herring	100
	Alosa mediocris	hickory shad	107
	Alosa pseudoharengus	alewife	126
	Dorosoma cepedianum	gizzard shad	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	512
Cyprinidae	*Carassius auratus*	goldfish	18
	Cyprinus carpio	common carp	3
	Hybognathus regius	eastern silvery minnow	1
	Notemigonus crysoleucas	golden shiner	13
	Notropis amoenus	comely shiner	0
	Notropis analostanus	satinfin shiner	0
	Notropis hudsonius	spottail shiner	281
	Notropis procne	swallowtail shiner	1
Catostomidae	*Carpiodes cyprinus*	quillback	0
	Erimyzon oblongus	creek chubsucker	1
Ictaluridae	*Ameiurus catus*	white catfish	0
	Ameiurus nebulosus	brown bullhead	1
	Ictalurus furcatus	blue catfish	0
	Ictalurus punctatus	channel catfish	2
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	1818
	Fundulus heteroclitus	mummichog	184
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	1
Atherinidae	*Menidia beryllina*	inland silverside	133
Percichthyidae	*Morone americana*	white perch	285
	Morone saxatilis	striped bass	12
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	6
	Lepomis cyanellus	green sunfish	10
	Lepomis gibbosus	pumpkinseed	130
	Lepomis macrochirus	bluegill	164
	Micropterus dolomieu	smallmouth bass	0
	Micropterus salmoides	largemouth bass	35
Percidae	*Etheostoma olmstedi*	tessellated darter	118
	Perca flavescens	yellow perch	43
Sciaenidae	*Micropogonius undulatus*	Atlantic croaker	6
TOTAL		4111	

Table 8

Adult and Juvenile Fish Collected by Seining
Gunston Cove Study - 2003

			27-Mar	10-Apr	29-Apr	15-May	29-May	12-Jun	26-Jun	7-Jul	24-Jul	21-Aug	22-Sep	9-Oct	24-Nov	10-Dec
Lepisosteidae	*Lepisosteus osseus*	longnose gar	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anguillidae	*Anguilla rostrata*	American eel	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clupeidae	*Alosa aestivalis*	blueback herring	0	0	0	0	0	0	5	0	1	0	94	0	0	0
	Alosa mediocris	hickory shad	0	0	0	0	0	50	0	0	0	0	0	57	0	0
	Alosa pseudoharengus	alewife	0	1	0	0	0	43	28	2	1	13	36	2	0	0
	Dorosoma cepedianum	gizzard shad	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	0	0	0	0	0	382	0	0	0	0	66	64	0	0
Cyprinidae	*Carassius auratus*	goldfish	0	0	0	0	0	0	0	0	0	0	5	0	2	11
	Cyprinus carpio	common carp	2	0	0	0	0	1	0	0	0	0	0	0	0	0
	Hybognathus regius	eastern silvery minnow	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Notemigonus crysoleucas	golden shiner	0	0	0	0	0	0	0	0	0	11	2	0	0	0
	Notropis amoenus	comely shiner	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Notropis analostanus	satinfin shiner	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Notropis hudsonius	spottail shiner	57	0	65	38	3	23	1	12	4	26	20	26	4	2
	Notropis procne	swallowtail shiner	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Catostomidae	*Carpiodes cyprinus*	quillback	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Erimyzon oblongus	creek chubsucker	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Ictaluridae	*Ameiurus catus*	white catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ameiurus nebulosus	brown bullhead	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Ictaturus furcatus	blue catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ictaturus punctatus	channel catfish	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	64	1	310	232	272	57	67	280	50	185	43	224	10	23
	Fundulus heteroclitus	mummichog	10	1	45	18	47	5	9	34	10	5	0	0	0	0
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Atherinidae	*Menidia beryllina*	inland silverside	0	0	1	15	6	3	4	4	13	3	7	77	0	0
Percichthyidae	*Morone americana*	white perch	3	4	19	11	3	1	9	5	9	31	12	134	44	0
	Morone saxatilis	striped bass	0	0	0	0	2	0	7	3	0	0	0	0	0	0
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	0	0	0	0	0	0	0	2	0	0	0	0	0	4
	Lepomis cyanellus	green sunfish	0	0	0	0	0	0	0	0	1	4	0	0	5	0
	Lepomis gibbosus	pumpkinseed	20	0	2	3	4	2	5	18	3	3	5	36	20	9
	Lepomis macrochirus	bluegill	5	0	0	1	0	2	0	4	4	42	11	34	35	26
	Micropterus dolomieu	smallmouth bass	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Micropterus salmoides	largemouth bass	0	0	1	0	2	2	0	1	16	4	1	8	0	0
Percidae	*Etheostoma olmstedi*	tessellated darter	6	0	5	14	6	1	8	31	24	6	0	15	1	1
	Perca flavescens	yellow perch	0	0	0	0	0	8	7	14	11	3	0	0	0	0
Sciaenidae	*Micropogonius undulatus*	Atlantic croaker	0	0	0	0	0	0	0	6	0	0	0	0	0	0
TOTAL			167	7	449	332	345	580	150	416	147	336	303	677	123	79

Table 9

Adult and Juvenile Fish Collected by Seining
Gunston Cove Study - 2003

			Station		
			4	6	11
Lepisosteidae	*Lepisosteus osseus*	longnose gar	0	0	0
Anguillidae	*Anguilla rostrata*	American eel	0	0	0
Clupeidae	*Alosa aestivalis*	blueback herring	56	10	34
	Alosa mediocris	hickory shad	50	0	57
	Alosa pseudoharengus	alewife	42	5	79
	Dorosoma cepedianum	gizzard shad	0	0	0
Engraulidae	*Anchoa mitchilli*	bay anchovy	16	250	246
Cyprinidae	*Carassius auratus*	goldfish	5	13	0
	Cyprinus carpio	common carp	2	1	0
	Hybognathus regius	eastern silvery minnow	0	0	1
	Notemigonus crysoleucas	golden shiner	11	2	0
	Notropis amoenus	comely shiner	0	0	0
	Notropis analostanus	satinfin shiner	0	0	0
	Notropis hudsonius	spottail shiner	102	56	123
	Notropis procne	swallowtail shiner	1	0	0
Catostomidae	*Carpiodes cyprinus*	quillback	0	0	0
	Erimyzon oblongus	creek chubsucker	0	1	0
Ictaluridae	*Ameiurus catus*	white catfish	0	0	0
	Ameiurus nebulosus	brown bullhead	1	0	0
	Ictalurus furcatus	blue catfish	0	0	0
	Ictalurus puctatus	channel catfish	0	2	0
Cyprinodontidae	*Fundulus diaphanus*	banded killifish	274	877	667
	Fundulus heteroclitus	mummichog	65	111	8
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish	0	0	1
Atherinidae	*Menidia beryllina*	inland silverside	8	58	67
Percichthyidae	*Morone americana*	white perch	35	51	199
	Morone saxatilis	striped bass	6	0	6
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish	2	4	0
	Lepomis cyanellus	green sunfish	10	0	0
	Lepomis gibbosus	pumpkinseed	62	58	10
	Lepomis macrochirus	bluegill	95	67	2
	Micropterus dolomieu	smallmouth bass	0	0	0
	Micropterus salmoides	largemouth bass	21	13	1
Percidae	*Etheostoma olmstedi*	tessellated darter	53	52	13
	Perca flavescens	yellow perch	4	36	3
Sciaenidae	*Micropogonius undulatus*	Atlantic croaker	0	0	6
TOTAL			921	1667	1523

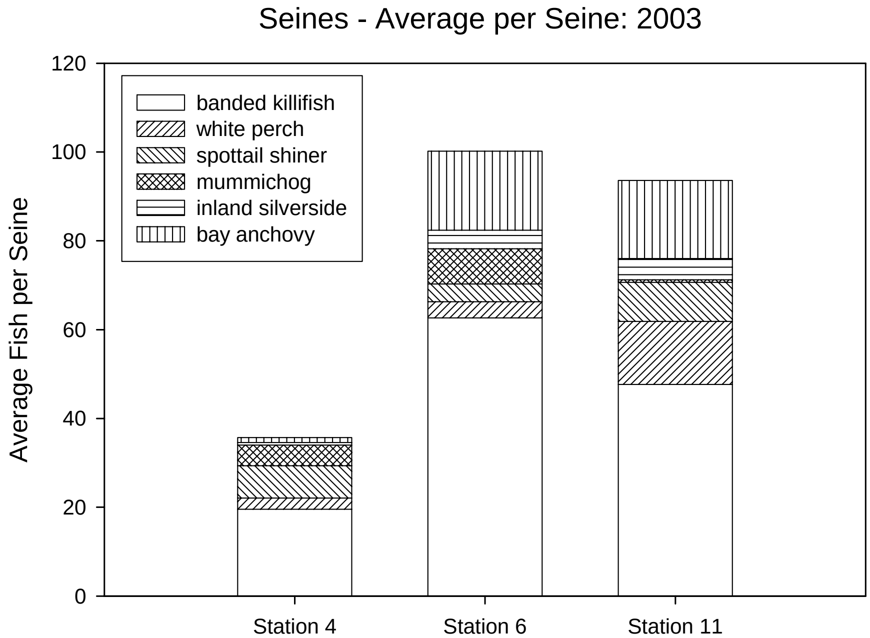


Figure 61. Adult and Juvenile Fish Collected by Seining. Dominant Species by Station.

Seine collections were generally substantially higher at Stations 6 and 11 than at Station 4 in Pohick Bay. Banded killifish were clearly the most abundant species with more than 50% representation on average at all stations (Figure 61). Bay anchovy were second in abundance at both stations 6 and 11, but were rarely found at Station 4. White perch was abundant in seines at Station 11, but less common at stations 4 and 6. Spottail shiner was most commonly found at Stations 4 and 11. Mummichog were found at Stations 4 and 6, but not at Station 11.

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

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

Seining is conducted in shallow water adjacent to the shoreline. Some fish minimize predation by congregating along the shoreline rather than disperse through the open water. While seines and trawls tend to collect about the same number of individuals per effort, seines sample a smaller volume of water emphasizing the higher densities of fish along the shoreline...

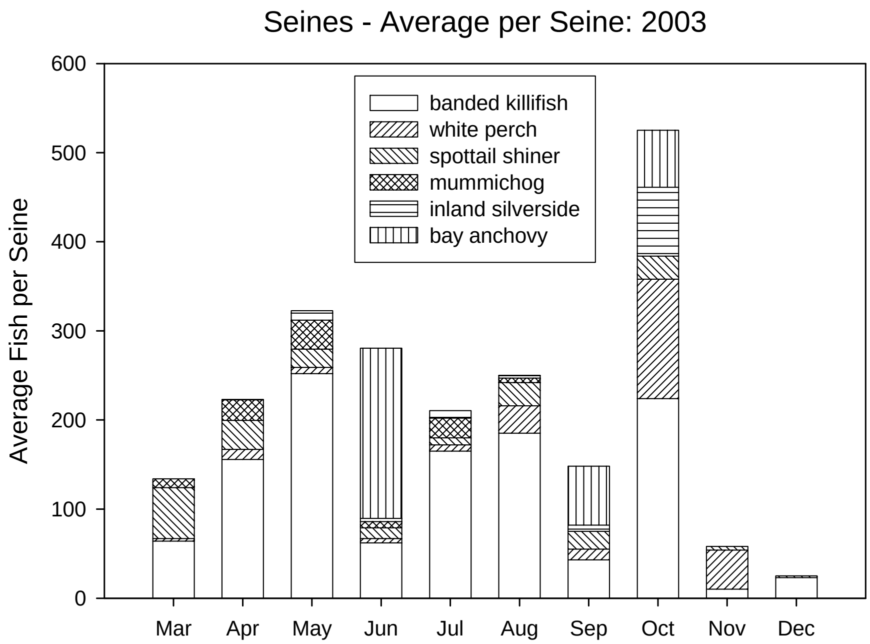


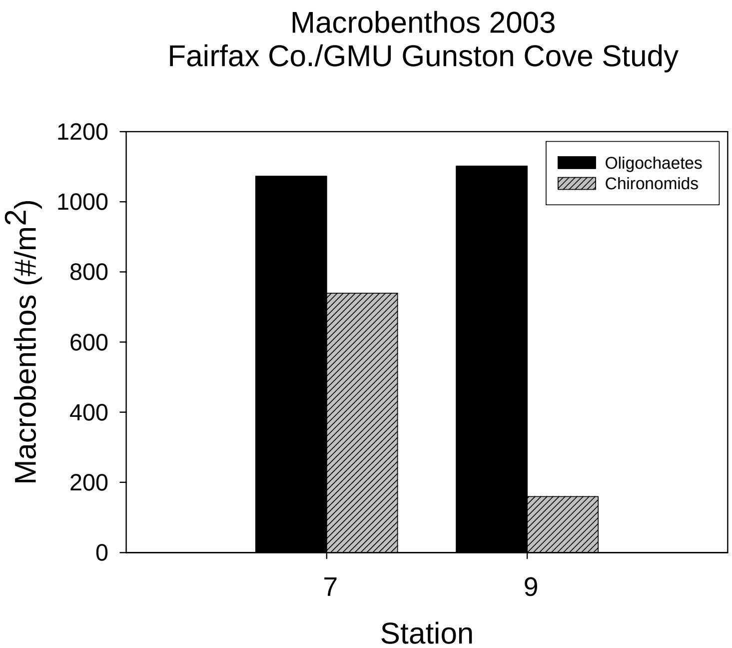
Figure 62. Adult and Juvenile Fish Collected by Seining. Dominant Species by Month.

Banded killifish were found in every month and often constituted over half of the average catch. White perch were mainly observed in the summer and fall as young of the year became large enough to be captured in the seine. Spottail shiner were observed throughout the year. Mummichog were principally observed in April, May, and July. Inland silverside was almost exclusively found in October, while bay anchovy was common in June, September, and October.

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

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

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

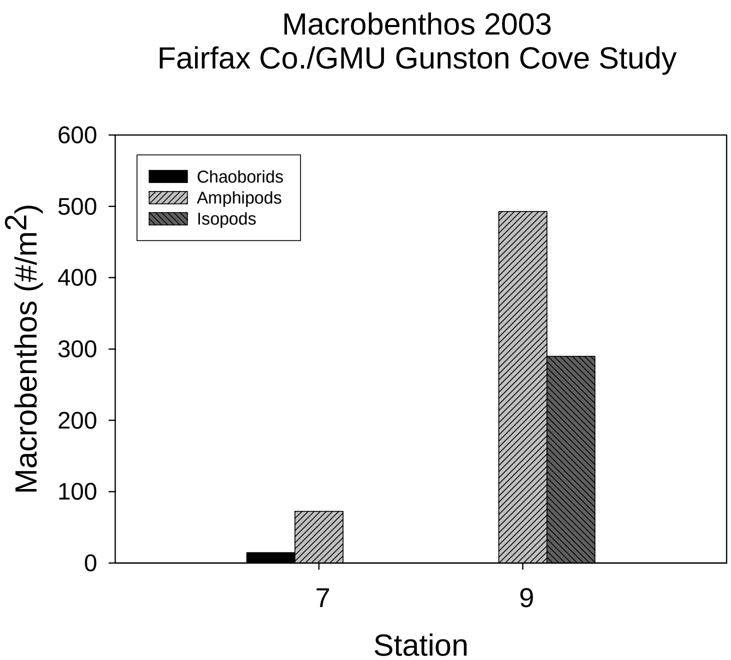


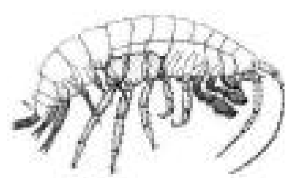

Oligochaete


Chironomid

Figure 63. Macrobenthos. Oligochaetes and Chronomids.

Oligochaetes were the most numerous macroinvertebrates in both river and cove (Figure 63) and exhibited very similar densities at each site. The second largest group, midge larvae of the family Chironomidae, were nearly as abundant in the cove, but substantially lower in the river. Among the other arthropods, amphipods (scuds) were found in both the cove and the river (Figure 64). As is typical scuds were much more abundant in the river than in the cove. Isopods (aquatic sowbugs) were also quite common in the river. chaoborids (phantom midges) were rare in the cove and not found in the river.




Amphipod
(*Gammarus*)

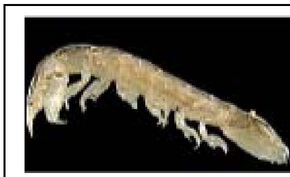

Isopod
(*Cyathura*)

Figure 64. Macrobenthos. Other Arthropods.

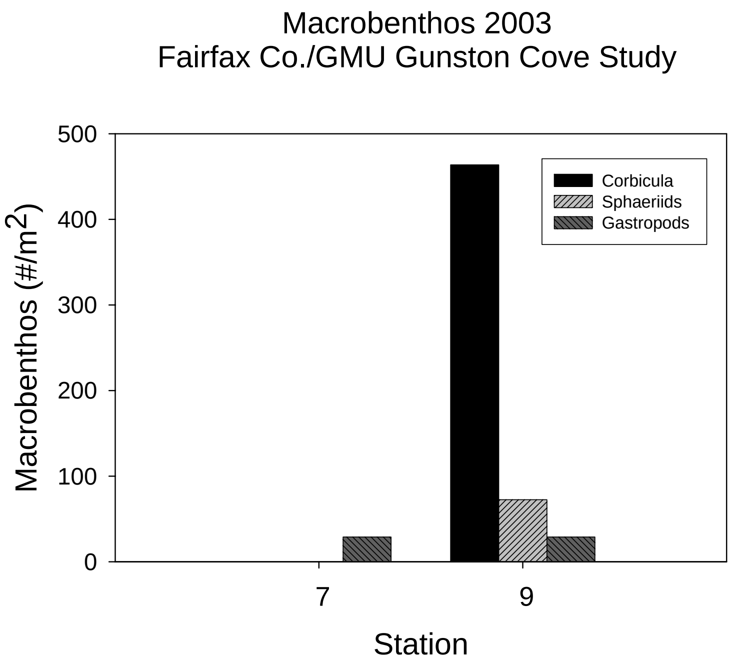


Figure 65. Macrobenthos. Mollucs.

Corbicula

Gastropod
(Cipangopaludina)

Among the molluscs *Corbicula* (Asiatic clam) was most abundant reaching nearly 500/m^2 in the river. Spheriid mussels were found at moderate abundances, while gastropods (snails) were present in low numbers in both river and cove.

DISCUSSION

A. 2003 Data

The year 2003 was characterized by below normal temperatures and abnormally high precipitation. Temperatures greatly below normal characterized the period from April through July. Precipitation was well above normal for May through December. This combination resulted in stream and river flows that were well above normal throughout the year. 2003 was the wettest year since the study began in 1984. The annual precipitation of 59.3 inches observed at National Airport was much greater than the previous highs of 51.0 inches observed in 1996 and 50.3 inches in 1989. Sampling dates in mid June, mid July, mid September, and mid November were immediately preceded by over 1 inch of rainfall which may have affected water quality in the cove. The mid September sampling was immediately preceded by Hurricane Isabel which also brought strong winds and storm surges to the area.

Specific conductance was similar at both sites with no evidence of brackish water intrusion as was observed in the low flow year 2002. The high flows in mid June, mid September, and mid November were reflected in declines in conductance as ions in the cove were diluted by stream flow. Chloride was higher in the cove than in the river, another indication that brackish water was not moving from downstream and declines in chloride were similar to those in conductance.

Dissolved oxygen was near saturation in the river, but exhibited significant supersaturation in the cove in late April, late June, and late August, probably corresponding to peaks in phytoplankton activity. Field pH displayed a similar temporal patter in the cove and was generally less variable in the river. Total alkalinity was generally higher in the river than in the cove and showed similar seasonal patterns in each area. Secchi depth was similar in the cove and in the river with most readings between 50 and 80 cm. Major declines were observed after major discharge events in September and November. Storm surge and strong winds from Hurricane Isabel also contributed to the decline in Secchi depth in September. Light attenuation coefficient and turbidity showed similar seasonal patterns.

Ammonia nitrogen was generally higher in the river (generally above 0.05 mg/L) than in the cove (generally below 0.05 mg/L). In the river summer values were typically higher than in spring or fall while in the cove there was little systematic difference. Un-ionized ammonia nitrogen increased rather markedly during the summer especially in the cove, but concentrations remained at least an order of magnitude below toxic thresholds. Nitrate nitrogen underwent similar patterns in cove and river with river concentrations running somewhat higher. A clear drawdown in nitrate was observed in the cove during the growing season, probably due to phytoplankton uptake. Nitrite was generally present at low levels with increases in late summer corresponding with somewhat elevated ammonia concentrations. Organic nitrogen was generally higher in the cove and showed a marked seasonal buildup related to algal uptake and incorporation.

Total phosphorus levels were fairly low in 2003 with most samples in cove and river below 0.1 mg/L. There was evidence for a gradual seasonal increase in the cove reflecting algal uptake topped off by a major spike in late November associated with a high flow event. Soluble reactive phosphorus exhibited a seasonal decline in the cove which also may be tied to algal growth. Values in the river were generally higher, perhaps indicating that P was not limiting so much there. N:P ratio was generally higher in the cove with some values approaching N limitation in late summer in the river. BOD was generally higher in the cove than the river with a seasonal increase due to algal growth and an November spike in the cove related to flow. TSS was generally between 10 and 30 mg/L in both cove and river with a spike from the November flow event. VSS was higher in the cove due to phytoplankton growth during the summer and the flow spike in November.

Chlorophyll exhibited a distinct seasonal pattern in both cove and river. In the cove values generally increased through early September reaching about 80 ug/L before dropping sharply with Hurricane Isabel. In the river the increase took longer to develop and started to decline before Isabel. Photosynthetic rate revealed a similar pattern. Phytoplankton density also showed a strong surge in late summer in cove and river. Phytoplankton biovolume surged earlier in both areas, but remained strong through early September.

Cyanobacteria dominated phytoplankton density due to their small cell size, but diatoms were clearly most important in terms of phytoplankton biovolume (and probably biomass). Diatom dominance of biovolume throughout the year in both cove and river was enhanced by the higher flows and cooler temperature found in 2003. Bloom forming *Microcystis* was detected, but only in small quantities in late July and early August. The dominant diatom in both cove and river was *Melosira*, a filamentous centric. Discoid centrics were also important in early spring and mid-summer.

Rotifers were the most abundant zooplankton and followed a typical seasonal pattern of much elevated summer abundances. In the cove elevated abundances began in late spring and extended through early fall, while in the river they were mainly restricted to the summer. *Brachionus* and *Keratella* were the most abundant with Conochilidae important in the river in the summer and *Filinia* in the cove. Cladocerans were present at substantial numbers, but only during restricted periods. They were generally much more abundant in the cove than the river except for *Leptodora*. This may have been due to the higher flow conditions in 2003. Copepod nauplii were more abundant in the river than in the cove with a peak in mid summer. The calanoid copepod *Eurytemora* exhibited a strong spring peak in abundance in both river and cove. *Diaptomus* and other calanoids were most common in the early summer and were more common in the cove.

Clupeids (herring and shad) were the dominant ichthyoplankton as in previous years, making up almost 90% of the total fish larvae collected. *Morone* spp. (white perch and striped bass) and *Perca flavescens* (yellow perch) made up almost all of the rest. Peak density of clupeids and *Morone* sp. occurred in late May, while yellow perch peaked in early April.

White perch was the most common fish collected in trawls comprising 30% of the total. Blueback herring (23.2%), channel cat (9.8%), and bay anchovy (9.1%) rounded out the group of most common species. In an unusual reversal, blueback herring were actually more common than white perch at both cove trawl sites. Most of the blueback herring were collected on three sample dates while the white perch were more evenly distributed through the year.

Banded killifish was the most common species collected at seine sites comprising 44% of the total catch. Other common species were bay anchovy (12.4%), white perch (6.9%), and spottail shiner (6.8%). Banded killifish were the most abundant species at all seining sites and on most sampling dates.

State and federal scientists have collected adult snakeheads this spring in Gunston Cove at our Station 6 seine site using electrofishing boats and much longer seines. The smallest was about 5-8 inches longs, but they also caught a large female that seemed ready to spawn. They asked us to notify them if we get any juveniles or adults. We feel confident that we can identify them.

Oligochaetes were the most abundant macrobenthic organisms in 2003 with similar densities observed in both river and cove. Chronomids were a close second in the cove while amphipods (scuds) and the Asiatic clam *Corbicula* were subdominant in the river. Isopods, spherid clams, and gastropods were also present in the river. Small populations of gastropods and chaoborids (phantom midges) were found in the cove.

B. Water Quality Trends: 1983-2003

To assess long-term trends in water quality, data form 1983 to 2002 were pooled into a single data file. The, subgroups were selected based on season and station. For water quality parameters, we focused on summer (June-September) data as this is the most stable period 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. The allows the detection of nonlinear patterns such as cycles and lags which are not easily detected by linear approaches such as linear regression. We also calculated the Pearson correlation coefficient and performed linear regression 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 the 2000 and 2001 reports.

Table 10
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1984-2003
GMU Water Quality Data
June-September

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Temperature	-0.020	----	NS	-0.102	----	NS
Conductivity, standardized to 25EC	0.221	5.54	0.002	0.046	----	NS
Dissolved oxygen, mg/L	-0.027	----	NS	0.272	0.066	0.001
Dissolved oxygen, percent saturation	0.008	----	NS	0.240	0.732	0.002
Secchi disk depth	0.367	0.870	<0.001	0.041	----	NS
Light extinction coefficient	0.226	0.055	0.008	-0.301	-0.072	0.002
pH, Field	-0.051	----	NS	0.143	----	NS
pH, Lab	-0.129	----	NS	0.109	----	NS
Alkalinity	0.054	----	NS	0.167	0.384	0.043
Chlorophyll, depth-integrated	-0.297	-3.36	<0.001	0.030	----	NS
Chlorophyll, surface	-0.317	-3.89	<0.001	-0.009	----	NS
Photosynthetic rate (light-saturation)	-0.230	-33.6	0.002	0.146	----	NS
P^B_{max}	0.051	----	NS	0.155	----	NS

For Station 7, n=181-209 except pH, Field where n=144 and Light extinction coefficient where n=135.
For Station 9, n=144-162 except pH, Field where n=111 and Light extinction coefficient where n=102.

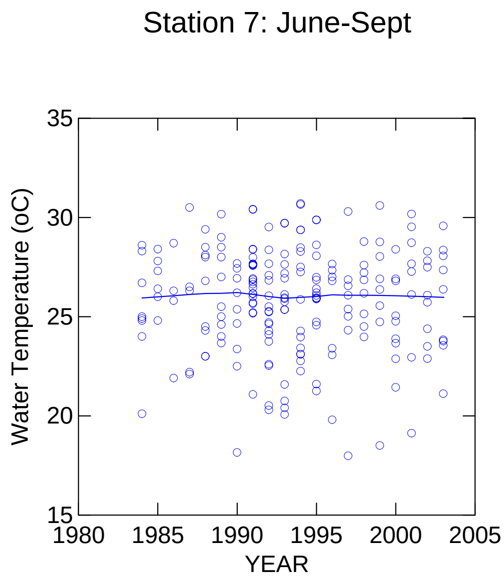
Significance column indicates the probability that a correlation coefficient this large could be due to chance alone. If this probability is greater than 0.05, then NS (not significant) is indicated.

Table 11
Correlation and Linear Regression Coefficients
Water Quality Parameter vs. Year for 1983-2003
Noman Cole Laboratory Data
June-September

Parameter	Station 7 Corr. Coeff.	Station 7 Reg. Coeff.	Station 7 Signif.	Station 9 Corr. Coeff.	Station 9 Reg. Coeff.	Station 9 Signif.
Chloride	0.159	1.024	0.009	0.145	1.027	0.017
Lab pH, NC	-0.116	-0.013	0.052	-0.144	-0.013	0.014
Alkalinity, NC	-0.138	-0.292	0.024	-0.029	----	NS
BOD	-0.319	-0.131	<0.001	-0.111	----	NS
Total Suspended Solids	-0.174	-0.578	0.006	0.093	----	NS
Volatile Suspended Solids	-0.344	-0.569	<0.001	-0.144	-0.094	0.027
Total Phosphorus	-0.356	-0.0038	<0.001	-0.067	----	NS
Soluble Reactive Phosphorus	0.048	----	NS	0.125	0.0003	0.041
Ammonia Nitrogen	-0.054	----	NS	-0.177	-0.003	0.003
Un-ionized Ammonia Nitrogen*	0.102	----	NS	-0.251	-0.001	<0.001
Nitrite Nitrogen	0.076	----	NS	-0.329	-0.002	<0.001
Nitrate Nitrogen	-0.393	-0.042	<0.001	-0.448	-0.039	<0.001
Organic Nitrogen	-0.274	-0.041	<0.001	-0.107	----	NS
N to P Ratio	-0.103	----	NS	-0.532	-1.084	<0.001

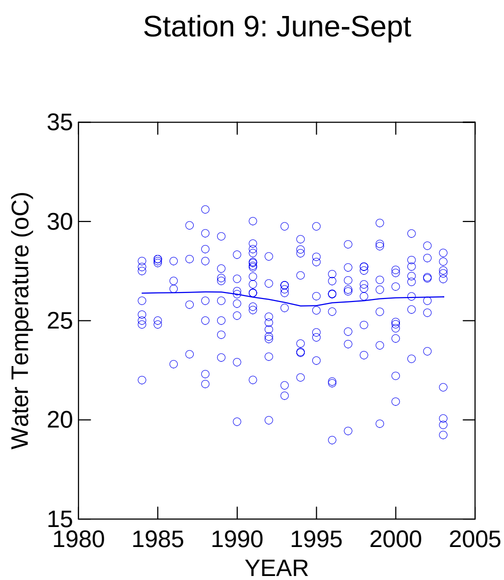
For Station 7, n=235-278 except Nitrite Nitrogen where n=208.
For Station 9, n=237-287 except Nitrite Nitrogen where n=208.

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



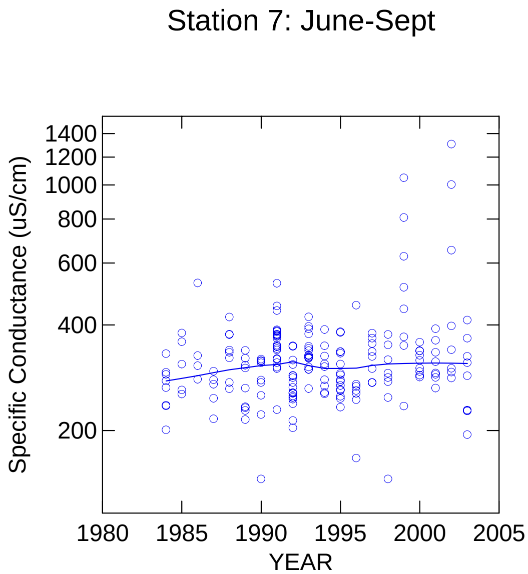
Water temperatures during the summer months generally varied between 20 and 30°C over the study period (Figure 66). The LOWESS curve indicated no systematic trend over this period in the cove. Linear regression analysis also indicated no trend in water temperature in the cove (Table 10).

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



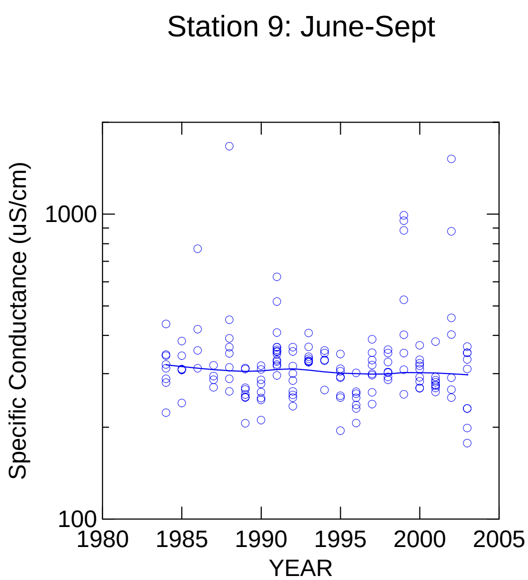
In the river summer temperatures have occupied a similar range to that in the cove (Figure 67). The trend line did show a little dip in the mid-1990's, but it was less than 0.5°C. Linear regression over the study period was also non significant (Table 10).

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



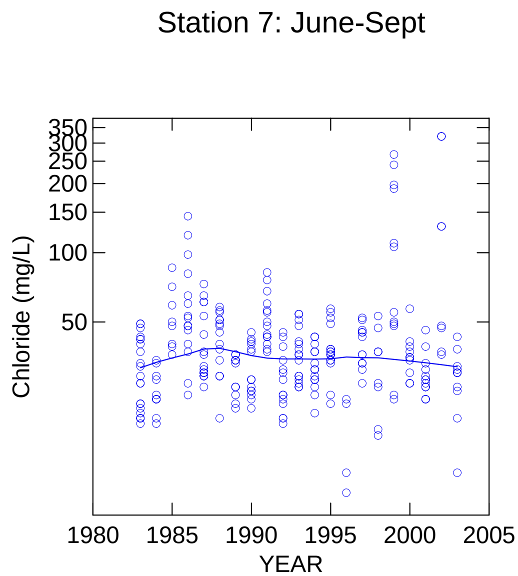
Specific conductance was generally in the range 200-400 uS/cm over the study period (Figure 68). Some significantly higher readings have been observed sporadically. A slight increase was suggested in specific conductance over the study period. This was confirmed by linear regression analysis which found a significant linear increase of 5.5 uS/cm per year over the longe term study period (Table 10).

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



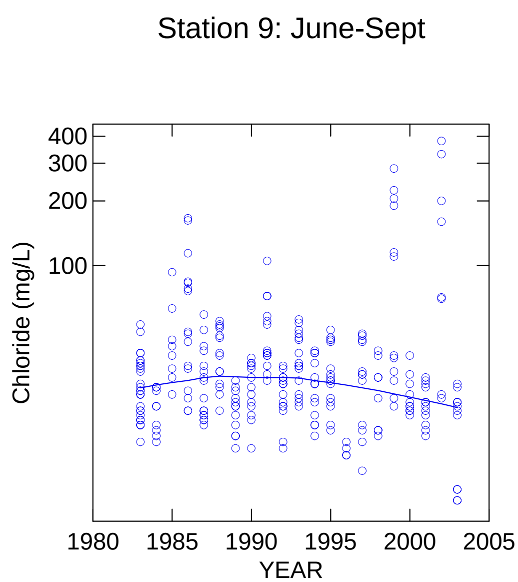
Long term trends in conductivity in the river were very similar to those in the cove (Figure 69). Most values were between 200 and 400 uS/cm with a few much higher values. These higher values are probably attributable to intrusions of brackish water from downstream during years of low river flow. Linear regression did not find a significant trend in river conductivity (Table 10).

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



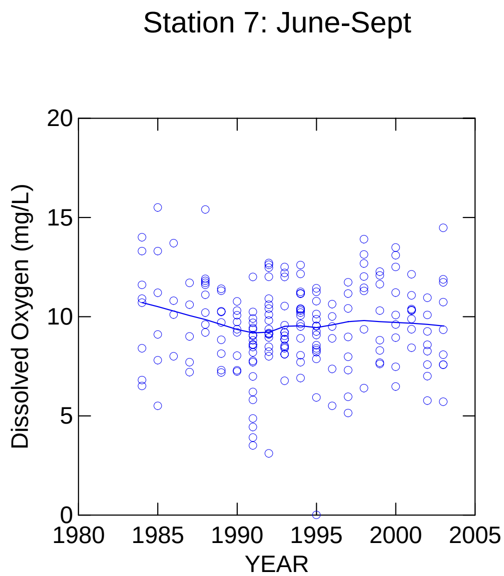
Chloride levels were clustered in a narrow range just under 50 mg/L for the entire study period (Figure 70). Higher values observed in some years were probably due to the estuarine water intrusions that occur in dry years. The trend line indicated a slight decline in recent years, but a linear regression demonstrated a significant linear increase in chloride over the study period at a rate of about 1 mg/L per year (Table 11).

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



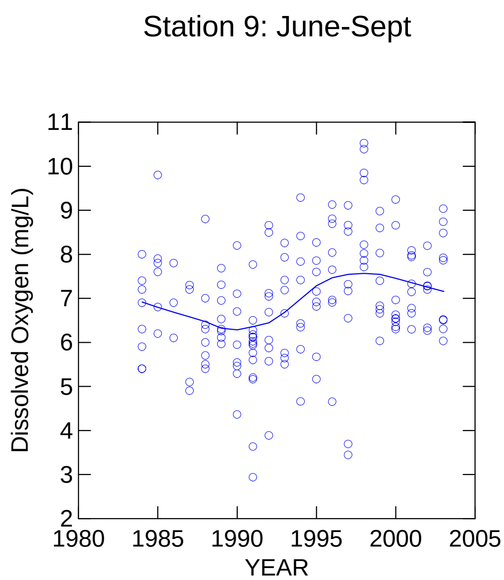
Chloride in the river has been slightly more variable than in the cove (Figure 71). The higher readings are again due to brackish water intrusions in dry years. A slight trend of increasing values in the 1980's and decreases in the late 1990's and 2000's was suggested by the trend line. Regression analysis revealed a significant linear increase of about 1 mg/L per year (Table 11).

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



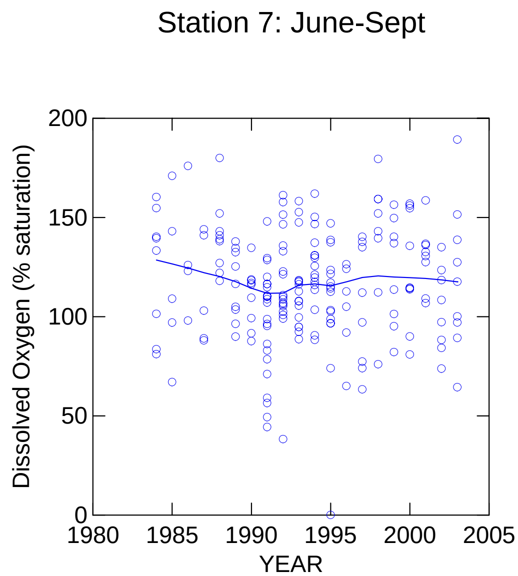
Dissolved oxygen in the cove has generally fallen in the range 7-12 mg/L during the summer months (Figure 72). A slight downward trend was observed through 1990, but since then the trend line has suggested no change at about 10 mg/L. In the cove dissolved oxygen (mg/L) did not exhibit a significant linear trend over the long term study period (Table 10).

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



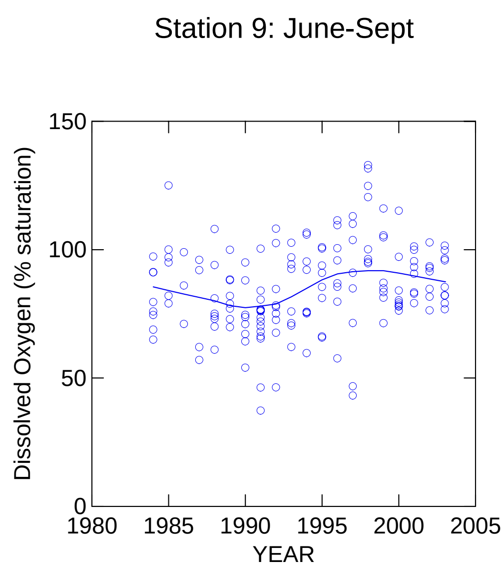
In the river dissolved oxygen values generally were in the range 6-8 mg/L over the long term study period (Figure 73). The LOWESS trend line suggested a decline in the 1980's, an increase in the early to mid 1990's and a slight decline in the 2000's. The linear regression analysis demonstrated a significant positive trend over the entire study period with slope of 0.066 mg/L per year (Table 10). This implies and increase of 1.32 mg/L over the 20 year study period.

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



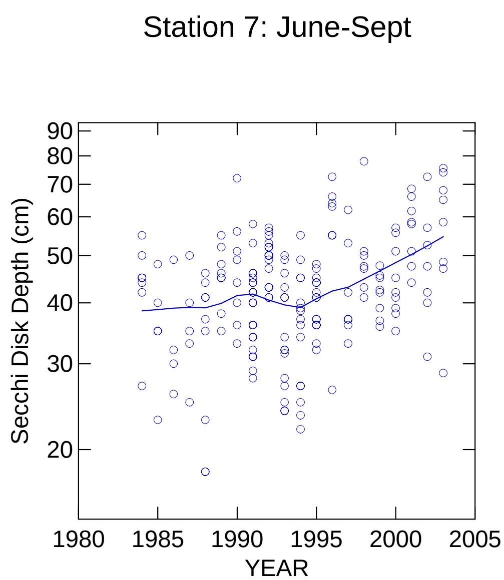
Dissolved oxygen was generally in the range 100-150% saturation in the cove over the long term study period indicating the importance of photosynthesis in the cove (Figure 74). A decline was indicated by the trend line through 1990 followed by a slight recovery in subsequent years. Percent saturation DO did not exhibit a significant linear trend over the long term study period (Table 10).

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



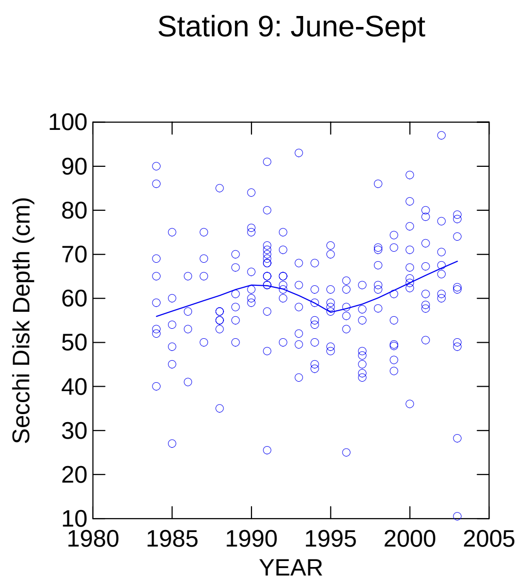
In the river dissolved oxygen was generally less than 100% indicating that photosynthesis was much less important in the river than in the cove (Figure 75). The temporal pattern a slight decline in the 1980's, an increase in the 1990's, and a subsequent slight decline in the 2000's. In the river a significant linear increase was indicated by regression analysis with a slope of 0.7% per year yielding a 14% increase over the 20 year study (Table 10).

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



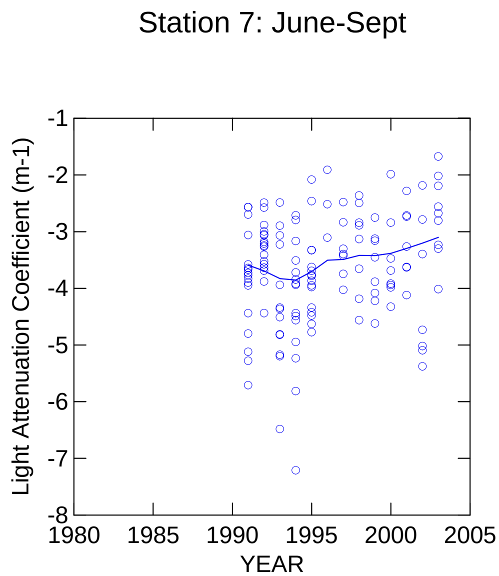
Secchi disk transparency is a measure of water clarity. Secchi disk was fairly constant from 1984 through 1995 with the trend line at about 40 cm (Figure 76). Since 1995 there has been a steady increase in the trend line from 40 cm to 55 cm in 2003. Linear regression was highly significant with a predicted increase of 0.87 cm per year or a total of 17.4 cm over the long term study period (Table 10). Summer secchi depths have started to more regularly approach and surpass 0.7 m in the cove which is should support SAV growth to 1.0 m according the Bay criteria (EPA 2003).

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



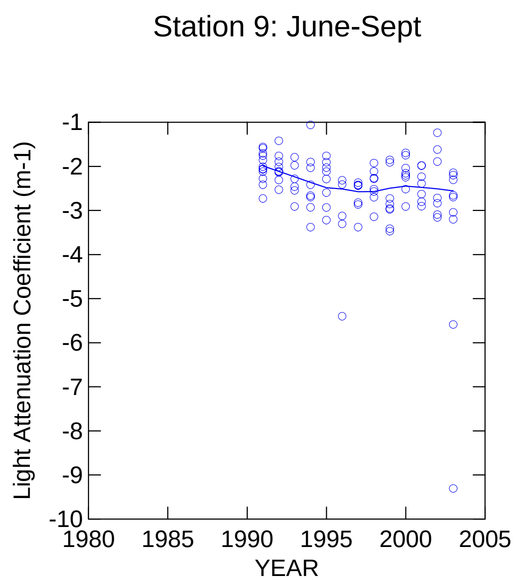
In the river Secchi depth was somewhat greater than in the cove (Figure 77). The trend line rose from 55 cm in 1984 to 62 cm in 1991. This was followed by a decline to about 58 cm in 1996 and then a steady increase to the 2000 level of nearly 70 cm. Secchi depth in the river did not demonstrate a significant linear regression (Table 10).

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



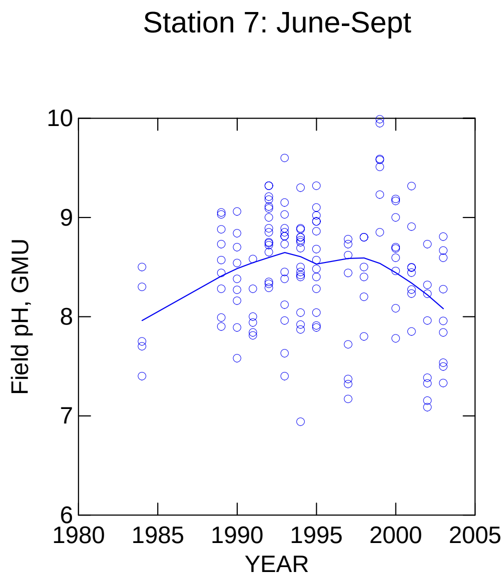
Light attenuation coefficient, another measure of water clarity, reinforced the conclusion that water clarity has been improving in the cove since 1995 (Figure 78). Trend line for the coefficient rose from about -4 to about -3 m^{-1} during that time. Consistent with this was the observation that regression analysis revealed a significant linear increase in light attenuation coefficient over the period 1991-2003 (Table 10).

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



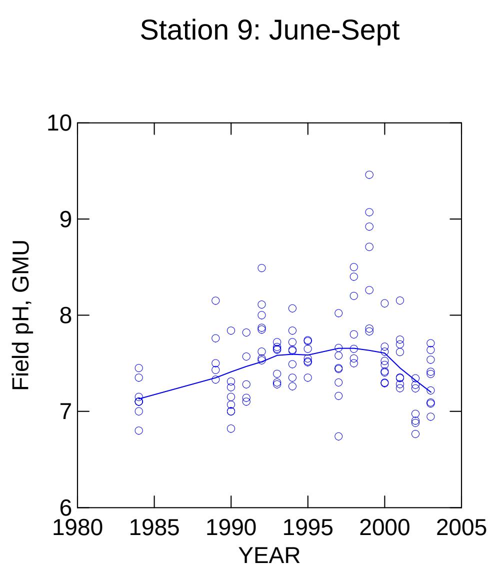
In the river light attenuation coefficient has suggested a decline in light transparency since 1990 (Figure 79) which was the opposite of the trend suggested by Secchi depths. This negative trend in light attenuation coefficient was reinforced by a significant linear regression coefficient (Table 10).

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



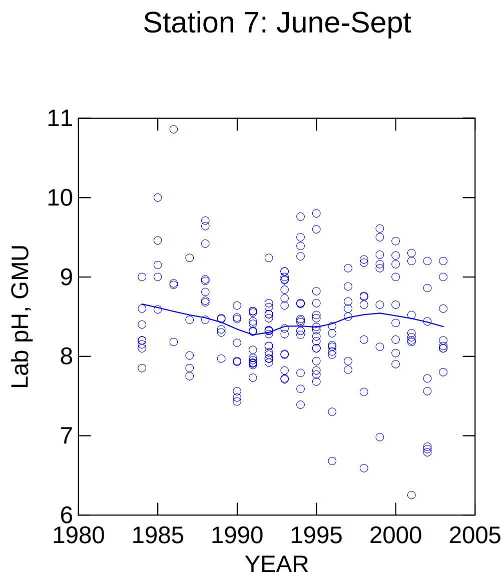
Field pH has not been measured as consistently over the whole long term study period as other parameters. However, since 1999 there has been a clear decline from about 8.5 to 8.1 in the cove (Figure 80). Linear regression analysis did not provide evidence of a linear trend over the study period (Table 10).

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



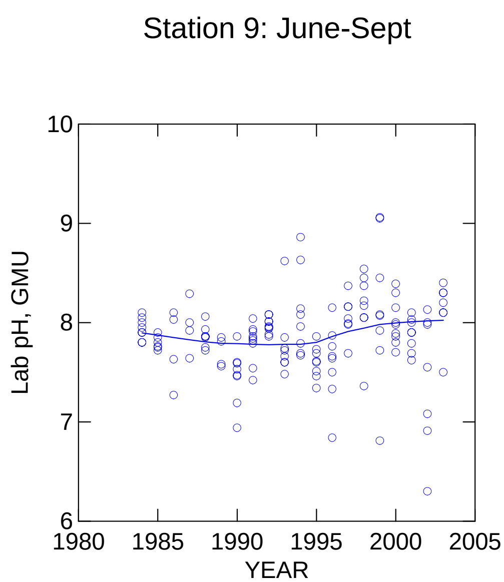
In the river a similar pattern has been observed in the river over this period (Figure 81). pH in the river has been consistently lower by about 1 pH unit than in the cove. A gradual increase from 7.2 in 1989 to 7.7 in 1999 has been recently followed by a decline to about 7.2. When all years were considered, no linear trend was found (Table 10).

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



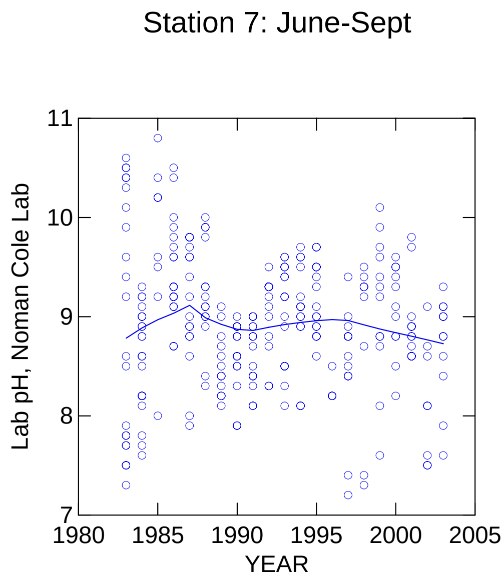
Lab pH as measured by GMU personnel generally remained in the range 8-9 over the long term study period (Figure 82). The trend line varied around about 8.5. Regression analysis was not significant (Table 10).

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



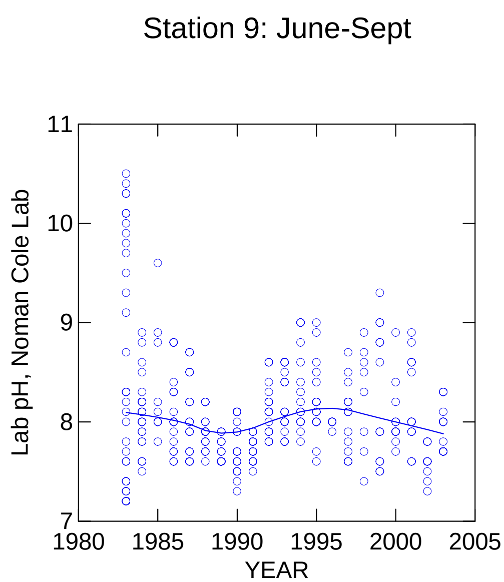
In the river lab pH varied from about 7.5 to 8.5 with a slight trend for increase over the long term study period (Figure 83). Linear regression indicated that there was not a temporal trend in this variable (Table 10).

Figure 83. Long term trend in Lab pH (GMU Data). Station 9. River mainstem.



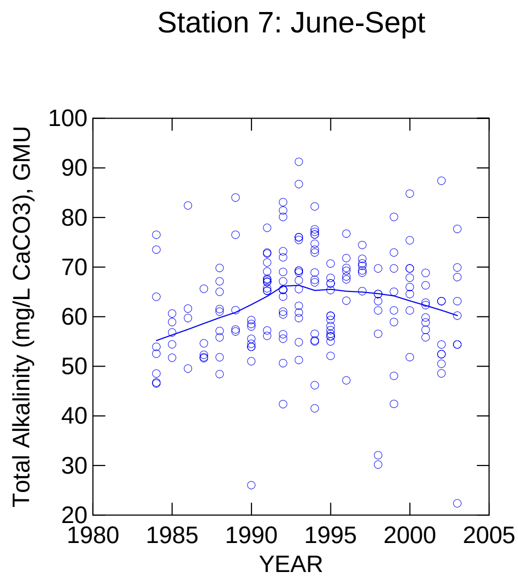
Lab pH as measured by LP personnel were generally in the range 8 to 9.5 over the long term study period (Figure 84). Recent data indicate a slight decline over recent years. Linear regression indicated a significant decline in pH over the study period at a rate of about 0.013 pH units per year or a total of 0.26 units over 20 years.

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



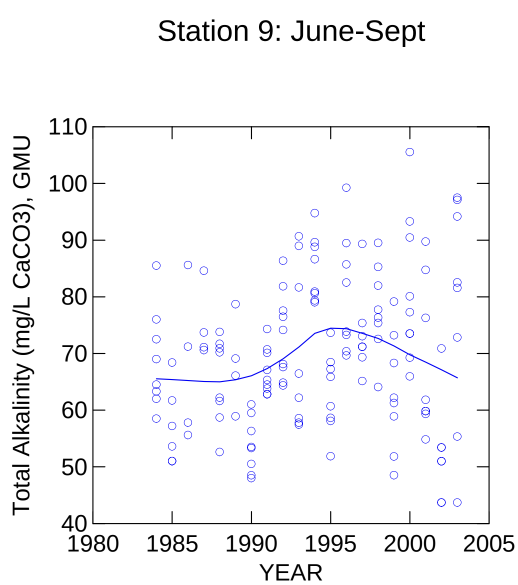
In the river, long term pH trends as measured by Noman Cole lab personnel indicate that most values fell between 7.5 and 9. The trend line has increased and decreased slightly over the years with the most recent trend a slight decline. pH in the river showed a significant linear decline identical to that in the cove (Table 11).

Figure 85. Long term trend in Lab pH (NC Lab Data). Station 9. Potomac mainstem.



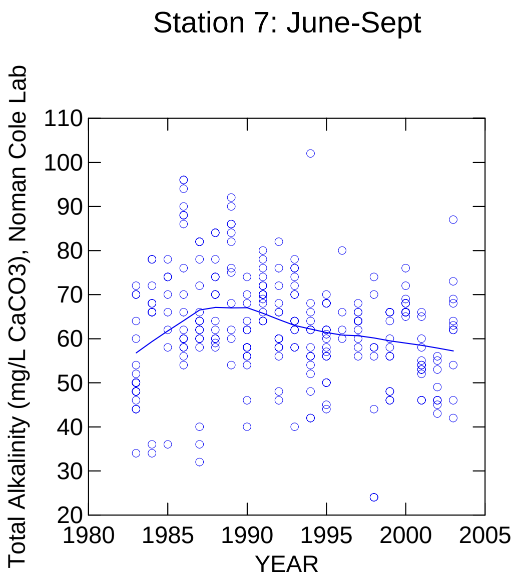
Total alkalinity as measured by GMU personnel has shown a trend line increase from about 55 mg/L as $CaCO_3$ in 1984 to about 65 mg/L in 1991 followed by a graduate decline which reached about 60 mg/L in 2003 (Figure 86). A linear regression over the whole study period was not significant (Table 10).

Figure 86. Long term trend in Total Alkalinity (GMU Lab Data). Station 7. Gunston Cove.



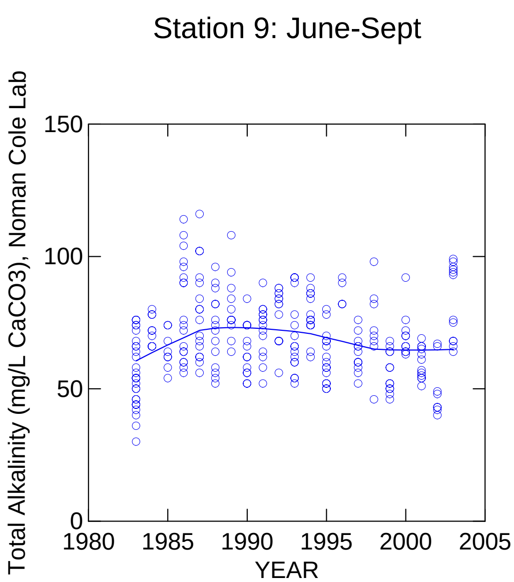
Total alkalinity in the river as measured by GMU personnel has covered a fairly broad range each year (Figure 87). The trend line was fairly constant from 1984 to 1990 at about 65 mg/L as $CaCO_3$, rose to about 75 mg/L in 1995 and has declined in recent years to about 65 mg/L in 2003. A significant increase in alkalinity was suggested by linear regression analysis at a rate of 0.38 mg/L per year (Table 10).

Figure 87. term trend in Total Alkalinity (GMU Lab Data). Station 9. River mainstem.



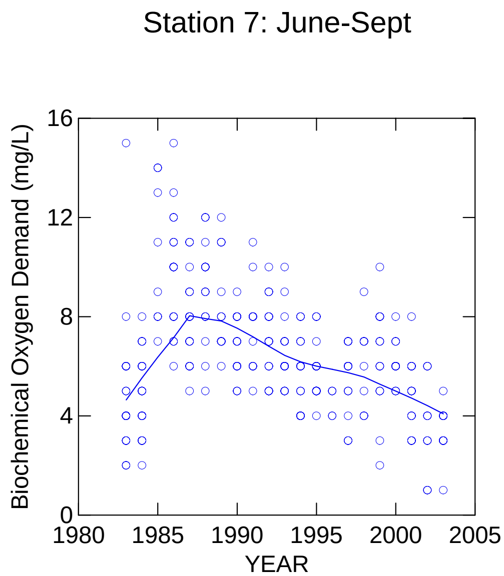
Total alkalinity as measured by Noman Cole lab personnel exhibited a rise from 1983 to 1990 and has been on a slow decline since that time (Figure 88). The trend line at 2003 was similar to the value in 1983. This parameter showed a significant linear decline over the long term study period at a rate of 0.29 mg/L per year (Table 11).

Figure 88. Long term trend in Total Alkalinity (NC Lab Data). Station 7. Gunston Cove.



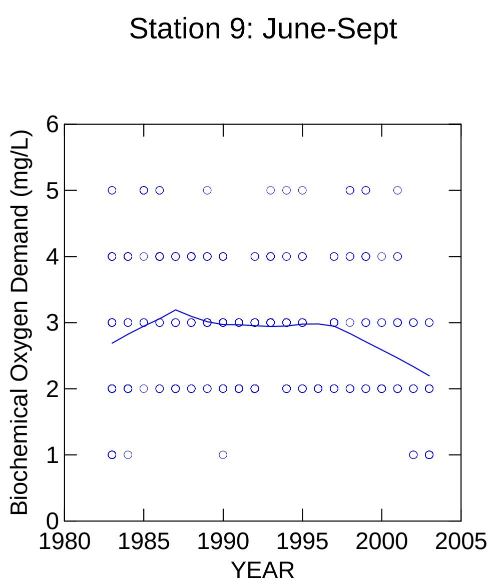
In the river a similar pattern was observed (Figure 89). Interestingly, alkalinity in the river in 2003 was mostly above the long term trend line. Linear trends in this parameter were not detected by regression analysis (Table 11).

Figure 89. Long term trend in Total Alkalinity (NC Lab Data). Station 9. Potomac mainstem.



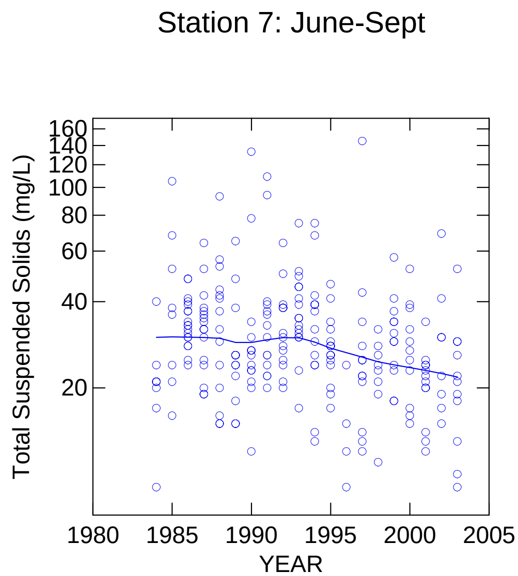
Biochemical oxygen demand has shown a distinct pattern over the long term study period in Gunston Cove (Figure 90). An increase in the 1980's saw the trend line rise from about 4.5 mg/L to 8 mg/L by 1987. Since then there has been a steady decline such that the trend line has dropped back to 4 mg/L. BOD showed a significant linear decline over the entire study period at a rate of 0.13 mg/L per year yielding a net decline of 2.6 mg/L (Table 11).

Figure 90. Long term trend in Biochemical Oxygen Demand (NC Lab Data). Station 7. Gunston Cove.



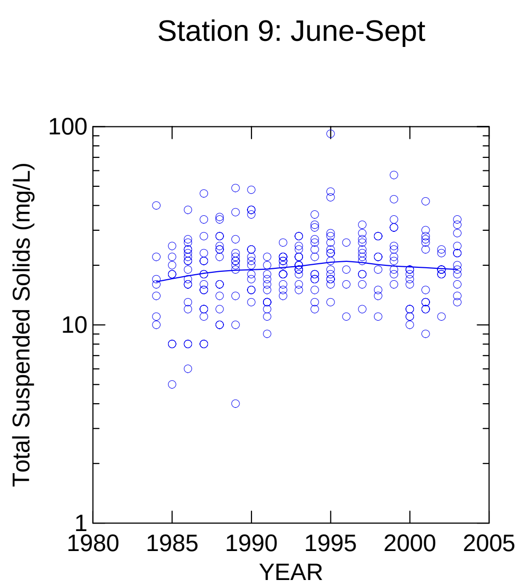
In the river biochemical oxygen demand has shown a less distinct pattern (Figure 91). Nonetheless it is clear that BOD has decreased in recent years with the median value dropping from 3 to 2 mg/L. BOD in the river did not exhibit a significant linear trend considered over the entire study period (Table 11).

Figure 91. Long term trend in Biochemical Oxygen Demand (NC Lab Data). Station 9. Potomac mainstem.



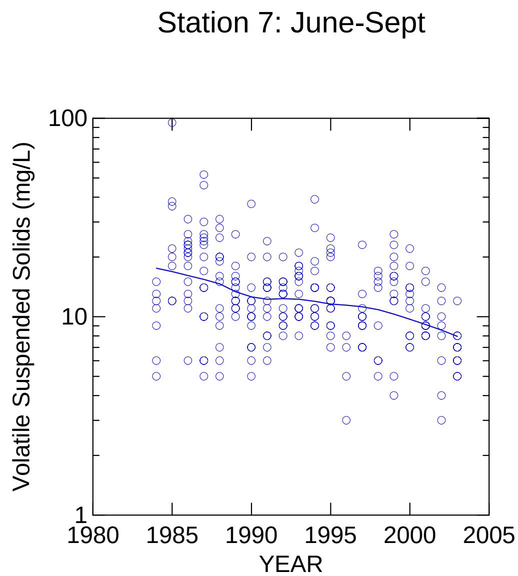
Total suspended solids (TSS) has shown a great deal of variability over the long term study period. Nonetheless, a decreasing trend has been detected in TSS in the cove with the trend line decreasing from about 30 mg/L in 1983 to about 20 mg/L in 2003 (Figure 92). Linear regression was significant indicating a decline of -0.58 mg/L per year yielding a total decline of 11.6 mg/L since 1984 (Table 11).

Figure 92. Long term trend in Total Suspended Solids (NC Lab Data). Station 7. Gunston Cove.



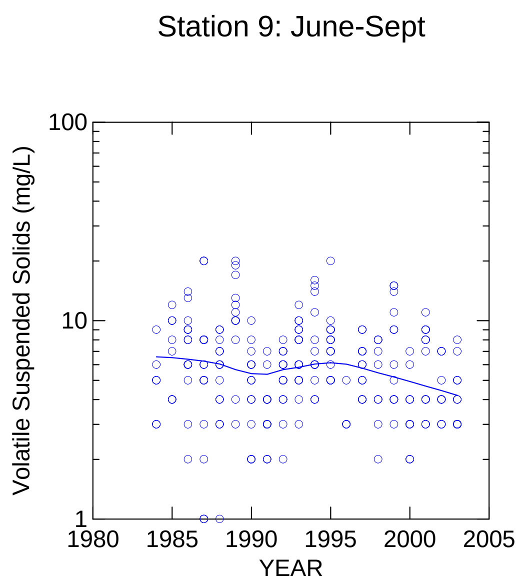
In the river TSS trends have not been as apparent (Figure 93). There has been a slight increase in the LOWESS curve for TSS in the river over the long term study period. In the river TSS did not exhibit a significant linear trend (Table 11).

Figure 93. Long term trend in Total Suspended Solids (NC Lab Data). Station 9. Potomac mainstem.



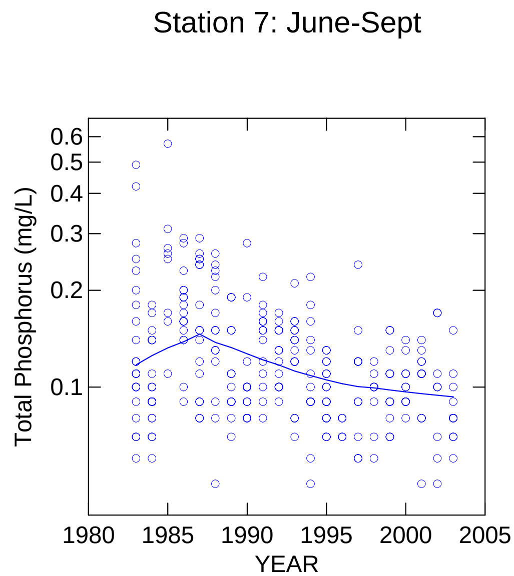
Volatile suspended solids has demonstrated a gradual decline over the study period (Figure 94). The trend line has declined from 20 mg/L in 1984 to 8 mg/L in 2003. VSS demonstrated a significant linear decline at a rate of 0.57 mg/L per year or a total of 11.4 mg/L over the study period (Table 11).

Figure 94. Long term trend in Volatile Suspended Solids (NC Lab Data). Station 7. Gunston Cove.



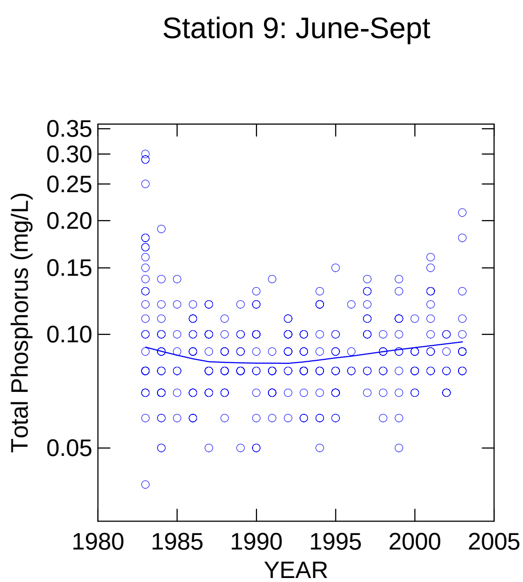
In the river volatile suspended solids (VSS) exhibited a slight decline over the study period with the trend line decreasing from 7 mg/L in 1983 to 4 mg/L in 2003 (Figure 95). VSS in the river demonstrated a significant linear decline at a rate of 0.094 mg/L per year or 1.9 mg/L since 1984 (Table 11).

Figure 95. Long term trend in Volatile Suspended Solids (NC Lab Data). Station 9. Potomac mainstem.



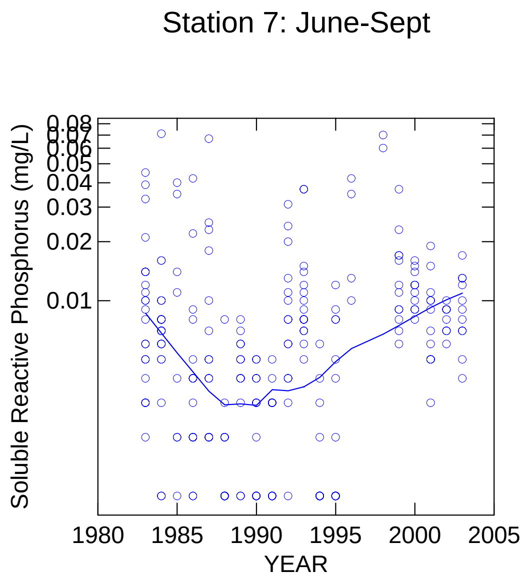
In the cove, total phosphorus (TP) continued to decline in 2003 (Figure 96). The late 1980's witnessed increasing TP with the trend line rising to about 0.15 mg/L by 1987 and numerous values above 0.2 mg/L during that period. By 2003 the trend line had dropped below 0.1 mg/L. Linear regression over the entire period of record indicated a significant linear decline of 0.004 mg/L per year or 0.8 mg/L over the entire study period (Table 11).

Figure 96. Long term trend in Total Phosphorus (NC Lab Data). Station 7. Gunston Cove.



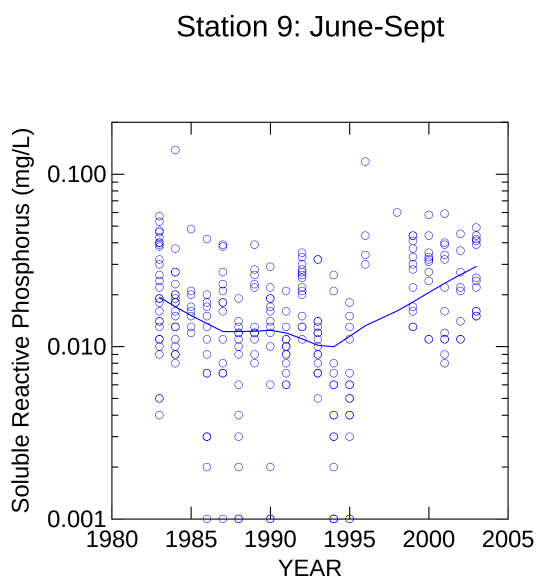
Total phosphorus (TP) values in the river have shown less of a trend over time (Figure 97). While a slight decline in the trend line was observed in the 1980's, the trend line for TP has increased since that time to a slightly higher level than in 1983. TP did not exhibit a linear trend over the long term study period (Table 11).

Figure 97. Long term trend in Total Phosphorus (NC Lab Data). Station 9. Potomac mainstem.



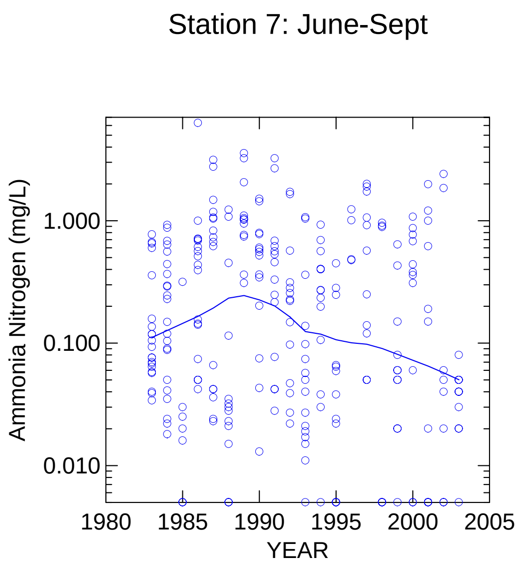
Soluble reactive phosphorus (SRP) declined in the cove during the first few years of the long term data set, but has since shown an increase to near its initial level (Figure 98). This may indicate a demand for phosphorus by phytoplankton which would allow soluble reactive phosphorus to accumulate in the water. SRP did not demonstrate a significant linear trend when all years were considered (Table 11).

Figure 98. Long term trend in Soluble Reactive Phosphorus (NC Lab Data). Station 7. Gunston Cove.



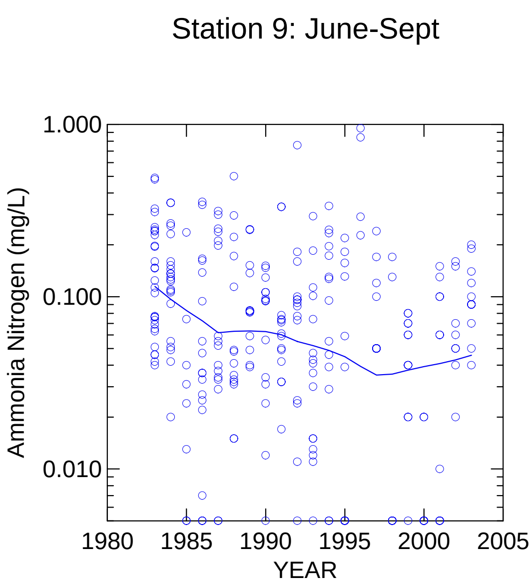
Soluble reactive phosphorus (SRP) in the river has generally been present at higher levels than in the cove (Figure 99). By 2003 the trend line in the river was at 0.03 mg/L compared to about 0.01 mg/L in the cove. Again, the may reflect less demand for P in the river; algae in the river may be more light-limited. In the river SRP showed a slight positive linear trend over the study period (Table 11).

Figure 99. Long term trend in Soluble Reactive Phosphorus (NC Lab Data). Station 9. Potomac mainstem.



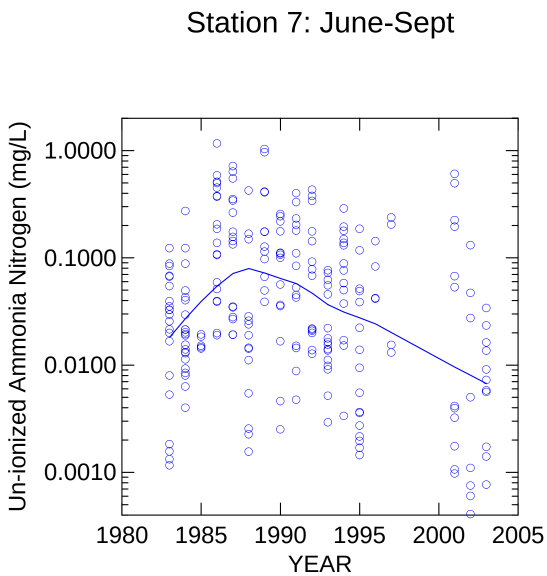
Ammonia nitrogen levels were very variable over the long term study period in the cove, but a trend of decreasing values is evident from the LOWESS trend line (Figure 100). Since 1989 the trend line has decreased from about 0.3 mg/L to about 0.05 mg/L. Linear regression over the entire period of record was not significant (Table 11).

Figure 100. Long term trend in Ammonia Nitrogen (NC Lab Data). Station 7. Gunston Cove.



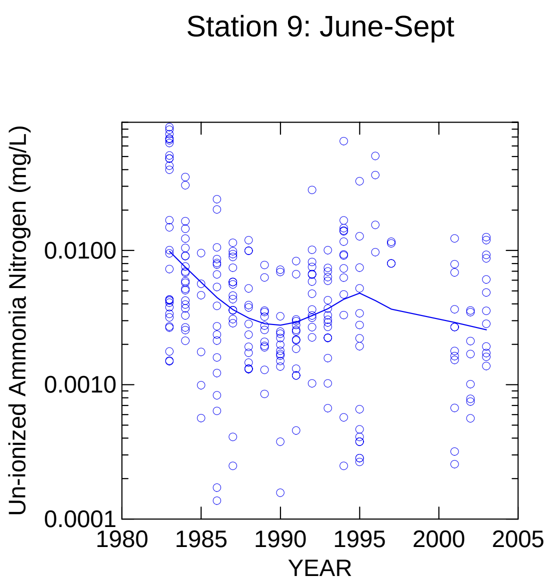
In the river a decreasing trend in ammonia nitrogen has also been observed over most of the study period (Figure 101). Between 1983 and 1999 the trend line dropped from 0.1 mg/L to 0.04 mg/L. Since 1999 it has risen slightly to 0.05 mg/L. In the river ammonia nitrogen demonstrated a significant decline over the study period at a rate of 0.003 mg/L per year of 0.06 mg/L since 1983 (Table 11).

Figure 101. Long term trend in Ammonia Nitrogen (NC Lab Data). Station 9. Potomac mainstem.



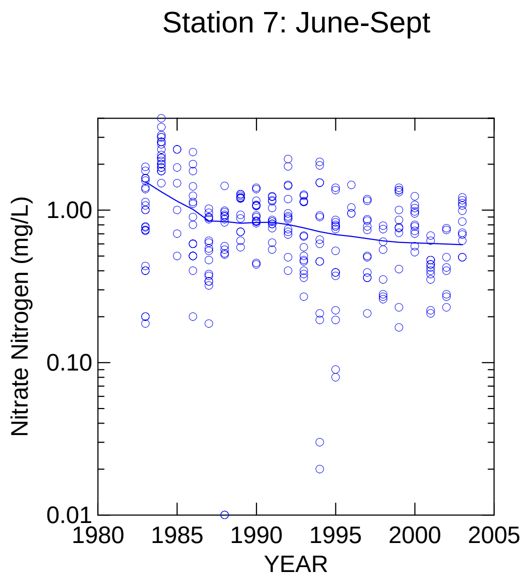
Un-ionized ammonia nitrogen in the cove demonstrated a clear increase in the 1980's with a continuous decline since that time (Figure 102). When considered over the entire time period, there was not a significant linear relationship (Table 11).

Figure 102. Long term trend in Un-ionized Ammonia Nitrogen (NC Lab Data). Station 7. Gunston Cove.



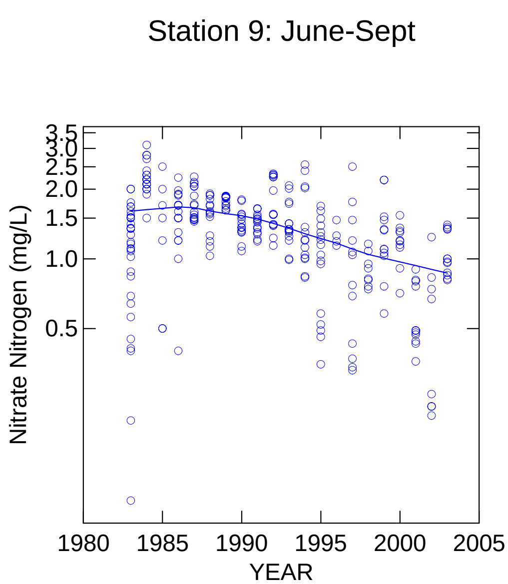
Un-ionized nitrogen in the river declined during the 1980's, increased somewhat the early 1990's and now has stabilized (Figure 103). Linear regression analysis over the entire period of record suggested a significant decline at a rate of 0.001 unit per year (Table 11).

Figure 103. Long term trend in Un-ionized Ammonia Nitrogen (NC Lab Data). Station 9. Potomac mainstem.



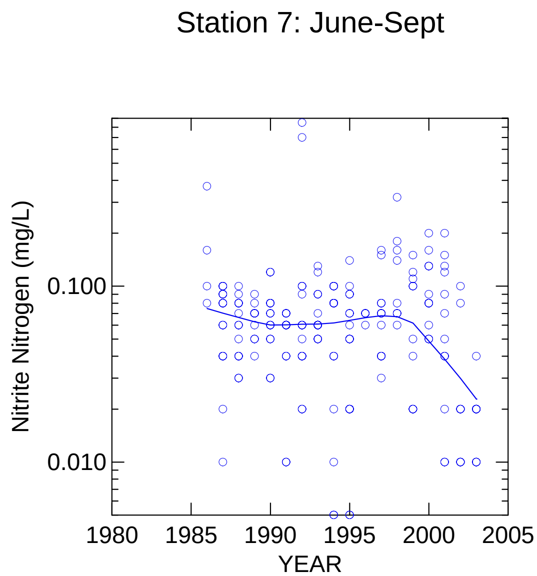
Nitrate nitrogen demonstrated a continuous decline in the cove over the entire period of record (Figure 104). The trend line was at 1.5 mg/L in 1983 and by 2003 was at 0.6 mg/L. Linear regression suggested a decline rate of 0.04 mg/L per year yielding a total decline of 0.8 mg/L over the long term study period (Table 11).

Figure 104. Long term trend in Nitrate Nitrogen (NC Lab Data). Station 7. Gunston Cove.



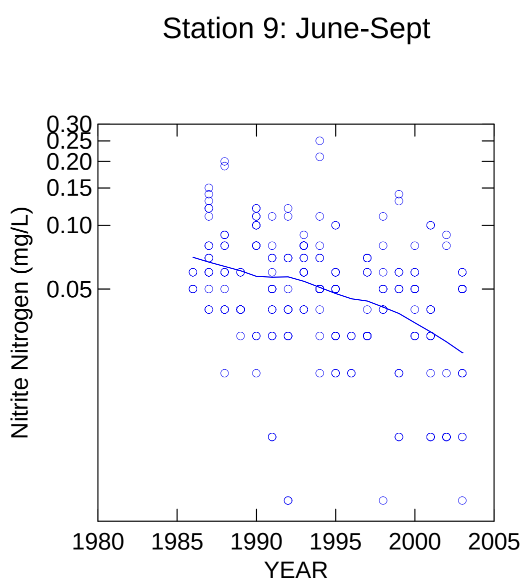
In the river nitrate nitrogen declined steadily over the study period (Figure 105). The trend line dropped from 1.6 mg/L in the mid 1980's to 0.8 mg/L in 2003. Linear regression indicated a similar rate of drop as in the cove which would have yielded a 0.8 mg/L drop in nitrate nitrogen (Table 11).

Figure 105. Long term trend in Nitrate Nitrogen (NC Lab Data). Station 9. River mainstem.



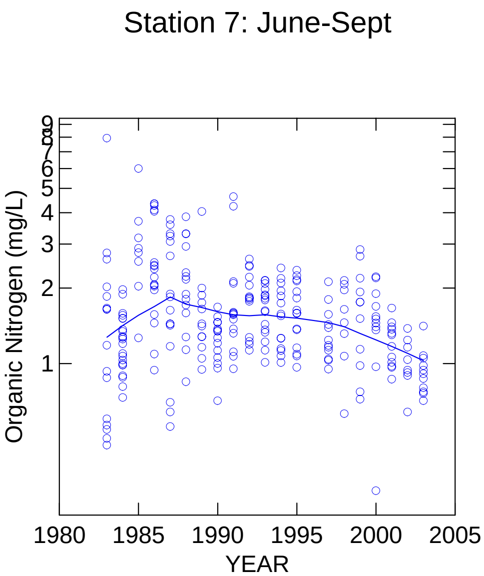
The trend line for nitrite nitrogen indicated steady values at about 0.06-0.07 mg/L through 1999 (Figure 106). Since then there is evidence for a decline. Linear analysis did not detect a significant linear trend in this long term data set (Table 11).

Figure 106. Long term trend in Nitrite Nitrogen (NC Lab Data). Station 7. Gunston Cove.



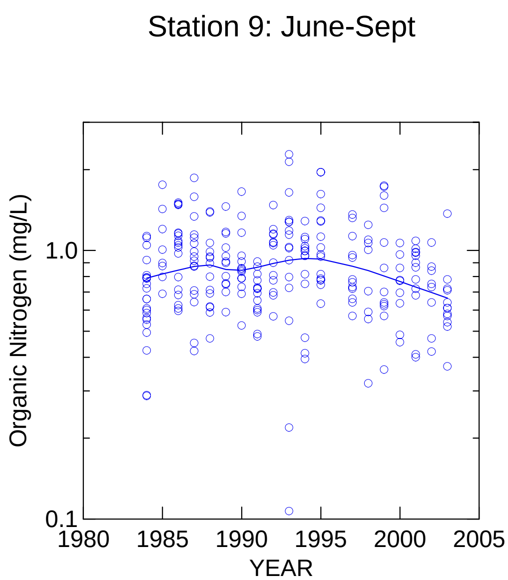
Nitrite nitrogen in the river demonstrated a pattern of decrease during the long term study period (Figure 107). The LOWESS line dropped from 0.07 mg/L in 1986 to 0.04 mg/L in 2003. Linear regression indicated a significant linear decline at a rate of 0.002 mg/L per year or 0.04 mg/L over the study period (Table 11).

Figure 107. Long term trend in Nitrite Nitrogen (NC Lab Data). Station 9. Potomac mainstem.



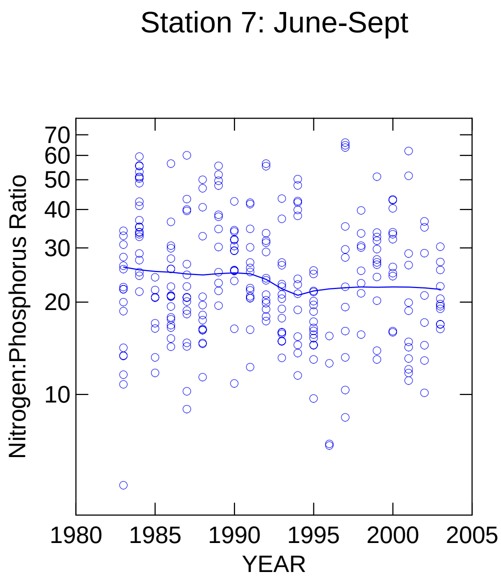
Organic nitrogen in the cove appeared to increase in the 1980's which has been followed by a consistent decline through 2003 (Figure 108). In 1983 the trend line was at 1.2 mg/L, rose to 1.8 mg/L in 1987, and dropped to 1.0 mg/L in 2003. Regression analysis indicated a significant decline over the study period at a rate of about 0.04 mg/L per year or a total of 0.8 mg/L over the whole study period (Table 11).

Figure 108. Long term trend in Organic Nitrogen (NC Lab Data). Station 7. Gunston Cove.



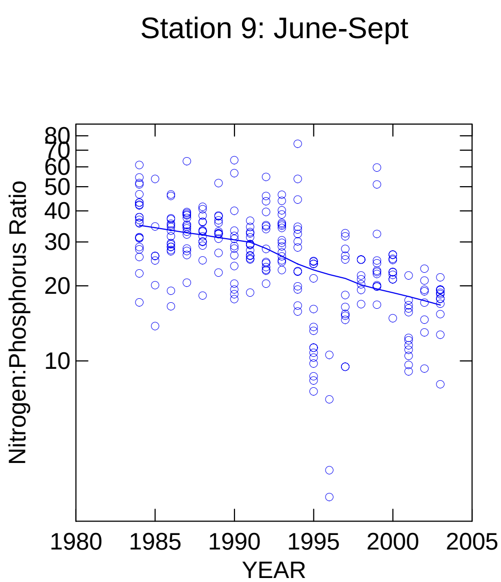
In the river organic nitrogen showed muted trends over the study period (Figure 109). A rather consistent decline has been suggested in recent years. Regression analysis did not reveal significant linear patterns when the entire period of record was considered (Table 11).

Figure 109. Long term trend in Organic Nitrogen (NC Lab Data). Station 9. River mainstem.



Nitrogen to phosphorus ratio (N/P ratio) exhibited large variability, but a general suggestion of decrease in the cove over the study period (Figure 110). Regression analysis was not significant (Table 11).

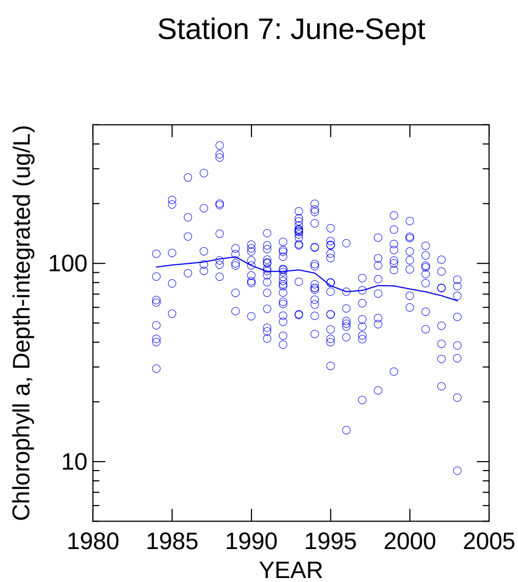
Figure 110. Long term trend in N to P Ratio (NC Lab Data). Station 7. Gunston Cove.



Nitrogen to phosphorus (N/P) ratio in the river exhibited a strong continuous decline through the entire study period (Figure 111). The LOWESS trend line declined from about 35 in 1984 to 18 in 2003. This is close to the N/P ratio of 16 at which nutrient limitation of phytoplankton growth may switch from P to N. Linear regression analysis confirmed this decline and suggested a rate of -1.08 units per year or a total of 21.6 units over the long term study period (Table 11).

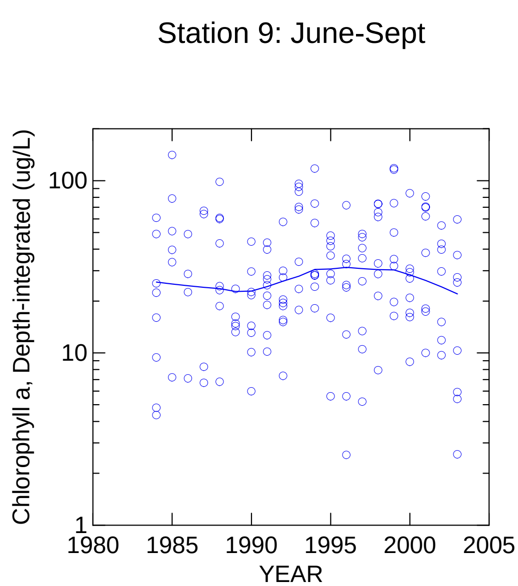
Figure 111. Long term trend in N to P Ratio (NC Lab Data). Station 9. River mainstem.

C. Phytoplankton Trends: 1984-2003



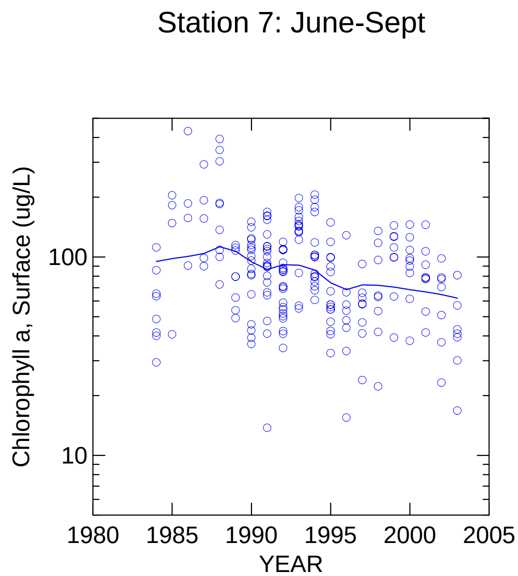
Depth-integrated chlorophyll *a* in the cove has demonstrated a gradual decline, particularly since 1988 (Figure 112). The LOWESS line declined from about 100 ug/L to a level of about 70 ug/L in 2003. Regression analysis has revealed a clear linear trend of decreasing values at the rate of 3.36 ug/L per year or about 70 ug/L over the 20 year long term data set (Table 10). Thus, management efforts to control nutrient input from point sources into the cove appear to being having the desired effect of decreasing phytoplankton biomass.

Figure 112. Long term trend in Depth-integrated Chlorophyll a (GMU Lab Data). Station 7. Gunston Cove.



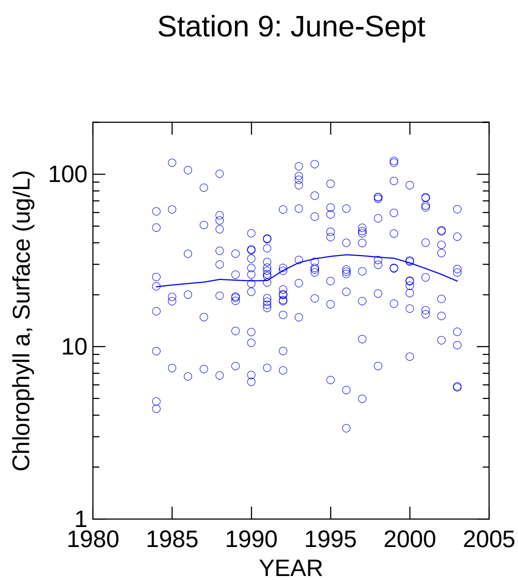
In the river depth-integrated chlorophyll a has been fairly consistent over the study period with the trend line varying between 20 and 30 ug/L (Figure 113). Regression analysis did not reveal a significant linear trend (Table 10).

Figure 113. Long term trend in Depth-integrated Chlorophyll a (GMU Lab Data). Station 9. River mainstem.



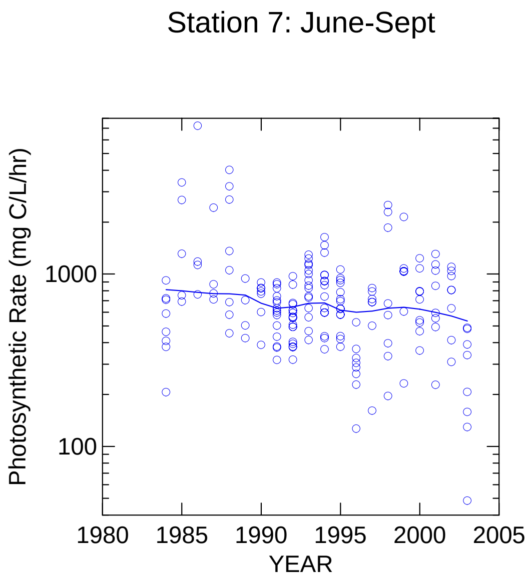
Surface chlorophyll a in the cove exhibited a clear decline over the long term study period, especially since 1988 (Figure 114). Trend line values of just over 100 ug/L in 1988 dropped to about 65 ug/L in 2003. Linear regression confirmed the linear decline and suggested a rate of -3.9 ug/L per year or 78 ug/L over the entire study (Table 10).

Figure 114. Long term trend in Surface Chlorophyll a (GMU Data). Station 7. Gunston Cove.



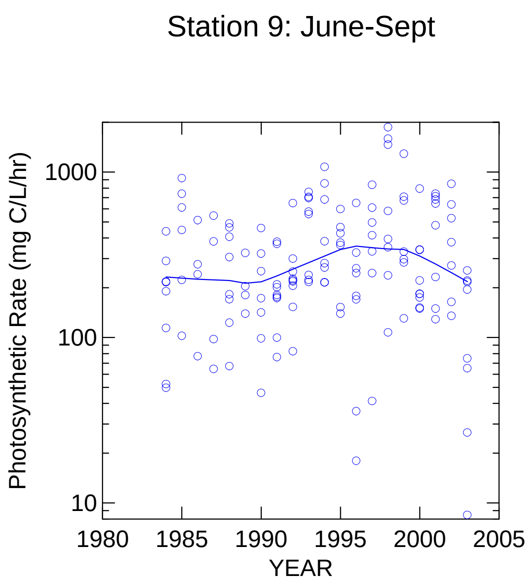
In the river surface chlorophyll a did not show any clear long term patterns with the trend line varying from 20-30 ug/L over the period (Figure 115). Linear regression did not reveal any significant trends across this period (Table 10).

Figure 115. Long term trend in Surface Chlorophyll a (GMU Data). Station 9. River mainstem.



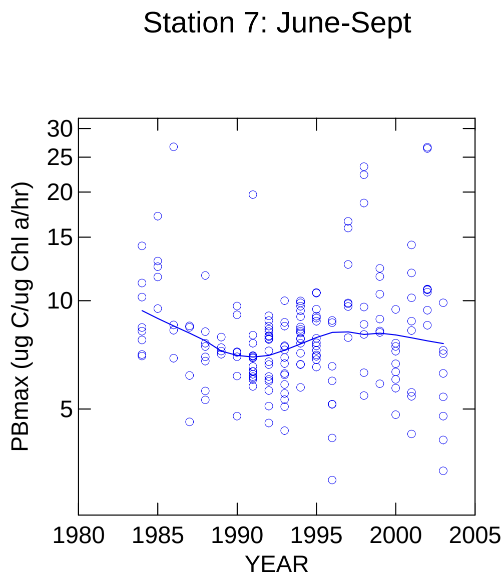
Photosynthetic rate in the cove showed a gradual decline over the study period (Figure 116). The trend line decreased from about 800 to about 550 mg C/L/hr over the period from 1984 to 2003. Linear regression analysis yielded a significant linear regression coefficient of -33.6 mgC/L/hr per year yielding a total decline of 672 mg C/L/hr over the long term study period (Figure 116).

Figure 116. Long term trend in Photosynthetic Rate at Light Saturation (GMU Lab Data). Station 7. Gunston Cove.



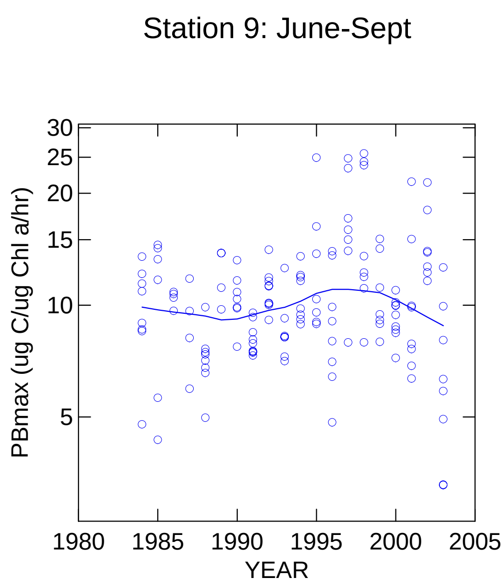
Photosynthetic rate in the river showed some systematic variability over the study period rising during the early 1990's and declining in recent years (Figure 117). Linear regression did not show a significant trend over the study period (Table 10).

Figure 117. Long term trend in Photosynthetic Rate at Light Saturation (GMU Lab Data). Station 9. River mainstem.



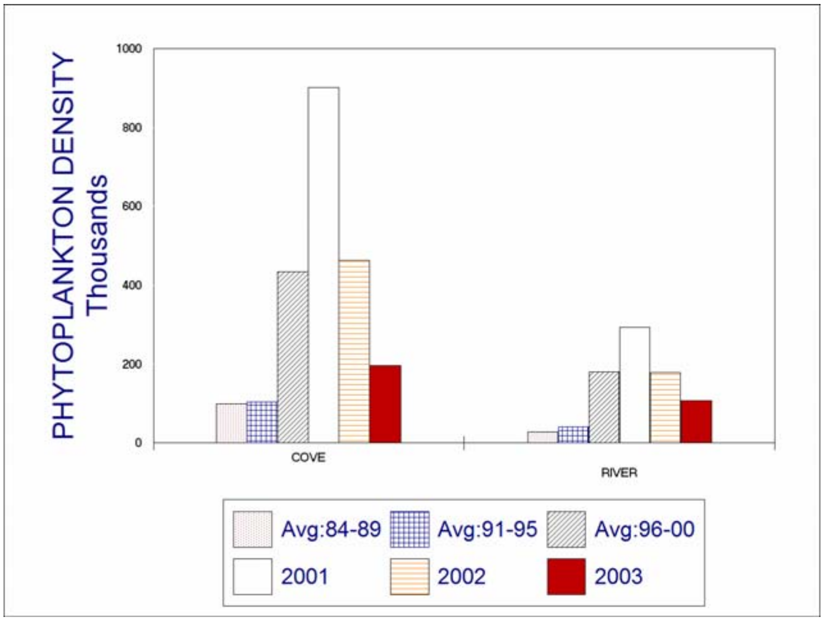
P^B_{max} (photosynthetic rate per unit chlorophyll *a*) showed some systematic variation with a decline in the 1980's and a rise in the early 1990's (Figure 118). Linear regression did not reveal any significant long term trends (Tale 10).

Figure 118. Long term trend in P^B_{max} (GMU Lab Data). Station 7. Gunston Cove.



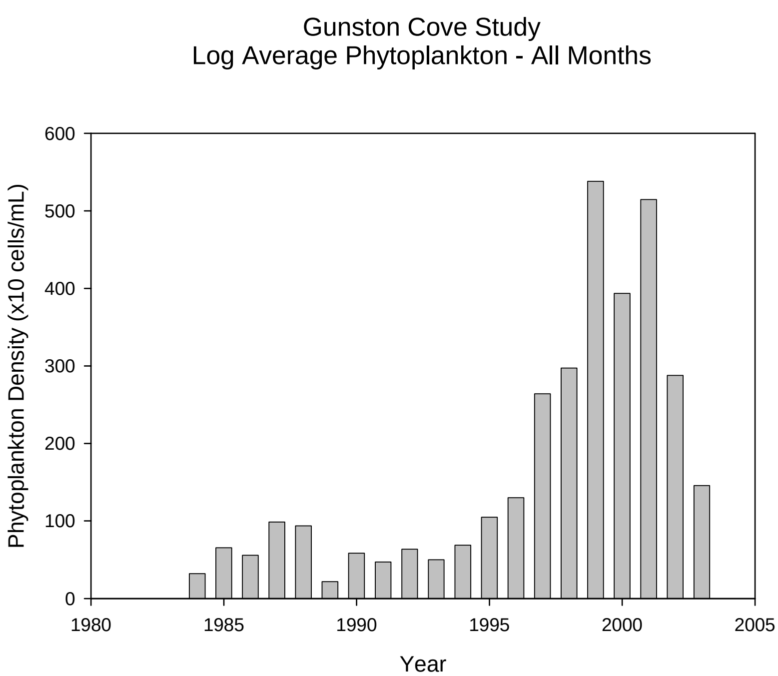
In the river the trend line for P^B_{max} has generally been about 10 ug C/ug Chl *a*/hr over the study period (Figure 119). Recent years have suggested a possible decline. Regression analysis over the period of record did not reveal any linear trends (Table 10).

Figure 119. Long term trend in P^B_{max} (GMU Lab Data). Station 9. Potomac mainstem.



Phytoplankton density in 2003 continued a decline in both study areas that was initiated in 2002. This decline was due almost entirely to a decrease in small cyanobacterial cells such as *Aphanocapsa* and *Merismopedia*. Interestingly, this decline was consistent across two years that were very different in river inflow: 2002 was dry and 2003 was wet.

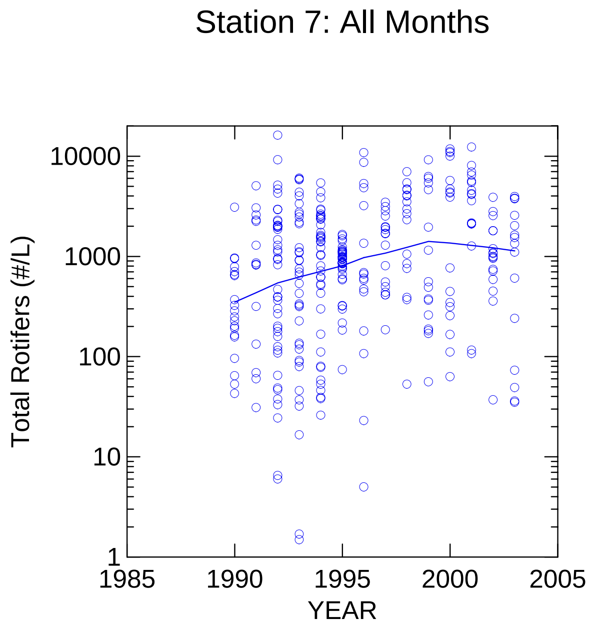
Figure 120. Interannual Comparison of Phytoplankton Density by Region.



In the longer term perspective, the 2003 densities have returned much closer to the levels observed in earlier years. This decline in cell density is probably a good sign in general, although its exact significance is not clear since cell density was lower during some of the early years which had more algal blooms.

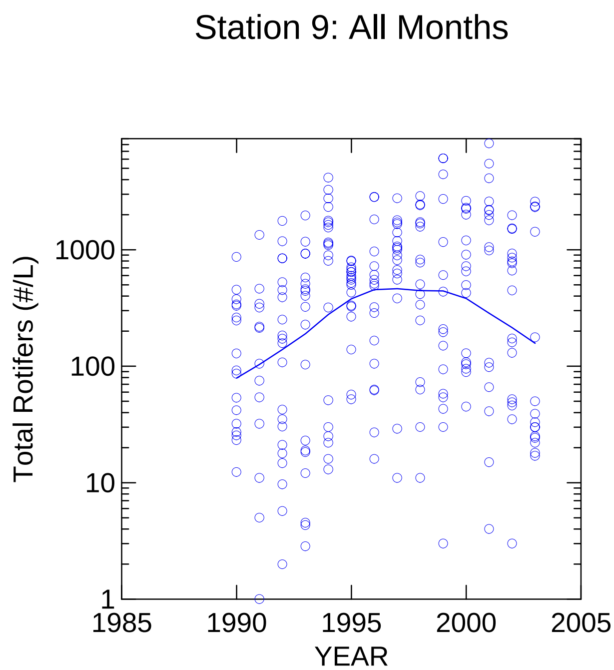
Figure 121. Interannual Trend in Average Phytoplankton Density

D. Zooplankton Trends: 1990-2003



In the Cove total rotifers continued to show a leveling and perhaps slight decline that began in about 2000 (Figure 122). The LOWESS fit line indicated about 1000/L in 2003, up from about 400/L in 1990. Linear regression analysis indicated strong evidence for a statistically significant linear increase in total rotifers over the study period (Table 12).

Figure 122. Long term trend in Total Rotifers. Station 7. Gunston Cove.



In the Potomac mainstem, rotifers appeared to continue a marked decline in abundance that began in about 1998 (Figure 123). Most of the values were below 100/L and the LOWESS line suggested about 200/L in contrast with values generally above 100/L and LOWESS line of about 500/L in 1996-1999 period. When the entire 1990-2003 period was considered, total rotifers were found to exhibit a statistically significant linear increase (Table 12).

Figure 123. Long term trend in Total Rotifers. Station 9. River mainstem.

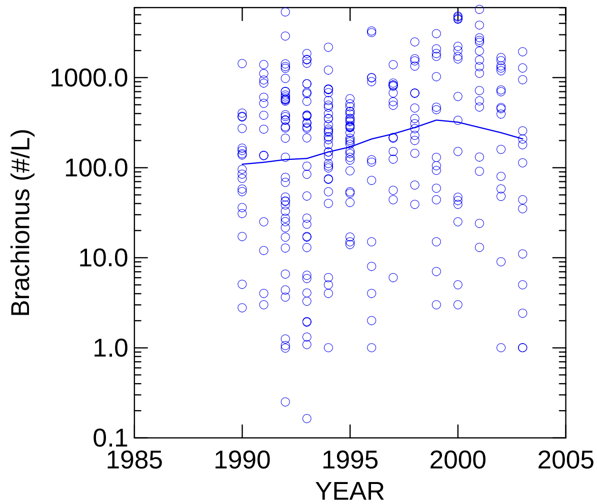
Table 12
Correlation and Linear Regression Coefficients
Zooplankton Parameters vs. Year for 1990-2003
All Nonzero Values Used, All Values Logged to Base 10

	Station 7			Station 9		
Parameter	Corr. Coeff.	Reg. Coeff.	Signif.	Corr. Coeff.	Reg. Coeff.	Signif.
Brachionus (m)	0.153 (294)	0.036	0.009	0.167 (219)	0.039	0.013
Conochilidae (m)	0.185 (265)	0.035	0.002	0.156 (192)	0.034	0.030
Filinia (m)	0.222 (246)	0.054	<0.001	0.250 (154)	0.047	0.002
Keratella (m)	0.279 (307)	0.058	<0.001	0.291 (231)	0.064	<0.001
Polyarthra (m)	0.203 (293)	0.041	<0.001	0.200 (215)	0.041	0.003
Total Rotifers (m)	0.236 (318)	0.045	<0.001	0.166 (238)	0.034	0.010
Bosmina (M)	0.166 (163)	0.034	0.035	0.277 (181)	0.054	<0.001
Diaphanosoma (M)	0.137 (249)	0.058	0.031	0.066 (151)	----	NS
Daphnia (M)	0.250 (217)	0.076	<0.001	0.039 (123)	----	NS
Chydorid cladocera (M)	0.455 (178)	0.118	<0.001	0.433 (105)	0.084	<0.001
Leptodora (M)	0.249 (118)	0.076	0.007	0.005 (72)	----	NS
Copepod nauplii (m)	0.374 (298)	0.059	<0.001	0.323 (234)	0.061	<0.001
Adult and copepodid copepods (M)	0.156 (415)	0.038	0.001	0.053 (279)	----	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.

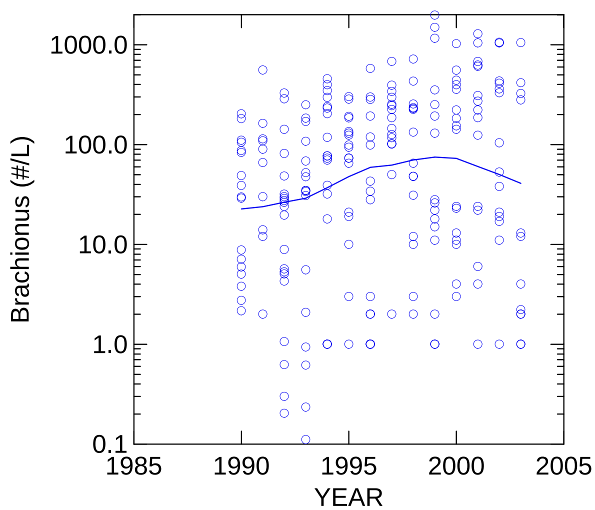
Station 7: All Months



Brachionus is the dominant rotifer in Gunston Cove and the trends in total rotifers are mirrored in those in *Brachionus* (Figure 124). The LOWESS line for *Brachionus* suggested about 200/L in 2003, down from 400/L in 1999, but higher than 100/L in 1990. A statistically significant linear increase was indicated over the entire study period (Table 12).

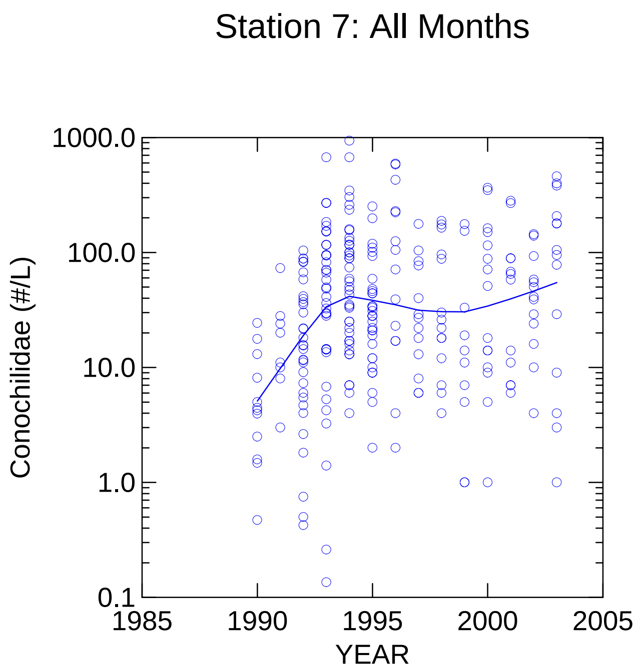
Figure 124. Long term trend in *Brachionus*. Station 7. Gunston Cove.

Station 9: All Months



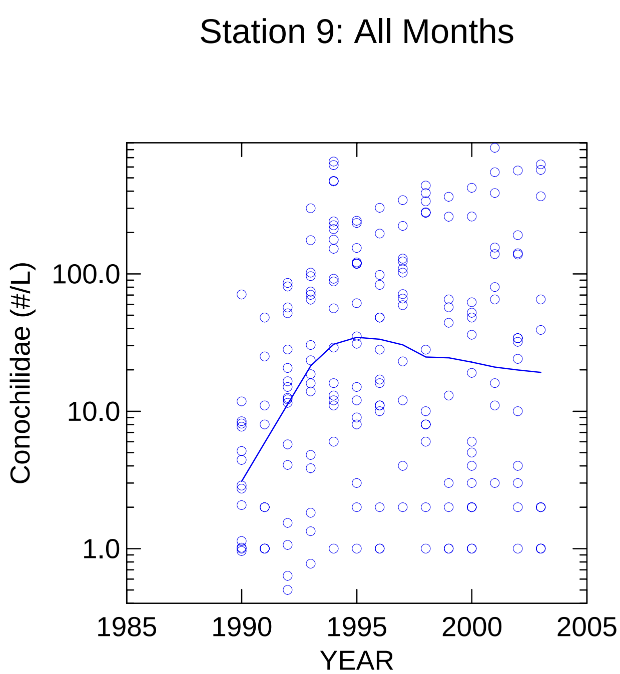
In the river the LOWESS line for *Brachionus* suggested a continued decline to about 40/L, below the peak of 80/L in 1999 (Figure 125). However, values seemed to fall into two groups: above 200/L and below 20/L. A marginally significant linear increase was indicated over the entire study period (Table 12).

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



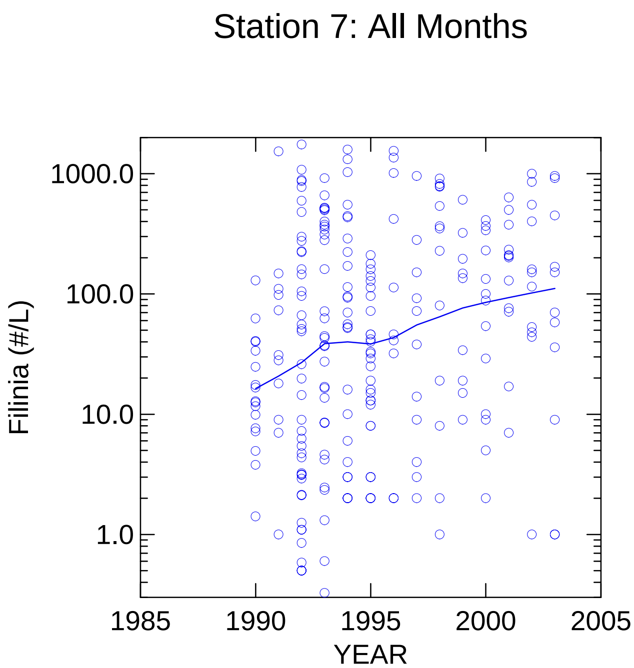
A continued increase in Conochilidae for 2003 was suggested by the LOWESS line to about 55/L (Figure 126). This was well above levels of about 5/L in 1990. Over the entire period of record, a significant linear increase was found (Table 12).

Figure 126. Long term trend in Conochilidae. Station 7. Gunston Cove.



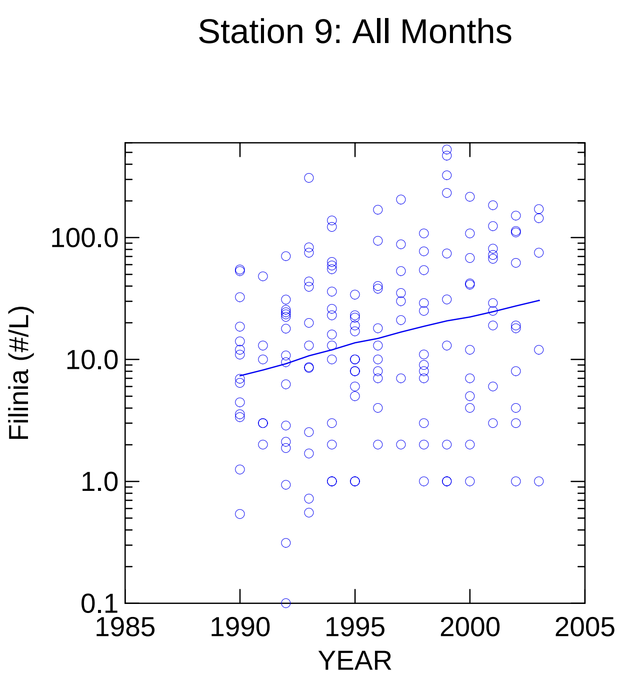
In the river, the LOWESS line suggested a continued slow decline in Conochilidae, but some values were near the maximum observe in previous years (Figure 127). The trend line was at 20/L, but values were scattered over a large range. When the entire period of record was examined, a weak linear trend was found (Table 12).

Figure 127. Long term trend in Conochilidae. Station 9. Gunston Cove.



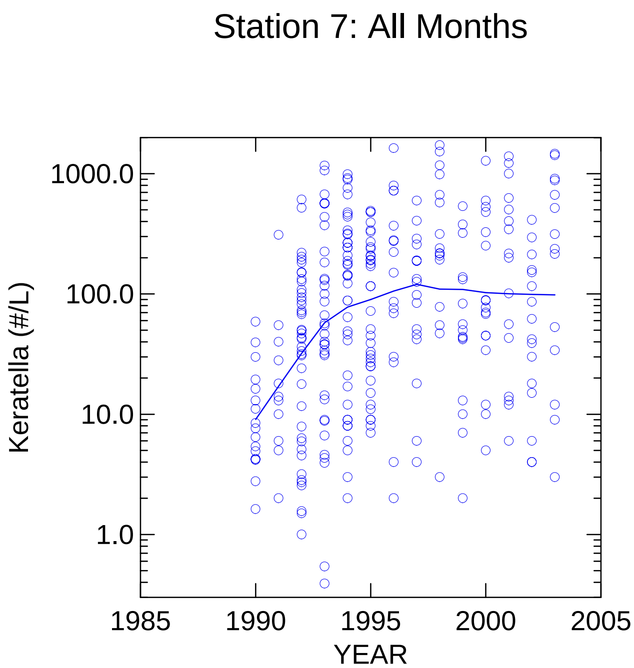
In the cove *Filinia* continued a long term increase with the LOWESS line exceeding 100/L for the first time (Figure 128). This compared to 20/L in 1990. When the entire period of record was considered, there was strong evidence for a linear trend (Table 12).

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



In the river *Filinia* demonstrated a continued rise as well attaining about 30/L in 2003 as compared to about 8/L in 1990 (Figure 128). When the entire period of record was examined, there was a clear linear trend (Table 12).

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



Keratella continued a stable density pattern in 2003 that has been characteristic since about 1996 at about 100/L (Figure 130). Before that there had been a progressive increase from 1990 values of about 10/L. When the entire period of record was examined, there was strong evidence for a linear increase (Table 12).

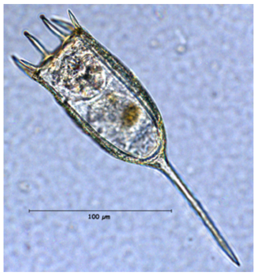
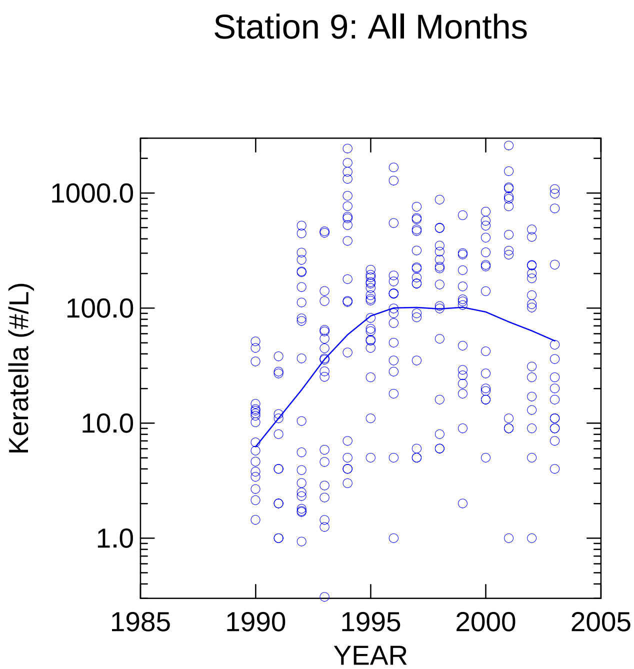
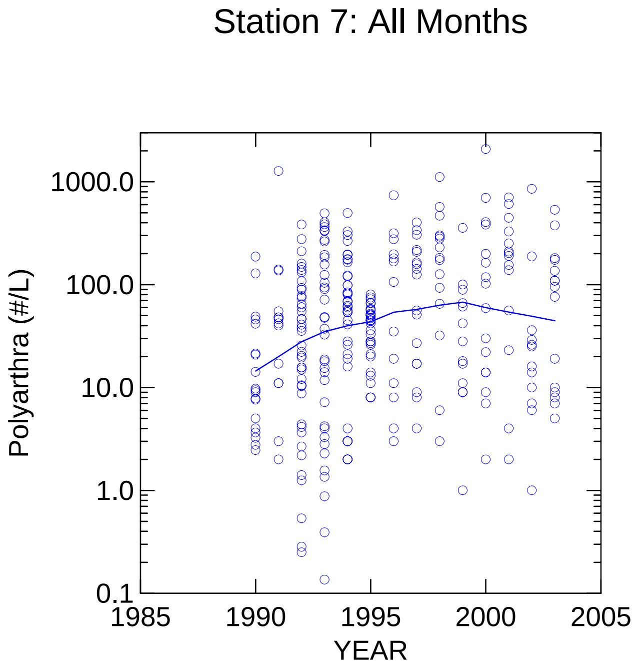


Figure 130. Long term trend in *Keratella*. Station 7. Gunston Cove.



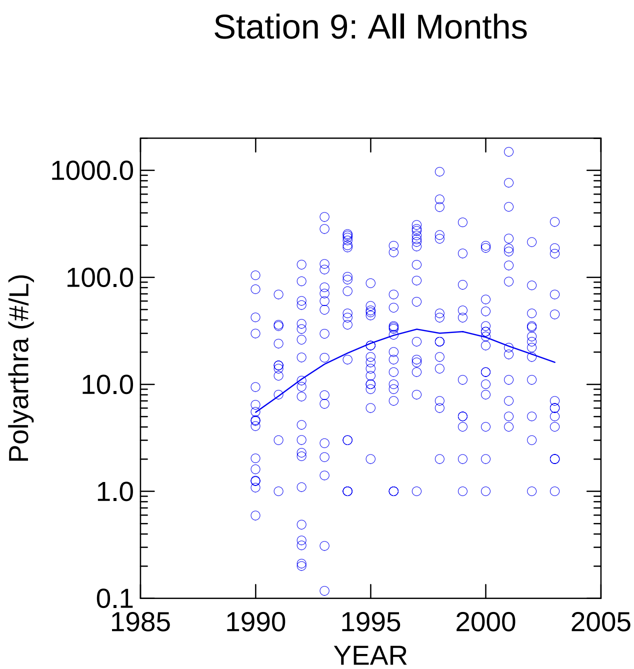
In the river *Keratella* showed evidence of continued decline in 2003 with the trend line reaching about 50/L, down from 100/L in the mid to late 1990's (Figure 131). Over the entire period of record there was strong evidence for a linear trend (Table 12).

Figure 131. Long term trend in *Keratella*. Station 9. Gunston Cove.



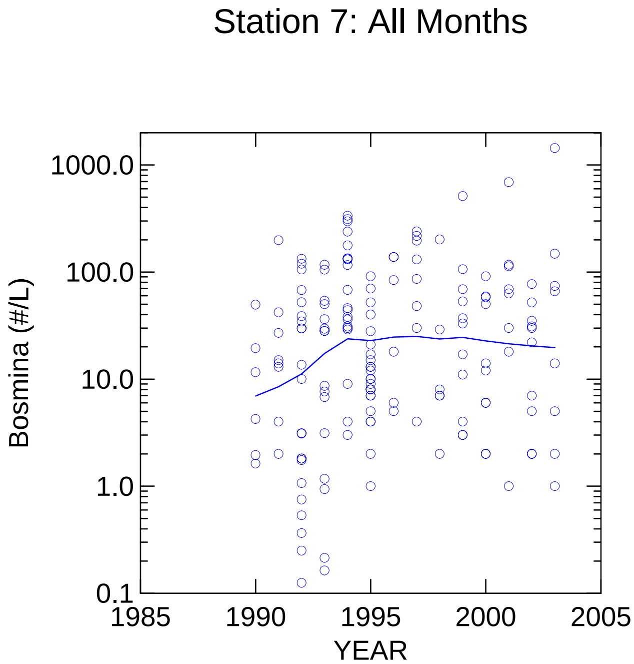
The trend line for *Polyarthra* in the cove pointed downward in 2003 to about 40/L, a slight drop from the peak in 1999 (Figure 132). However, this was higher than the values of about 15/L found in 1990. Regression analysis indicated a significant linear increase when the entire period of record was examined (Table 12).

Figure 132. Long term trend in *Polyarthra*. Station 7. Gunston Cove.



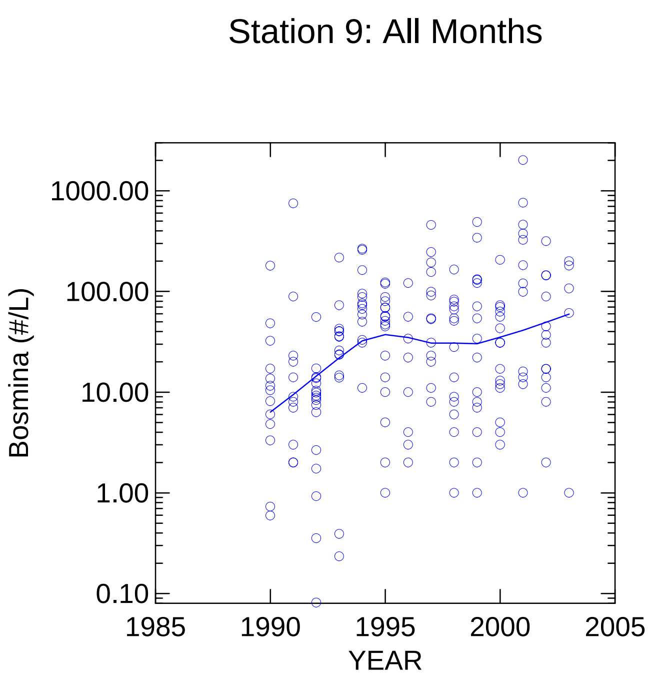
In the river *Polyarthra* also declined with the LOWESS line reaching about 20/L, down from about 30/L in 1997, but well above 5/L in 1990 (Figure 133). Linear regression analysis indicated a significant trend over the period of record (Table 12).

Figure 133. Long term trend in *Polyarthra*. Station 9. River mainstem.



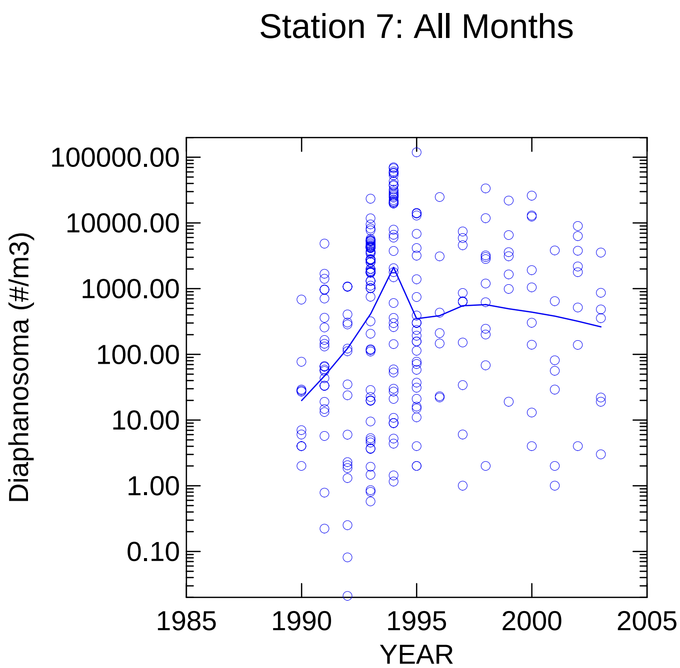
Bosmina in the cove exhibited a continued flat trend in 2003 with the LOWESS line suggesting about 20/L, up from about 7/L in 1990 (Figure 134). Linear regression indicated a weak linear increase over the entire period of record (Table 12).

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



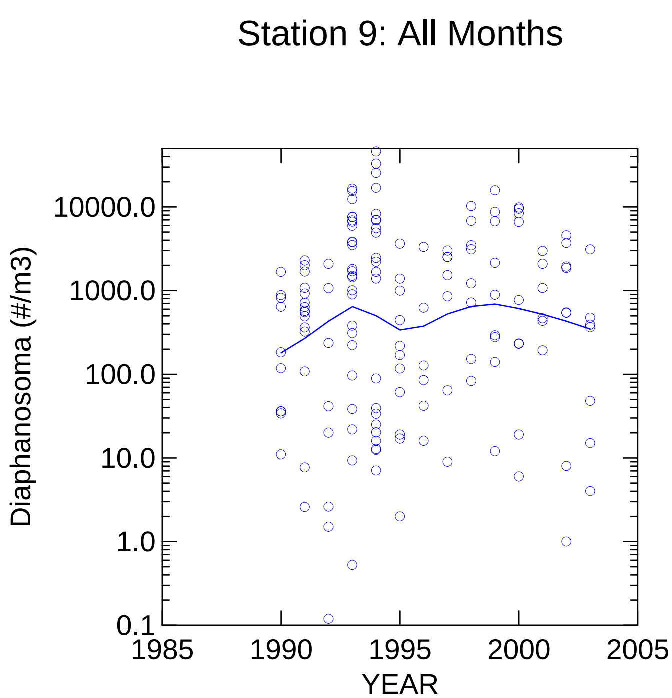
In the river mainstem a slight upward trend in *Bosmina* was suggested by the LOWESS curve to about 60/L, higher than the 30-40/L for the period 1995-2001 (Figure 135). This value was much greater than 6/L found for 1990. Regression analysis indicated strong support for an increase over the entire period of record (Table 12).

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



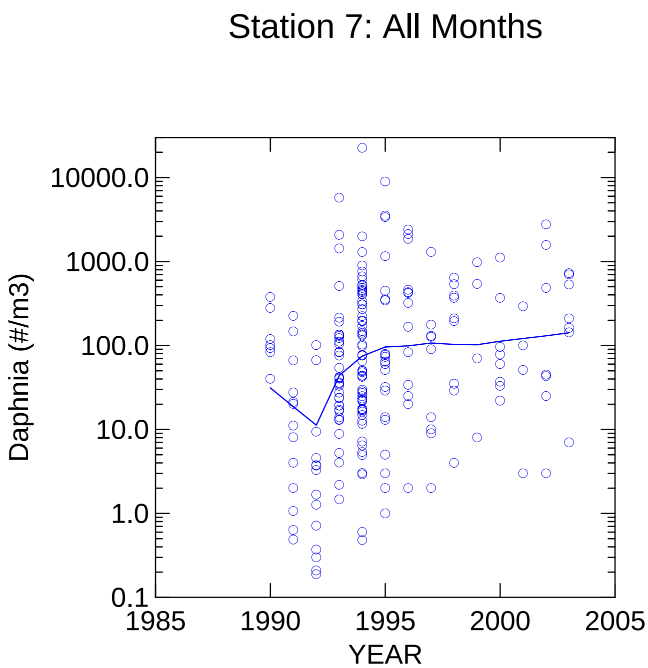
Diaphanosoma continued a very slight downward trend which has characterized the period since 1997 (Figure 136). The LOWESS line suggested 300/m^3 in 2003 compared with 500/m^3 in 1997. Both values were substantially above the 20/m^3 for 1990. Linear regression analysis of the entire period of record indicated a marginally significant increase over the period of record (Table 12).

Figure 136. Long term trend in *Diaphanosoma*. Station 7. Gunston Cove.



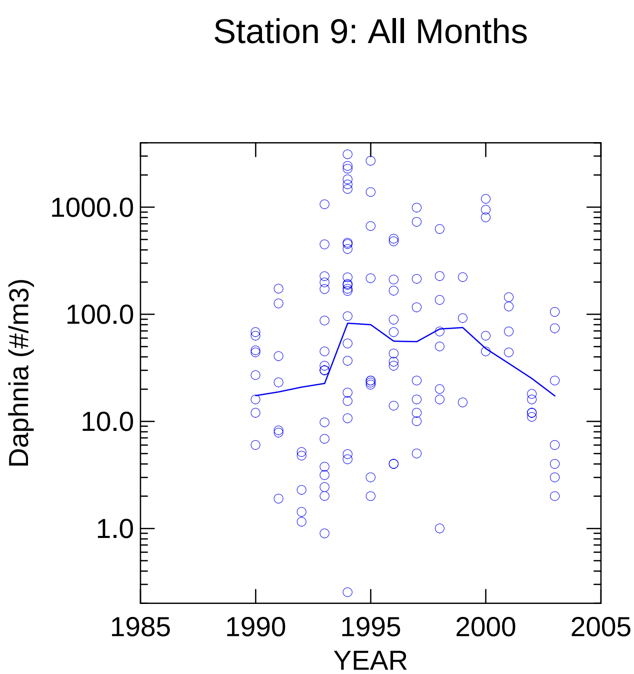
In the river the LOWESS line suggested continuation of a slight decline in *Diaphanosoma* which started in 1999 (Figure 137). The value of 300/m^3 found in 2003 compared with values as high as 800/m^3 in 1999 and 1993 and values as low as 200/m^3 in 1990. Regression analysis indicated no significant linear trend over the period of record (Table 12).

Figure 137. Long term trend in *Diaphanosoma*. Station 9. River mainstem.



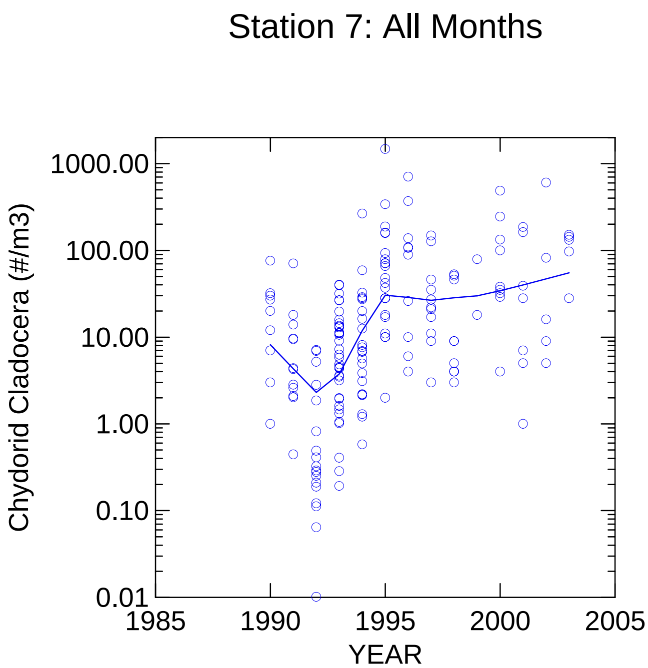
Daphnia exhibited a slight increase in 2003 with the trend line reaching almost 150/m^3 (Figure 138). This is up from the low of about 10/m^3 in 1992 and the value of 40/m^3 in 1990. Regression analysis over the period of record gave strong support for a linear increase (Table 12).

Figure 138. Long term trend in *Daphnia*. Station 7. Gunston Cove.



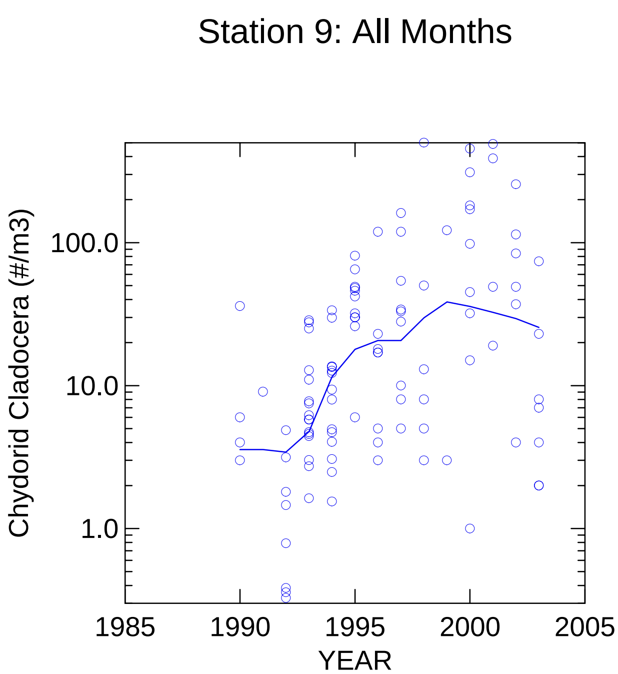
Daphnia in the river continued a decline which has been apparent since 1999 (Figure 139). The trend line in 2003 reached 20/m^3, roughly equal to the level observed at the beginning of the record in 1990. Regression analysis indicated no significant linear trend over the study period (Table 12).

Figure 139. Long term trend in *Daphnia*. Station 9. River mainstem.



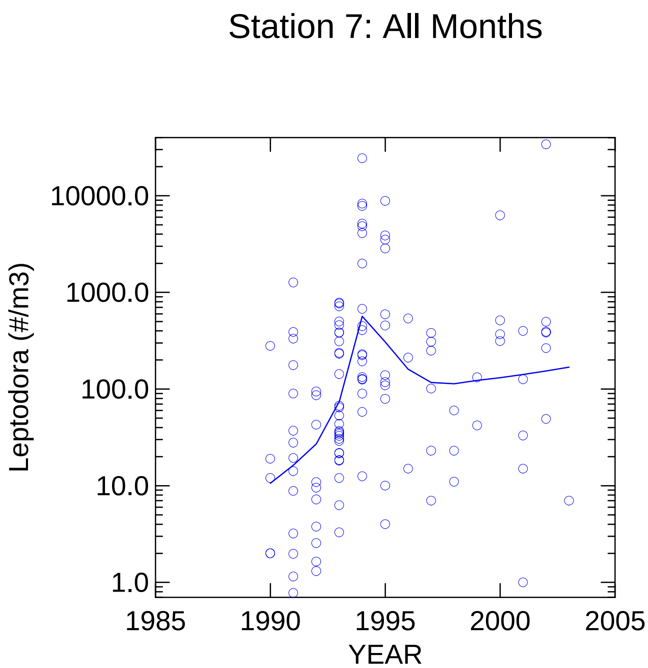
Chydorid cladocera in the cove continued a gradual increase to about 60/m^3, substantially higher than the low of 3/m^3 in 1992 and the initial value of 8/m^3 in 1990 (Figure 140). Regression analysis gave strong evidence for a linear increase over the study period (Table 12).

Figure 140. Long term trend in Chydorid Cladocera. Station 7. Gunston Cove.



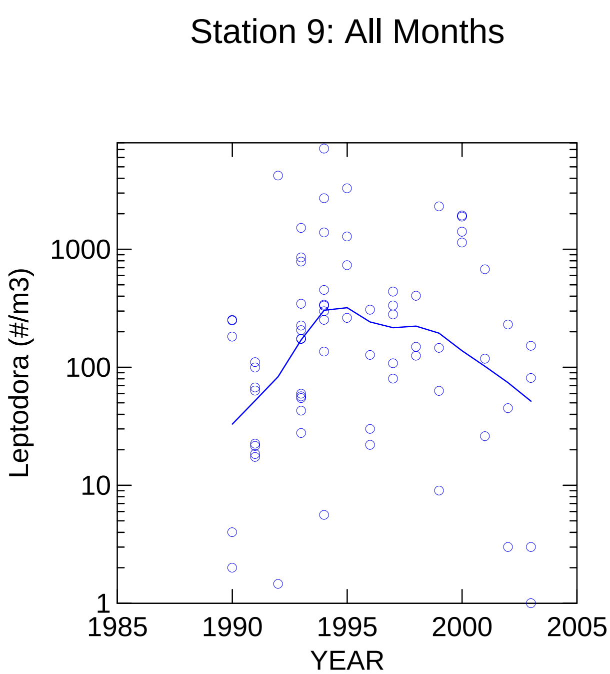
In the river mainstem chydorids exhibited a slight decline in 2003 to about 25/m^3 from the 1999 high of 40/m^3 but well above the low of about 4/m^3 in the early 1990's (Figure 141). A strong linear increase in chydorids over the entire study period was indicated by linear regression analysis (Table 12).

Figure 141. Long term trend in Chydorid Cladocera. Station 9. River mainstem.



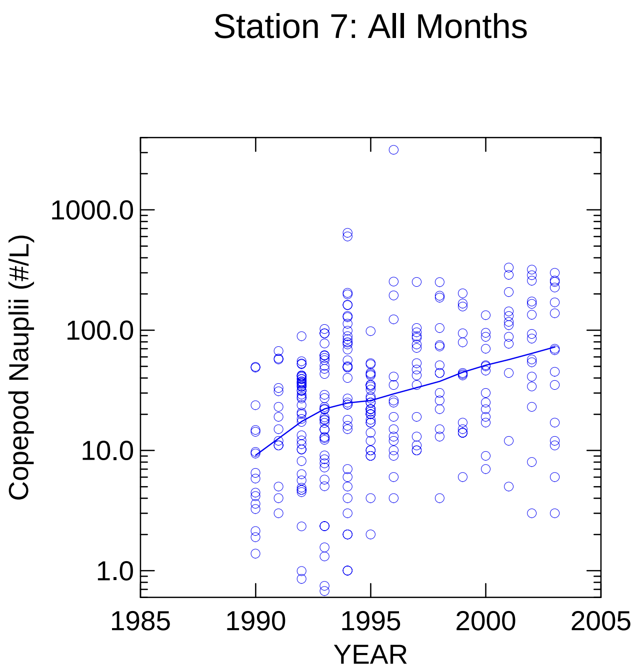
In the cove *Leptodora*, the large predaceous cladoceran, remained fairly steady in 2003 at about 200/m^3, down from its high of about 700/m^3 in 1994, but well above the 1990 value of 10/m^3 (Figure 142). There was good evidence for a significant linear increase in Leptodora over the entire study period (Table 12).

Figure 142. Long term trend in *Leptodora*. Station 7. Gunston Cove.



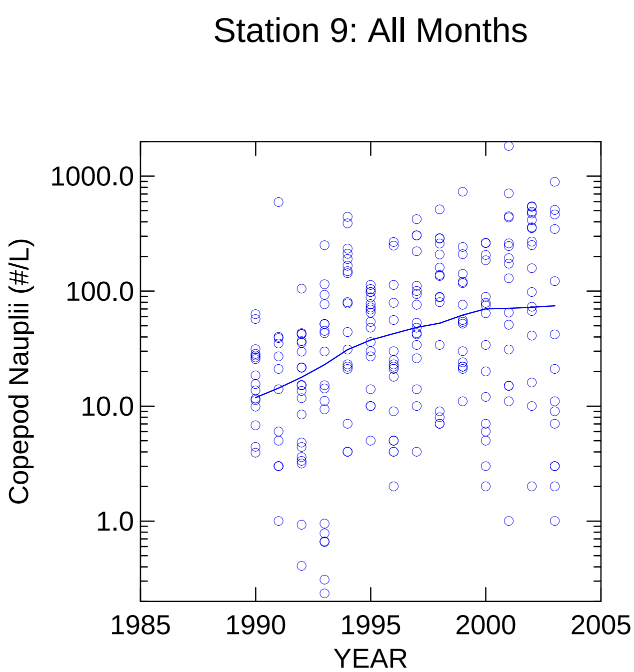
In the river, *Leptodora* continued a decline which began in 1995 and resulted in trend line values of about 50/m^3 for 2003 (Figure 142). These values are only slightly higher than those observed in 1990. Linear regression analysis did not detect a significant linear trend when the whole study period was considered (Table 12).

Figure 142. Long term trend in *Leptodora*. Station 9. River mainstem.



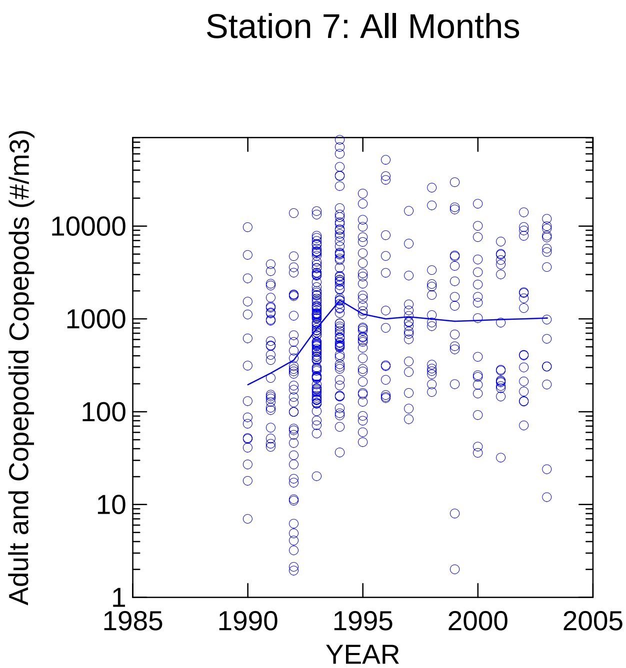
Copepod nauplii, the immature stages of copepods, continued their steady increase (Figure 144). Trend line values reached 70/L in 2003 well above the initial level of 10/L observed in 1990. A strong linear increase was observed over the study period (Table 12).

Figure 144. Long term trend in Copepod Nauplii. Station 7. Gunston Cove.



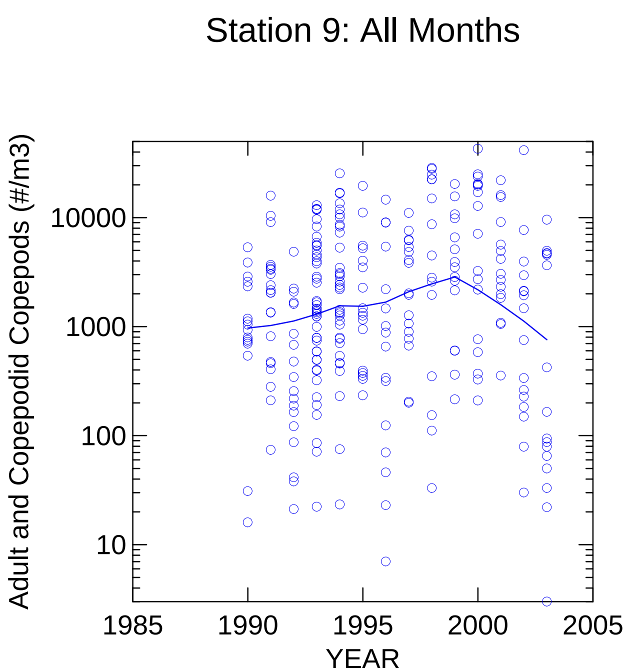
In the river mainstem, copepod nauplii also continued to increase albeit at a slower rate (Figure 144). The 2003 LOWESS trend line value was 80/L, up from an initial value of 10/L in 1990. There was good evidence for a significant linear increase in nauplii over the study period (Table 12).

Figure 144. Long term trend in Copepod Nauplii. Station 9. River mainstem.



Adult and copepodid copepods remained constant during 2003 continuing a trend begun in the mid-1990's (Figure 147). The 2003 level of about 1000/m^3 was well above the initial level of 200/m^3 observed in 1990. Copepods exhibited a significant linear increase over the study period (Table 12).

Figure 147. Long term trend in Adult and Copepodid Copepods. Station 7. Gunston Cove.



Adult and copepodid copepods declined in 2003 continuing a trend begun in 1998 (Figure 148). The trend line in 2003 reached 800/m^3, well below the maximum of 3000/m^3 in 1998 and slightly below 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 148. Long term trend in Adult and Copepodid Copepods. Station 9. River mainstem.

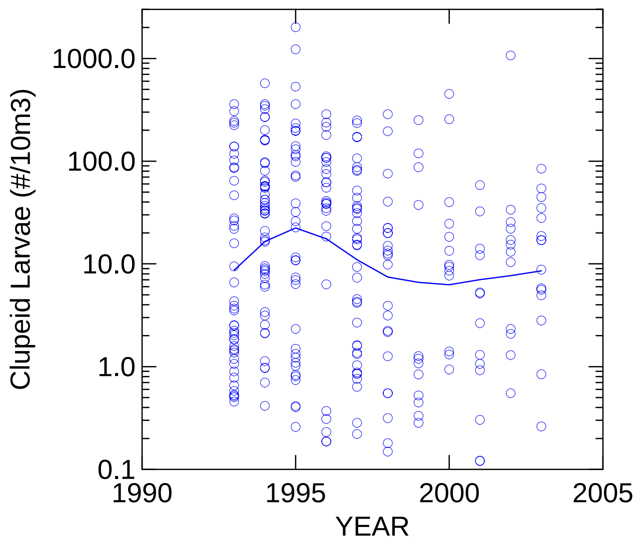


Figure 148. Long term trend in Clupeid Larvae.

A graph of clupeid fish larvae averaged over all stations from 1993 through 2003 is shown in Figure 148. 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 indicates a continued slight rise in clupeid larvae per 10 m^3 since a low in 2000. This appears to reflect mostly the increase in gizzard shad larvae in the river, but also indicates the continued moderately strong presence of alewife and blue-back herring larvae in the cove and the river .

E. Ichthyoplankton Trends

The total number of fish larvae caught was lower in 2003 than it had been in 2002. The greatest drop in abundance was in *Alosa* sp. larvae. The catch in 2003 was only 26.6 % of the 2002 catch. Even when the number caught is divided by the volume of water filtered to capture them, the catch per $10m^3$ of clupeid larvae in 2003 (Fig. 57.) was much lower than that of 2002. However, the number of gizzard shad larvae caught was more than twice as great in 2003 as it was in 2002. The number of white perch larvae caught was about 75% of that of the previous year, but when corrected for volume of water filtered, the number per $10m^3$ in 2003 (Fig. 58.) reached a peak value slightly greater than that of 2002..

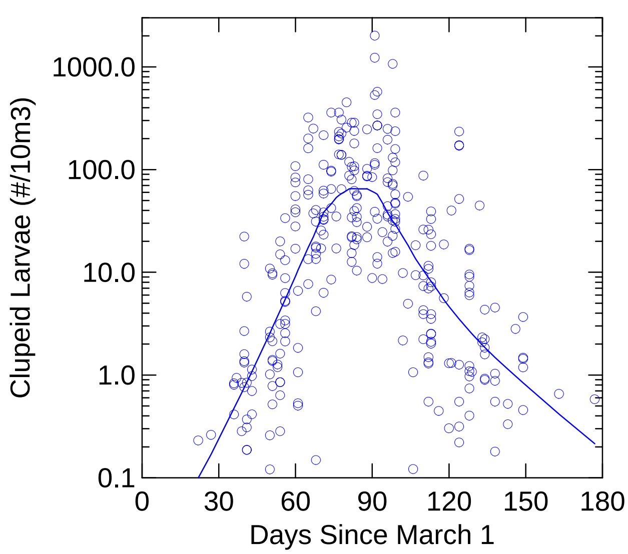
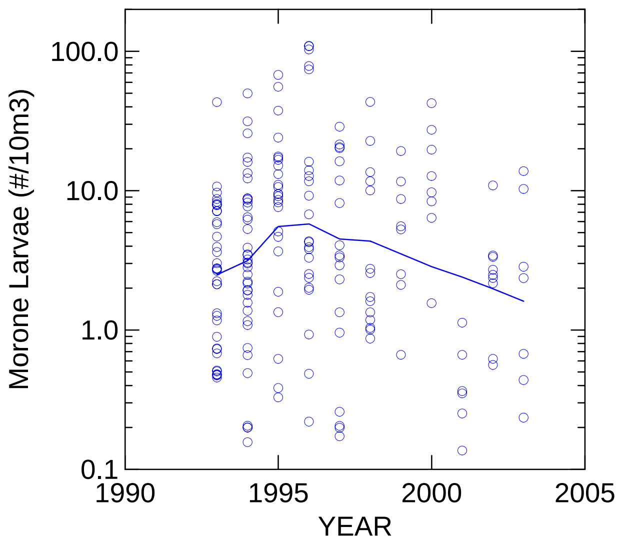


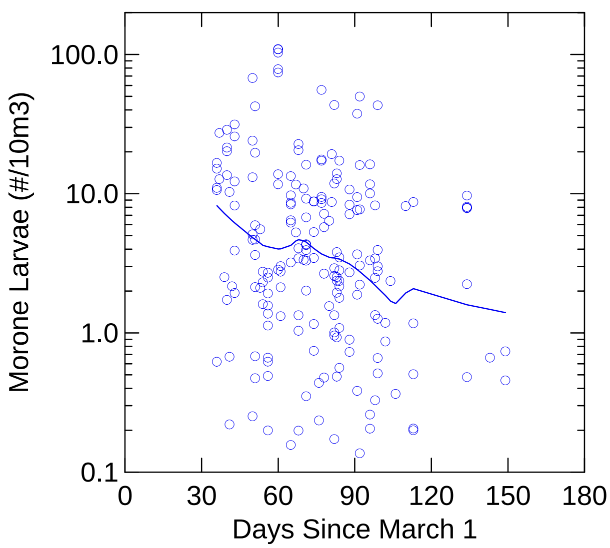
Figure 149. Seasonal pattern in Clupeid Larvae.

The seasonal pattern clupeid larvae for 1993-2003 (Figure 149) that a peak in density occurs about 80-85 days after March 1, or in the last two weeks of May. A first explanation of the timing and breadth of the peak most certainly lies in the interannual variability of the development of warming of the creek and cove water. A second explanation is the sequentially extended spawning period by the three dominant clupeid species. The occurrence of the peak late in the spring may indicate a dominance of gizzard shad larvae in the data.



The trend in number of white perch larvae per 10 m^3 since 1993 is depicted in the LOWESS graph in Figure 150. A steady decline in abundance is shown since 1996, despite what appears to be slightly higher values in 2003.

Figure 150. Long term trend in *Morone* Larvae.



The seasonal occurrence of number of white perch larvae per 10 m^3 is shown in Figure 151. 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 151. Seasonal pattern in *Morone* Larvae.

In Lippson et al. (1979) the distribution of striped bass eggs is shown for 1974 and 1975 to be primarily below Quantico and Douglas Point, but with lower abundances up the river as far as Alexandria. In 1976 the highest concentration was dispersed over a stretch from Quantico to Mount Vernon. The larvae were generally found in greater numbers downriver of the location of the eggs, but were present at low levels in the main channel off Gunston Cove in all three years. The young larvae of *Morone* spp. are difficult to distinguish into species, but the older larvae are clearly different. We feel confident that most of the larvae we collect are *Morone americana*.

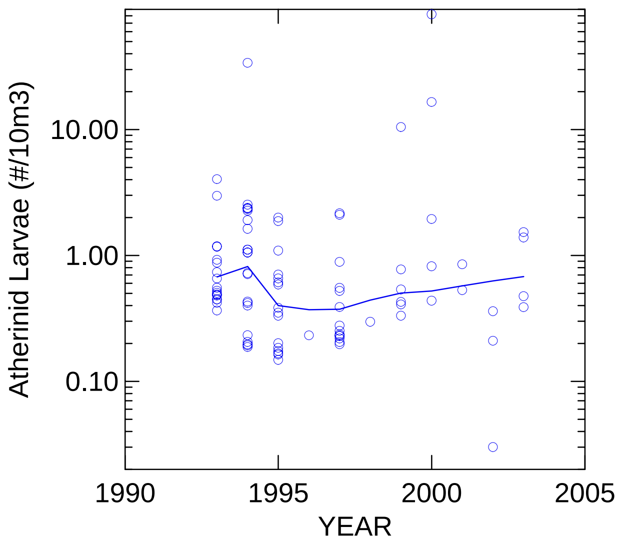


Figure 152. Long term trend in Atherinid Larvae.

The long term trend in density of Atherinid larvae (probably all inland silverside larvae) is presented in a LOWESS graph in Figure 152. A slightly increasing trend is evident since 1997. The number of atherinid larvae per 10m^3 caught in 2003 (Fig. 58.) was greater than that of 2002 These open water collections are probably not representative of the population of larvae in the cove, since they may remain in the shallows along the shore or in the

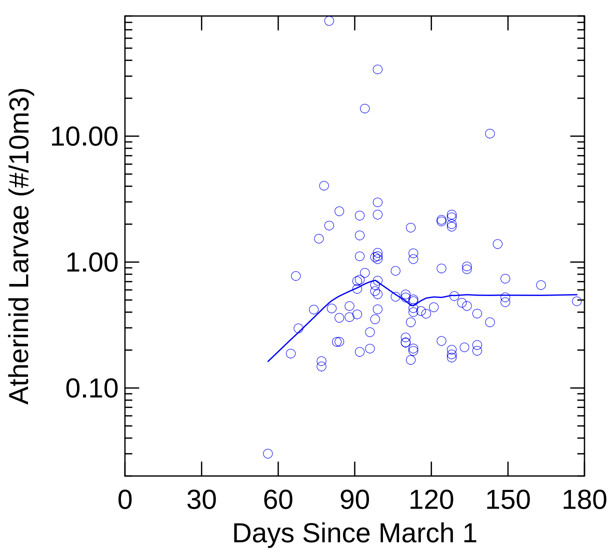
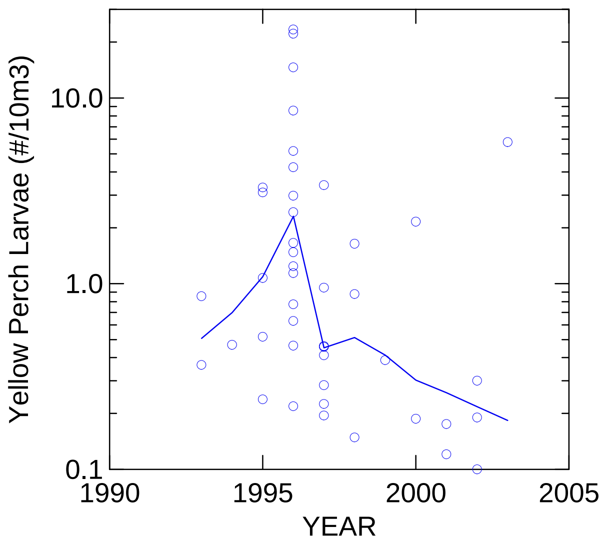


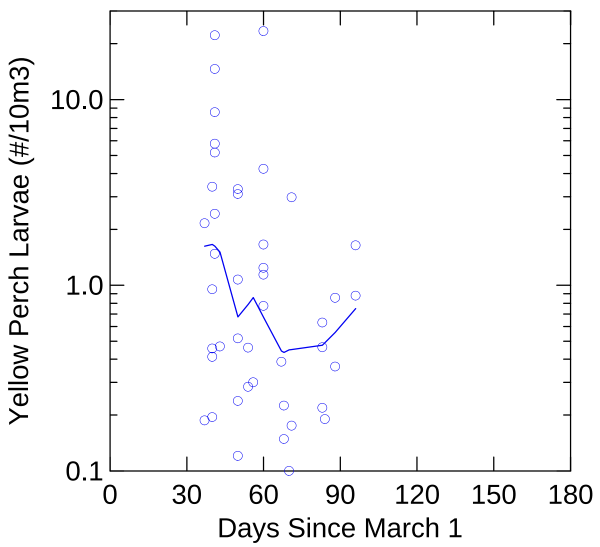
Figure 153. Seasonal pattern in Atherinid Larvae.

The seasonal occurrence of Atherinid larvae per 10m^3 is shown in a LOWESS graph in Figure 153. 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 154 gathers the trend in density of yellow perch since 1993. Following unusually high densities in 1996, the general trend is a decline to ever lower numbers.

Figure 154. 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 155. The greatest densities occur in early April, but larvae persist as late as early June.

Figure 155. Long term trend in Yellow Perch Larvae.

In summary, the trend in densities of fish larvae per 10 m^3 since 1993 indicate slightly increasing trends in gizzard shad larvae since 2000 and in inland silverside larvae since 1997, and declining trends in white perch larvae and yellow perch larvae since 1996. The two trends may be related, since the juveniles and adults of both increasing species of fish are prey of the juveniles and adults of the two species that are declining. However, this probably too simplistic to be the complete explanation.

F. Adult and Juvenile Fish Trends

Trawls

The mean annual catches per trawl at Stations 7 and 10 combined for the 20 years we have sampled are gathered in Table 13. Annual means are shown for all species combined and separately for eight typically abundant species. The mean catch of all species combined in 2003 was almost as low as the previous low of 1996. This is shown graphically in Fig. 156a. The LOWESS diagram (Fig. 156b.) indicates a continued slow increase since 1997, but that trend appears to be leveling off in 2003.

Most of the decline is apparently caused by the low numbers of YOY and juvenile white perch, whose average catch per trawl was lower than the previous low of 1989. Since white perch are known to spawn in Gunston Cove and also in the Potomac River from Alexandria to Aquia Creek (Lippson et al. 1979), the primary spawning area may just be shifted further upriver or further downriver. Since 2003 produced higher river discharge events in the spring than is typical (Fig. 2), the shift is more likely to have been downriver. However, the down trend has persisted through 4 or 5 years, and the pattern of river discharge has not been regular. The population of 2 year old and older white perch seems to be robust, and I think that we will see a continued dominance of the white perch population in Gunston Cove in future years. Nevertheless, the offshore bottom in the upper part of Pohick Bay and Accotink Bay and the shorelines of these bays are increasingly occupied by submersed aquatic vegetation (mostly *Hydrilla*), and this may be less suitable for white perch spawning or use by juveniles. It certainly interferes with sampling the fishes with either a trawl or a seine, and the presence of thick beds of submersed aquatic vegetation was noted at Station 10 as early as May 15. Indeed, reduced ability to catch the white perch that are there may explain part of the decline.

No juvenile or adult gizzard shad were collected in 2003 at all, though their numbers have been low since 1989. Fewer pumpkinseed were collected, but more bluegill were taken.

On the other hand, the mean catch per trawl of blueback herring was high in 2003, and the mean catch of alewife, bay anchovy, spottail shiner, and brown bullhead were comparable to most previous years.

The mean annual catch per trawl at Station 9 in the river channel for all species combined and for eight typically abundant species are presented in Table 14. Of the species considered at Station 9, only the bay anchovy catch and perhaps the spottail shiner catch might be judged low, and the abundance of bay anchovy is usually low in the trawls at Station 9. Larger numbers of white perch, brown bullhead, channel catfish, tessellated darter, and hogchoker have been caught since 2000. All are known to feed on benthic animals or on other fishes. This might be explained by an increase in the abundance of benthic animal prey associated with the placement of dredged sediment in the deep basin in the Potomac channel off Fort Belvoir.

Table 13
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
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 14
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	tesselated darter	hog-choker
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

When the two tables are combined for all three stations, as is done in Table 15, the mean catch of all species was lower than most years, but still was higher than that of 1996.

In summarizing the trawl catch data, the mean catch of white perch was almost as low as that of 1989 and was much lower than the typical catch of previous years. This accounts for most of the low combined catch for 2003, since white perch is the most abundant species. Gizzard shad and pumpkinseed also had low mean catches in 2003. The mean catches of alewife, spottail shiner, and brown bullhead were typical of previous years, and those of blueback herring, bay anchovy, and channel cat were higher than normal.

The number of trawls that were made at all stations combined is shown in Table 16. One fewer trawl set per month was done in August and September of 2003, but that does not seem to be an important factor in the lower catch of white perch.

The mean catch of all species combined at each station in 2003 and in previous years is presented in Table 17. This highlights the lower catch in 2003 especially at Station 10, and to a somewhat lesser degree at Station 7.

Commercial fish landing records of the Potomac River Fisheries Commission for 2003 (Peggy Hudson, personal communication) report the following catches of fish from the stretch of the tidal Potomac from Washington, D.C. to the electric power lines that cross the river at Possum Point above Quantico:

Channel catfish and blue catfish	29,686 lbs.
Bullheads	20,426
American eel	3,525
Striped bass	1,708
White perch	218

This is a harvest of a substantial quantity of fishes, and part of it is caught in the Gunston Cove area. Records from previous years have been requested.

No records are collected for the harvest made by sport fishermen.

Table 15
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
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 16
The number of trawls in each month at Stations 7, 9, and 10 in each year

Year	Station	Months: J	F	M	A	M	J	J	A	S	O	N	D
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 17
Mean catch of adult and juvenile fishes per trawl in all months at each station

Year	Station 10	Station 7	Station 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	

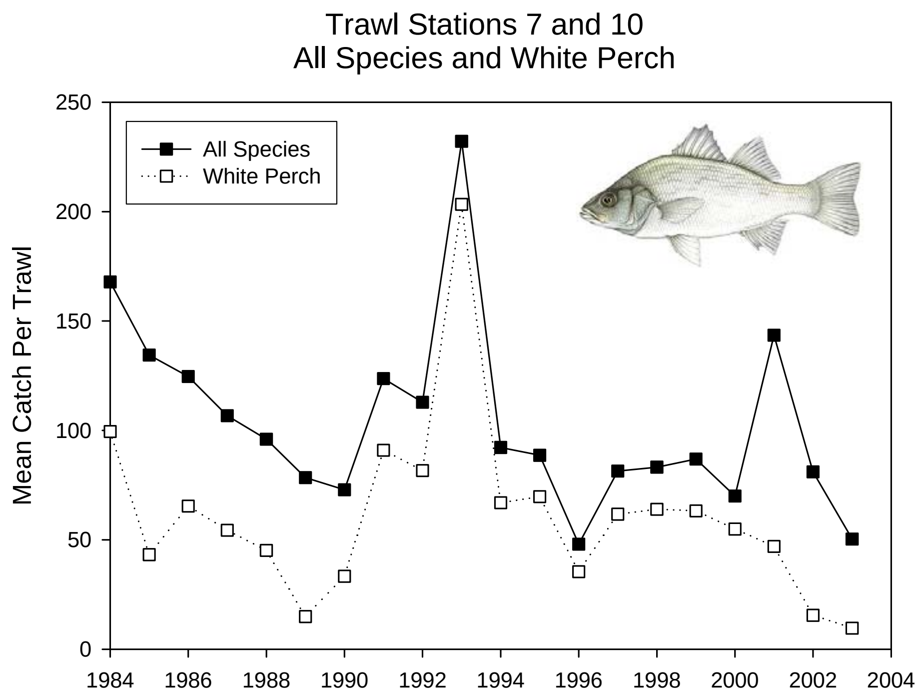


Figure 156a. Trawls. Annual Averages. All Species and White Perch. Cove Stations.

At cove stations, the mean catch of all species combined for 2003 was almost as low as the previous low of 1996 (Figure 156a). Interestingly, the three lows in white perch all occurred in wet years. The LOWESS trend line did not pick this up, but indicated continuation of slightly reduced catch per trawl (Figure 156b). Most of the decline in 2003 was due to the poor performances of white perch indicated by both the average number and the LOWESS trend line (Figures 156a and 156c). The number of white perch found in 2003 was the lowest of any year since the study began in 1984 and was the second year of very low catches. The LOWESS line suggested a consistent trend of lower values from 1995 through 2003 for white perch.

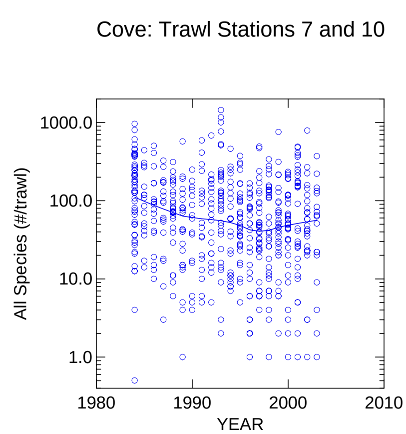


Figure 156b. Trawls. Long Term Trend in Total Catch.

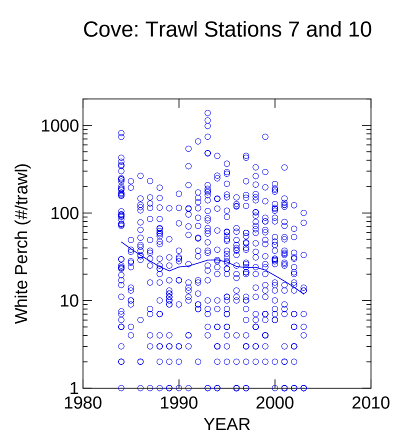


Figure 157c. Trawls. Long term trend in White Perch (*Morone americana*)

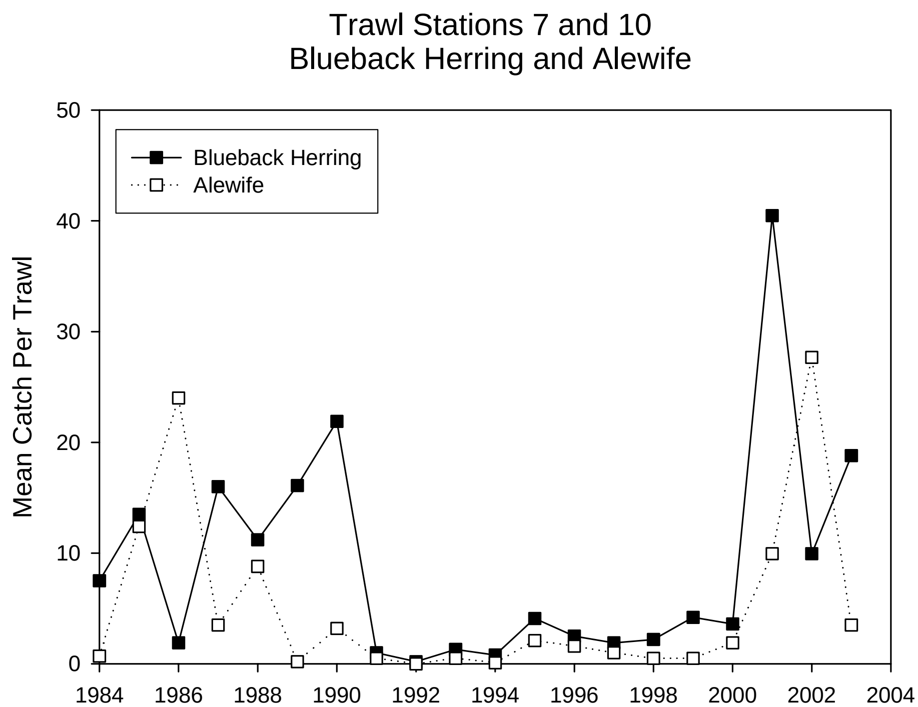


Figure 157a. Trawls. Annual Averages. Blueback Herring and Alewife. Cove Stations.

The mean catch of blueback herring in Gunston Cove was quite high in 2003 (Figure 157a) reflecting a trend of increasing abundances of this species suggested by the LOWESS plot as having been underway since about 1996 (Figure 157b). The abundance of alewife was lower in 2003 than in 2002, but higher than the 1990's. The LOWESS plot suggested a continuing increase in alewife (Figure 157c).

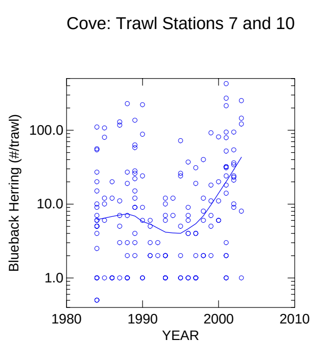


Figure 157b. Trawls. Long term trend in Blueback Herring (*Alosa aestivalis*). Cove Stations.

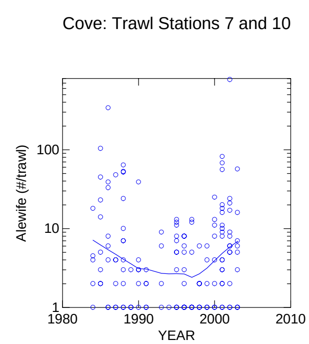


Figure 157c. Trawls. Long term trend in Alewife (*Alosa pseudoharengus*). Cove Stations.

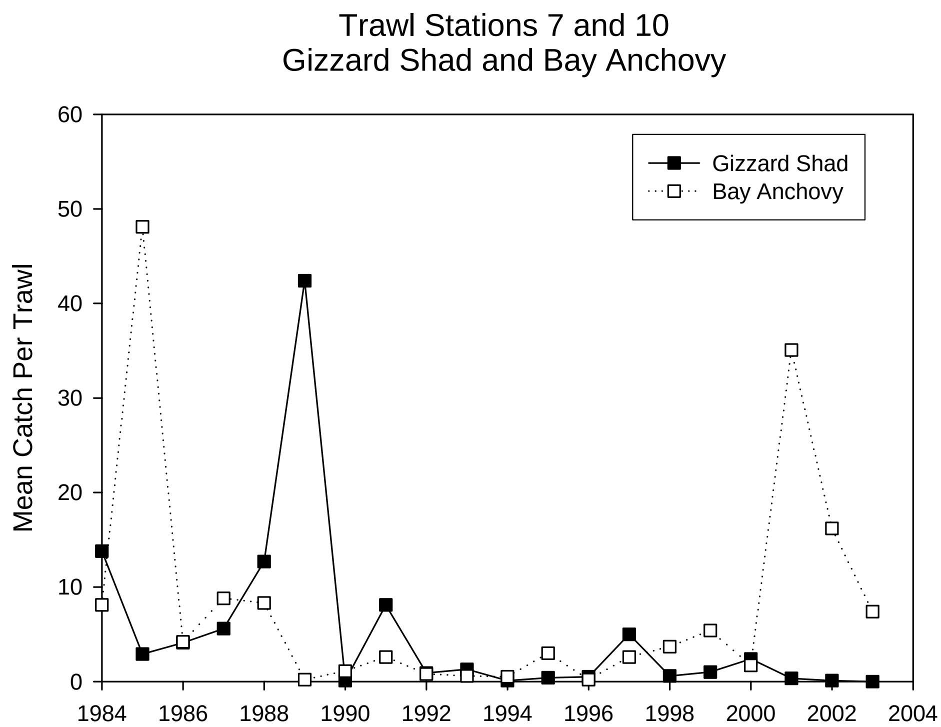
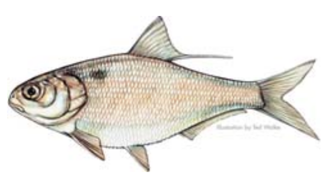
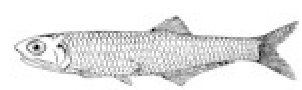


Figure 158a. Trawls. Annual Averages. Gizzard Shad and Bay Anchovy. Cove Stations.

Gizzard shad were not observed in the Gunston Cove trawls in 2003 (Figure 158a), continuing a trend of low or no catches in recent years (Figure 158b). Bay anchovy, on the other hand, were fairly abundant in 2003, being found at higher levels than during the 1990's and continuing a general upward trend in the LOWESS plots (Figure 158c).





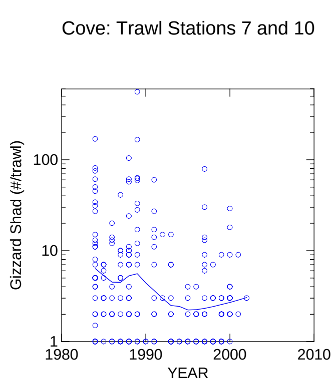


Figure 158b. Trawls. Long term trend in Gizzard Shad (*Dorosoma cepedianum*). Cove Stations.

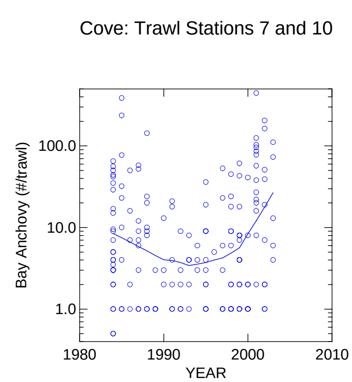


Figure 158c. Trawls. Long term trend in Bay Anchovy (*Anchoa mitchilli*). Cove Stations.

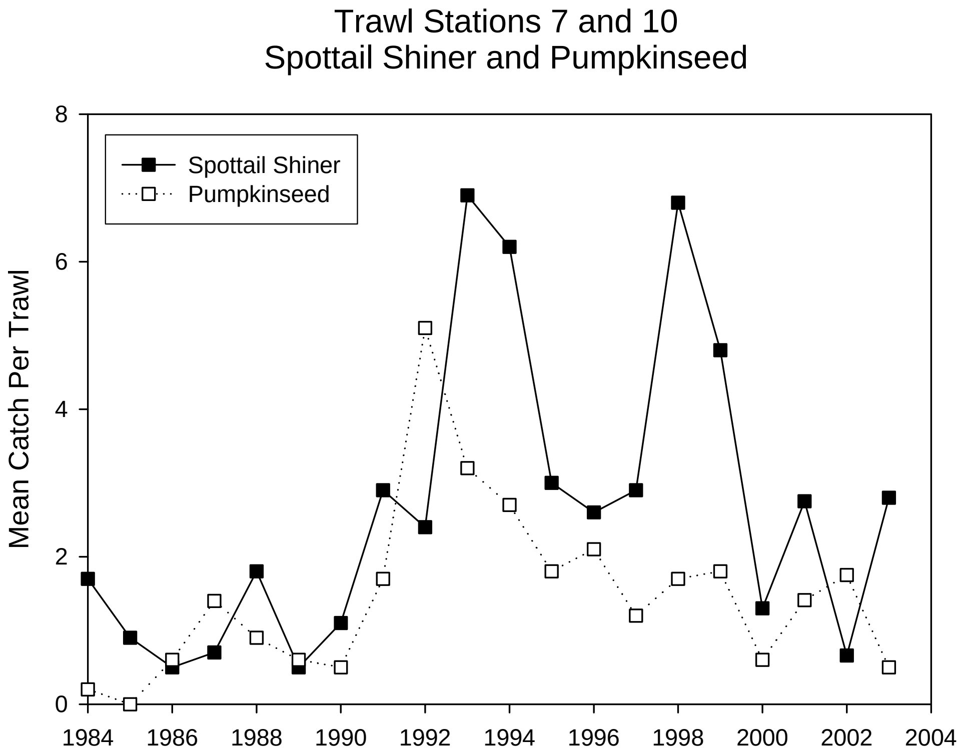
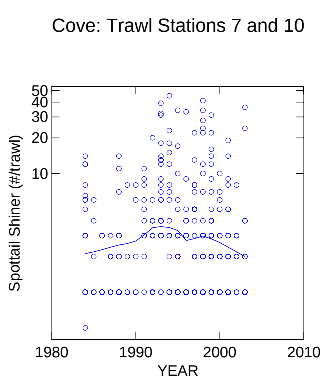


Figure 159a. Trawls. Annual Averages. Spottail Shiner and Pumpkinseed. Cove Stations.

Spottail shiner was collected at moderate densities in 2003 in Gunston Cove (Figure 159a), down from its peak in the 1990's (Figure 159b). Pumpkinseed was found at relatively low levels in 2003, down from its peak in the early 1990's (Figure 159c).



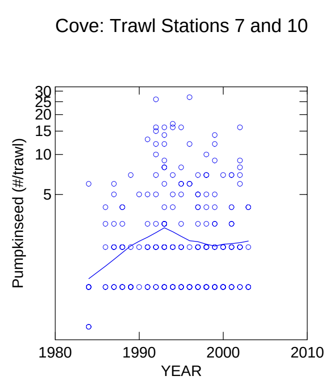


Figure 159b. Trawls. Long term trend in Spottail Shiner (*Notropis hudsonius*). Cove Stations.

Figure 159c. Trawls. Long term trend in Pumpkinseed (*Lepomis gibbosus*). Cove Stations.

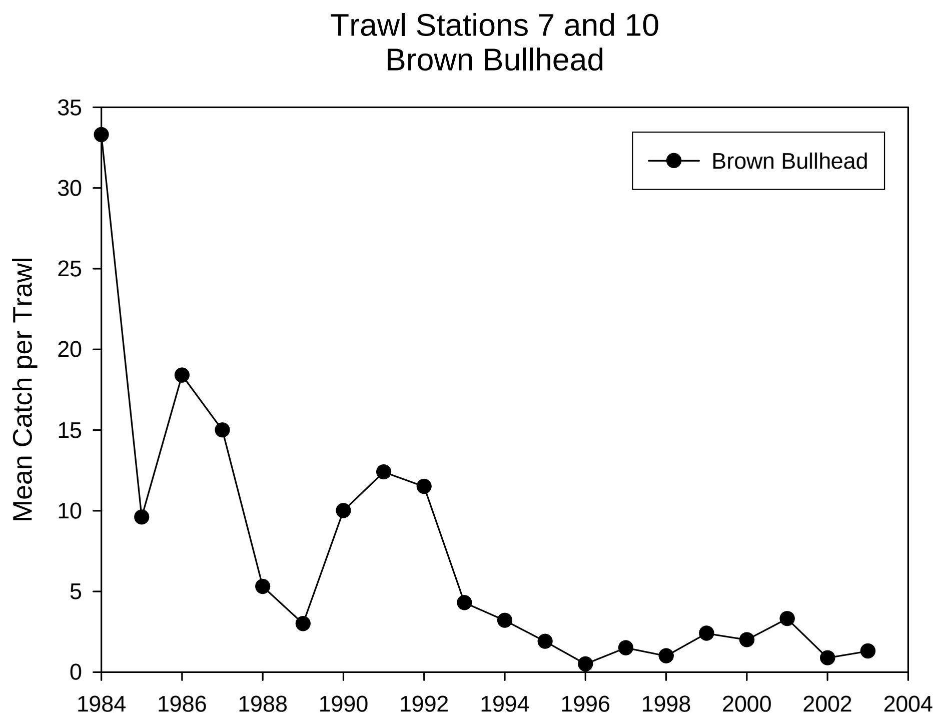
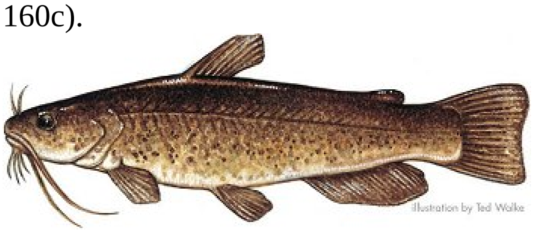
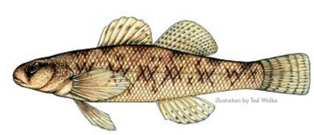
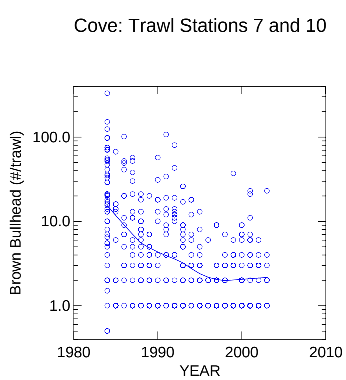


Figure 160a. Annual Averages. Brown Bullhead. Cove Stations.

Brown bullhead continued to be present in the cove, but at low levels in 2003 trawls (Figure 160a). The clear decline from over 10 to 1-2 per trawl is also clearly shown in the LOWESS plot (Figure 160b). Possible explanations include commercial harvest, increased water clarity, and disturbance from trawling. Tesselated darters were found at low levels in the trawls (Figure 160c).







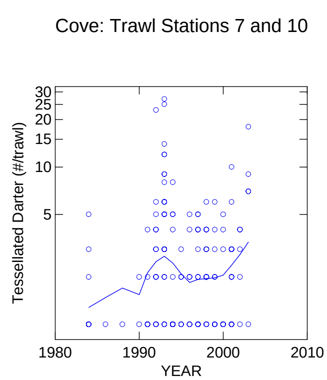


Figure 160b. Trawls. Long term trend in Brown Bullhead (*Ameirus nebulosus*). Cove Stations.

Figure 160c. Trawls. Long term trend in Tessellated Darter (*Etheostoma olmstedi*). Cove Stations.

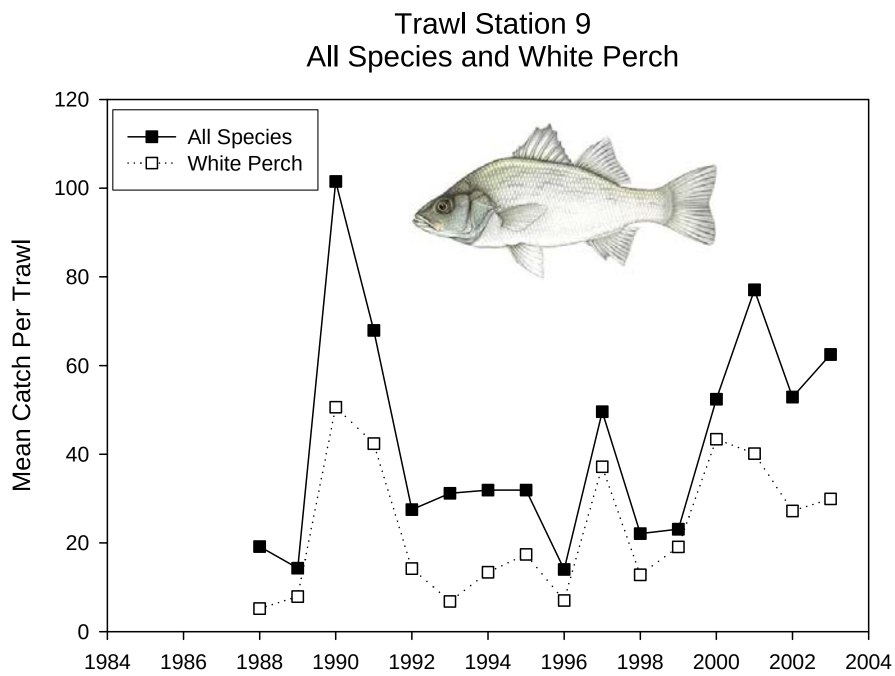


Figure 161a. Trawls. Annual Averages. All Species and White Perch. River Station.

Total trawl catch in the cove in 2003 was in the high end of the range of values for recent years (Figure 161a). The LOWESS plot suggested a continuing increase in total trawl catch since the late 1990's (Figure 161b). White perch had a moderately strong year in the river (Figure 161a), making up about half of the total trawl catch. This was part of a general increase that has occurred since the mid-1990's. The increase in several fish species at this station may reflect an increase in benthic macroinvertebrate food resources following the placement of dredge sediment in winter 1999-2000.

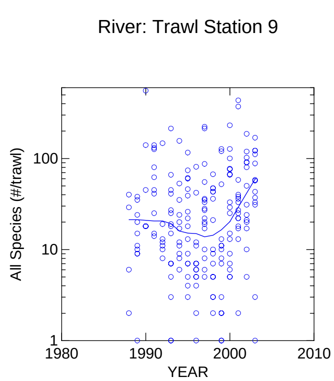


Figure 161b. Trawls. Long term trend in Total Catch. River Station.

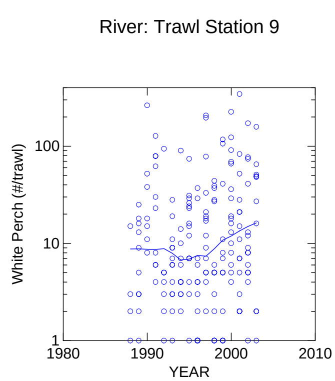


Figure 161c. Trawls. Long term trend in White Perch (*Morone americana*). River Station.

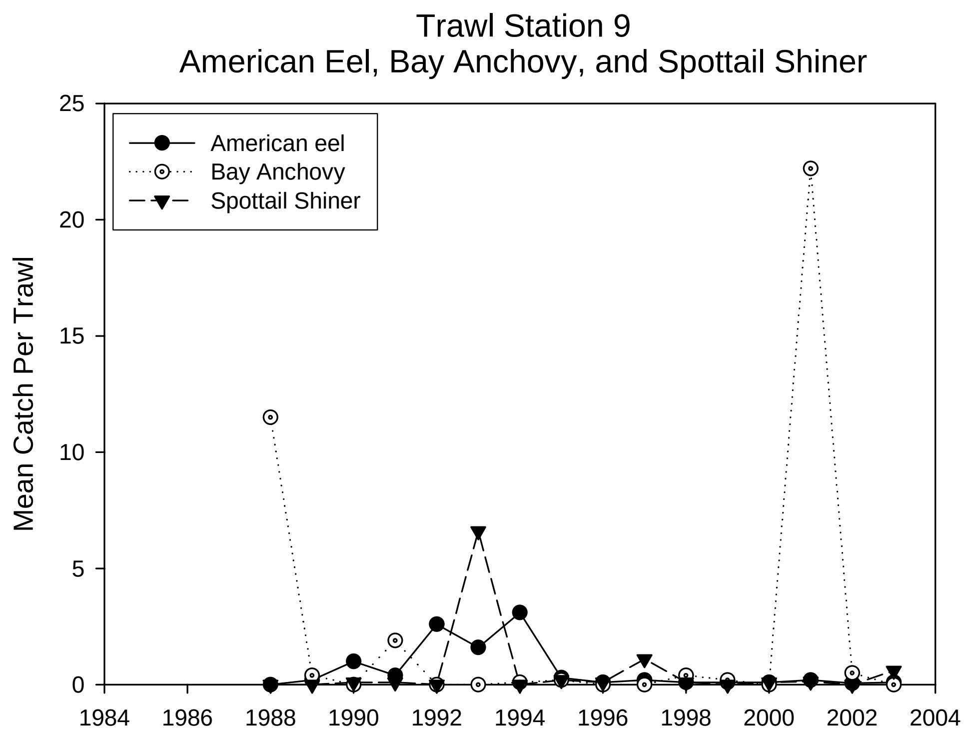
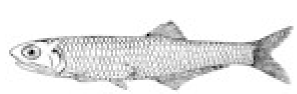
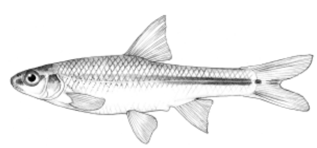
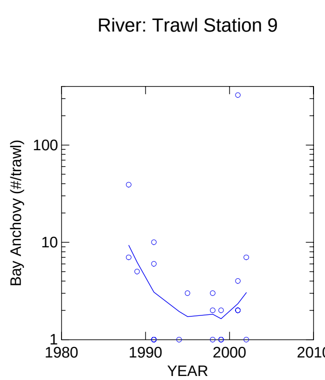


Figure 162a. Trawls. Annual Averages. Eel, Bay Anchovy, and Spottail Shiner. River Station.

Eel, bay anchovy, and spottail shiner were present in only very low densities in 2003 in the river (Figure 162a). Due to the variability and frequent zero values observed for these species, trends in abundance across years were not obvious (Figures 162b,c).







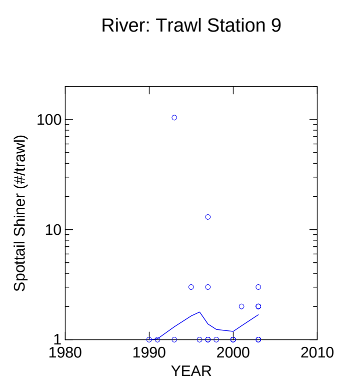


Figure 162b. Trawls. Long term trend in Bay Anchovy (*Anchoa mitchilli*). River Station.

Figure 162c. Trawls. Long term trend in Spottail Shiner (*Notropis hudsonius*). River Station.

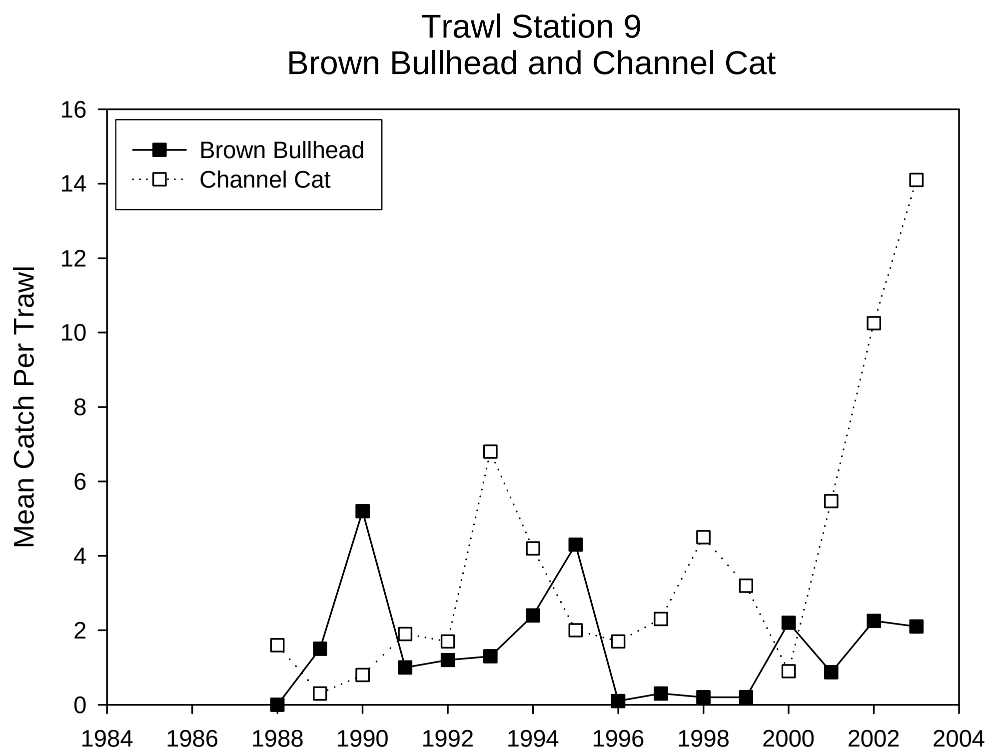


Figure 163a. Trawls. Annual Averages. Brown Bullhead and Channel Cat. River Station.

Brown bullhead were present in river trawls at moderate values in 2003 (Figure 163a). Values since 2000 have been a marked improvement over the lows in the late 1990's (Figure 163a,b). Channel cat increased incrementally again in 2003, reaching the highest level since the sampling at station 9 began in 1988 (Figure 163c).

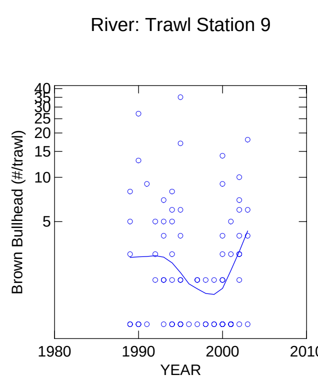


Figure 163b. Trawls. Long term trend in Brown Bullhead (*Ameiurus nebulosis*). River Station.

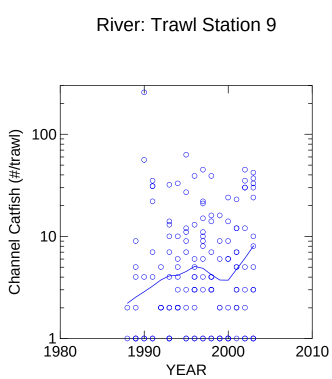


Figure 163c. Trawls. Long term trend in Channel Cat (*Ictalurus punctatus*). River Station.

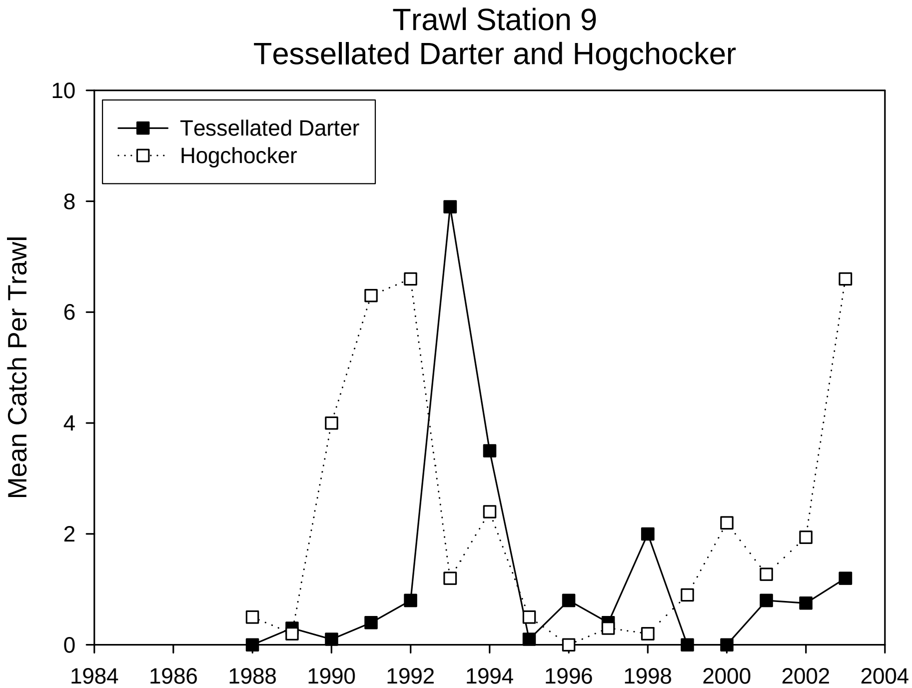
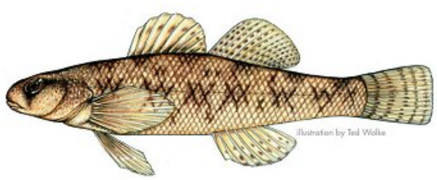
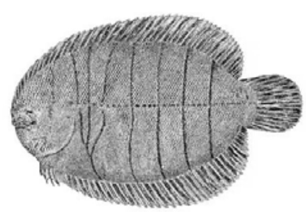
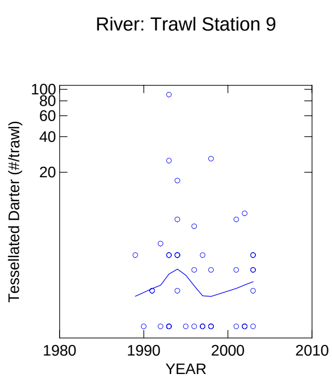


Figure 164a. Trawls. Annual Averages. Tessellated Darter and Hogchoker. River Station.

Tessellated darter (Figure 164a) was present at moderate levels in 2003 up slightly from 2002 and maintaining the upward trend since 2000 (Figure 164b). Hogchoker (Figure 164a) increased strongly in 2003 approaching the highest levels observed in the early 1990's. This continued a sustained increase since 1996.







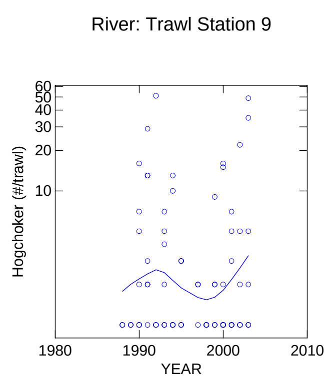


Figure 164b. Trawls. Long term trend in Tessellated Darter (*Etheostoma olmstedi*). River Station.

Figure 164c. Trawls. Long term trend in Hogchoker (*Trinectes maculatus*). River Station.

Seines

The mean annual catch per seine at Stations 4, 6, and 11 combined for the 19 years we have sampled are gathered in Table 18. Annual means are shown for all species combined and separately for six typically abundant species. The mean catch of all species combined is lower than most previous years, but is not by much. Again, most of the decline is because of the low catch of white perch, which is lower than all previous years, though it is almost the same as the seine catch in 1993. The 2003 seine catch of spottail shiner and inland silverside were also lower than that of most previous years, but again, not very much lower than the catch of several years. The seine catch of banded killifish was comparable to some of the highest of previous years' catches. The catches of blueback herring and alewife were typical of many previous years.

The number of seines made each month at the three stations in each year are shown in Table 19. The frequency of seine sampling in 2003 was similar to recent years, but had one less seine at each station in August and September. Over most of the entire study period the sampling regime has been consistent, although in a few years such as 1994 and 1986-87, there were some missing months or individual samplings. The mean catch per seine in each year at each seine station is presented in Table 20. The catch at Station 4 was lower than all but two previous years, but the catch at Station 6 was generally typical of most previous years, and the catch at Station 11 was higher than 12 of the 18 previous years.

To summarize the seine catch data, the abundance of white perch was very low, primarily because of fewer YOY in the catch. The catch of inland silverside YOY was also low. Blueback herring, alewife, and spottail shiner were caught in numbers comparable to most previous years. The catch of banded killifish remained very abundant and dominated the numbers of other species. The growth of more extensive beds of submersed aquatic vegetation (mostly *Hydrilla*) at Station 4 and, to a lesser degree, at Station 6, was much greater than in previous years. It was mentioned in the field notes as interfering with the seining process at Station 4 on October 9, but certainly was present there since early summer.

Table 18
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
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

Table 19
The number of seines in each month at Station 4, 6, and 11 in each year

Year	Station	J	F	M	A	M	J	J	A	S	O	N	D
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	

Table 20
Mean catch of adult and juvenile fishes per seine in all months at each station

Year	Station 4	Station 6	Station 11
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

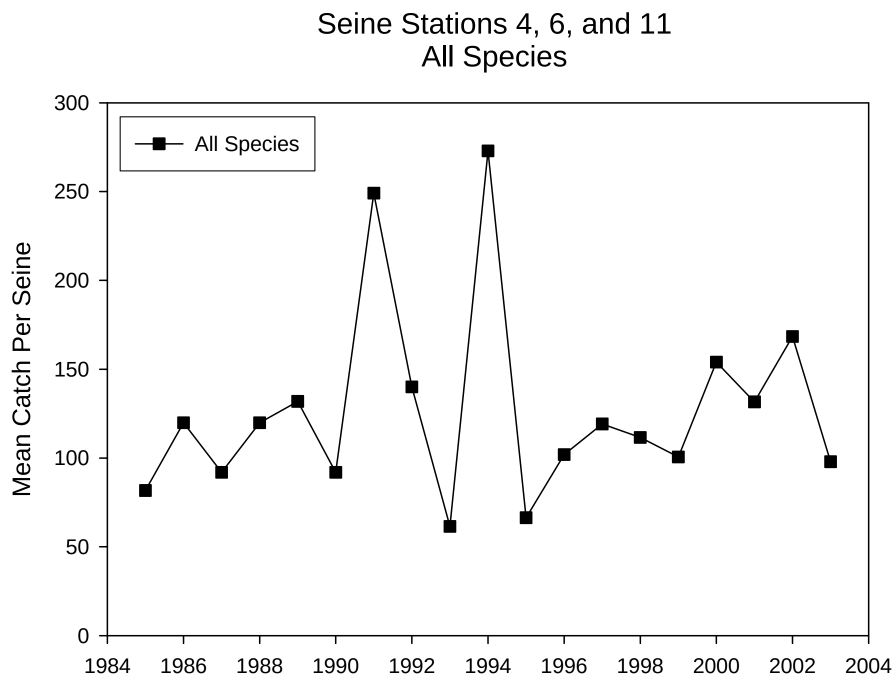


Figure 167. Seines. Annual Average over All Stations. All Species.

Mean catch per seine over all seine stations decreased in 2003, but remained at moderate values (Figure 167). The LOWESS line suggested a continued slight increase over the past 10 years.

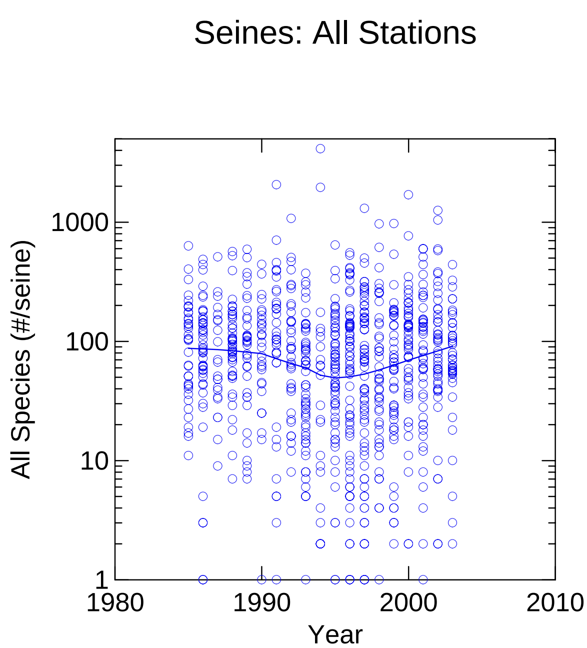


Figure 168. Seines. Long term trend in Total Trawl Catch.

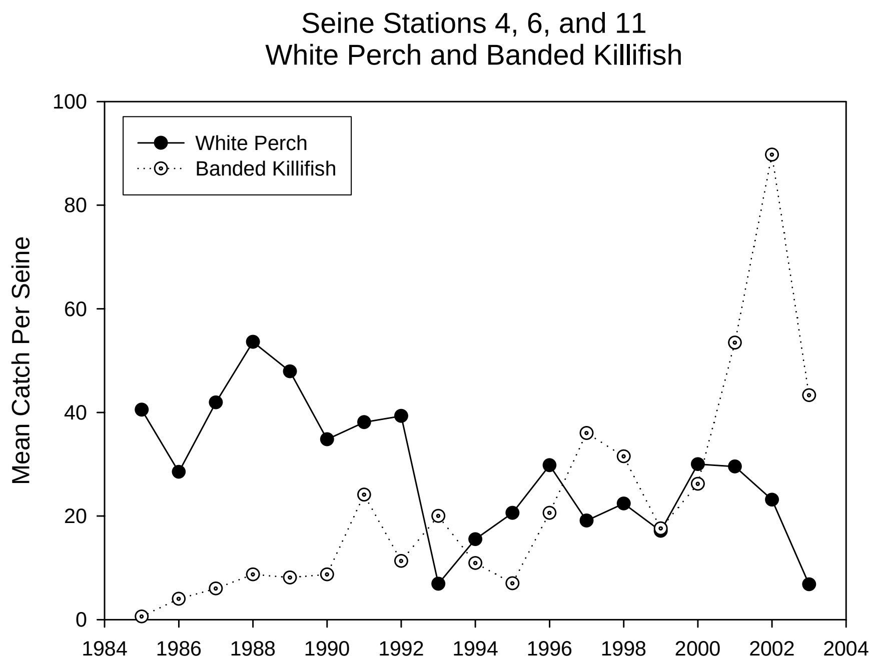


Figure 169. Seines. Annual Average over All Stations. White Perch and Banded Killifish.

White perch continued a long term decline in seine collections with a major decrease in 2003 to equal the lowest levels since the study began (Figure 169). This was somewhat contradicted by the LOWESS plot which showed a continued slight increase since the late 1990's (Figure 170). Banded killifish was lower than its peak in 2002, but still among the highest values recorded since the study began (Figure 169). The LOWESS plot suggested that the increase was still continuing (Figure 171).

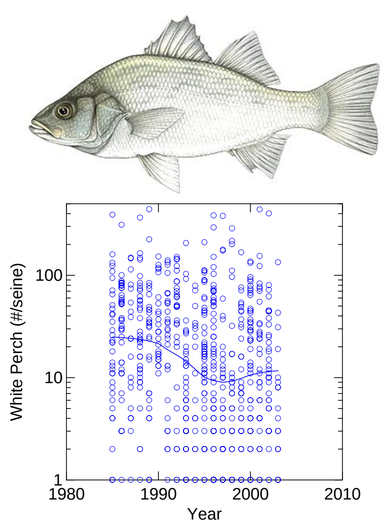


Figure 170. Seines. Long term trend in White Perch (*Morone americana*). All Stations.

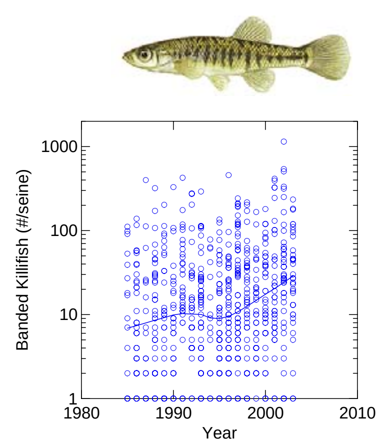


Figure 171. Seines. Long term trend in Banded Killifish (*Fundulus diaphanus*). All Stations.

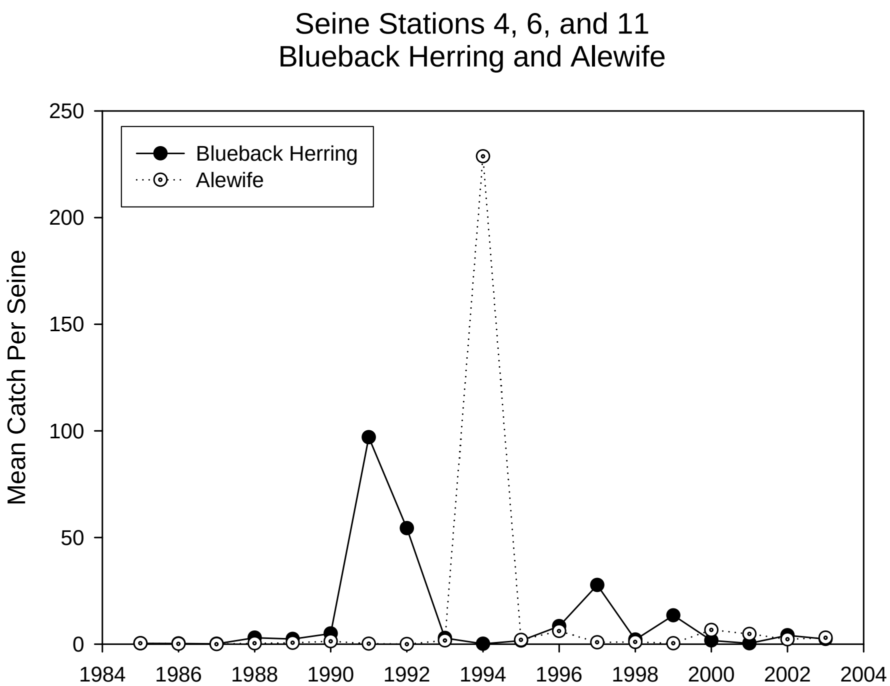


Figure 172. Seines. Annual Average over All Stations. Blueback Herring and Alewife.

Blueback herring and alewife were present in a number of seine samples in 2003, but when averaged over all samples did not obtain very large numbers. LOWESS trends were not strongly expressed, probably due to a large number of zero catches among the data set. The extremely high value in 1994 was the combination of a single very large catch and a reduced sampling regime. The catch of schooling alosids and anchovy is often hit or miss; if you happen to hit the school you can get very large catches.

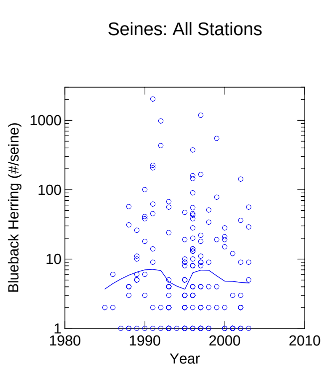


Figure 173. Seines. Long term trend in Blueback Herring (*Alosa aestivalis*). All Stations.

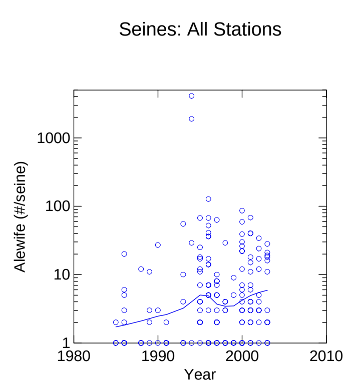


Figure 174. Seines. Long term trend in Alewife (*Alosa pseudoharengus*). All Stations.

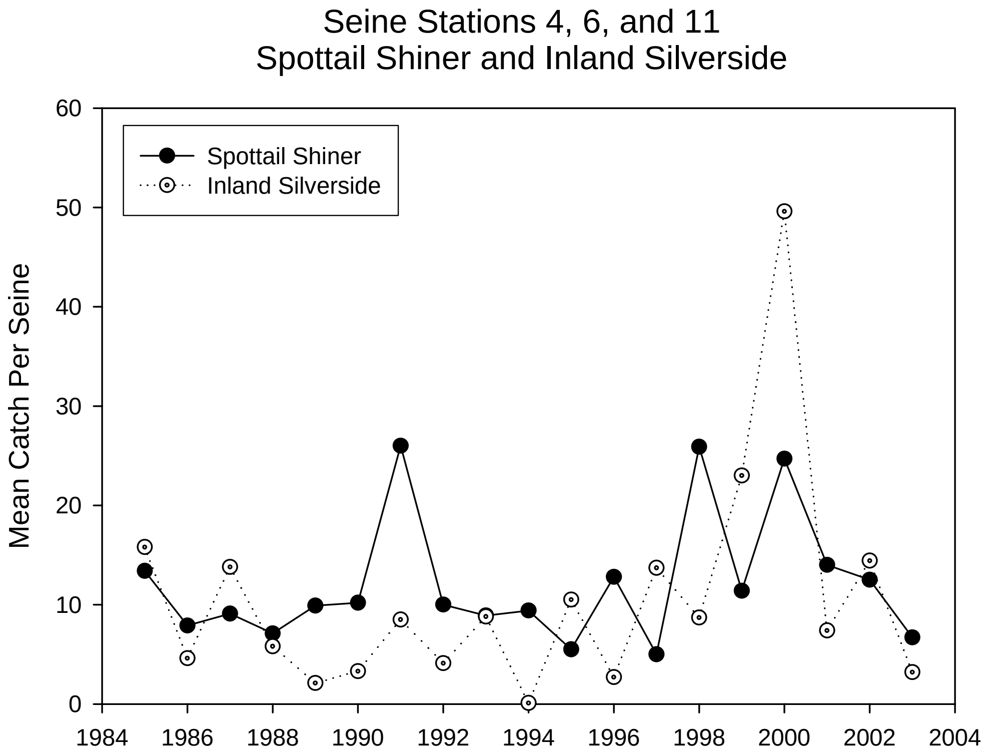
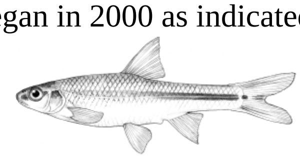


Figure 175. Seines. Annual Average over All Stations. Spottail Shiner and Inland Silverside.

Spottail shiner decreased in average catch in 2003, but remained a common species in trawl samples (Figure 175). The long term trend for this species is rather constant at about 6-9 individuals per trawl (Figure 176). Inland silverside also declined in 2003, continuing a slide that began in 2000 as indicated by both average values and LOWESS plots (Figure 175, 177).



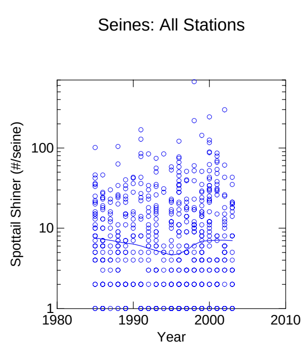


Figure 176. Seines. Long term trend in Spottail Shiner (*Notropis hudsonius*). All Stations.

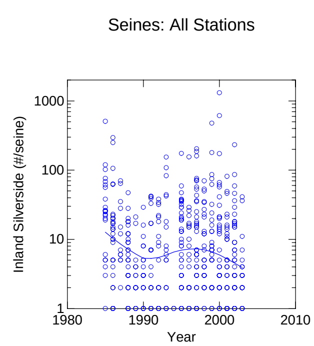
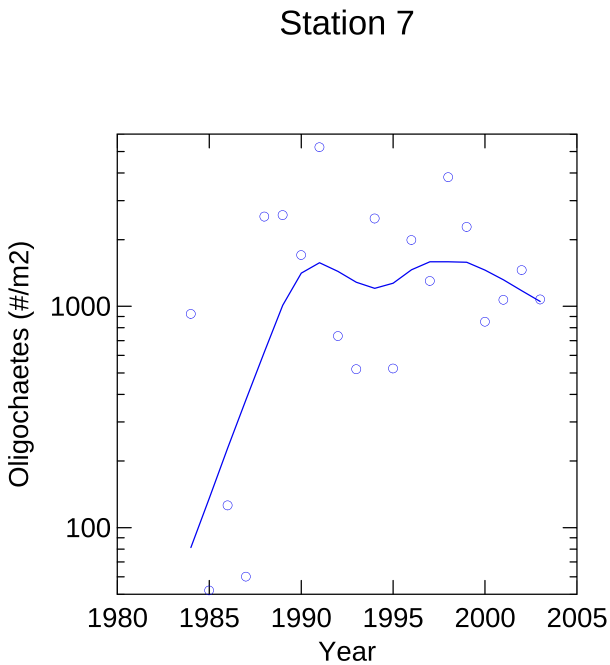


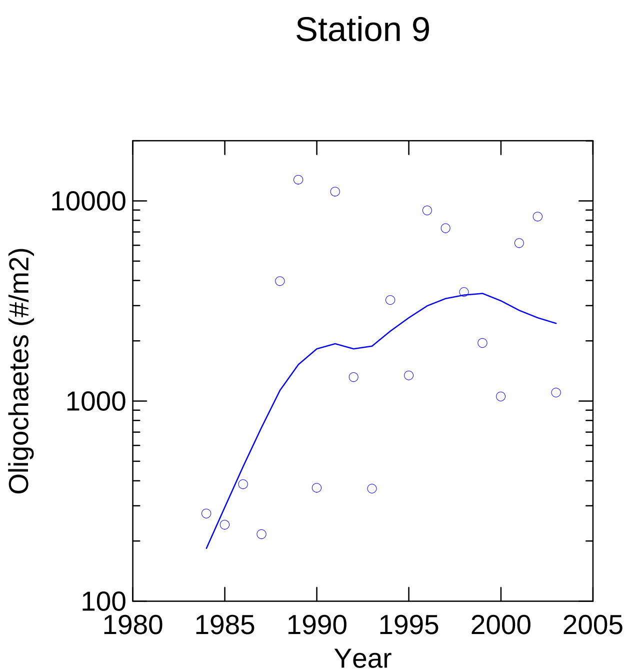
Figure 177. Seines. Long term trend in Inland Silverside. (*Menidia beryllina*). All Stations.

G. Benthos Trends



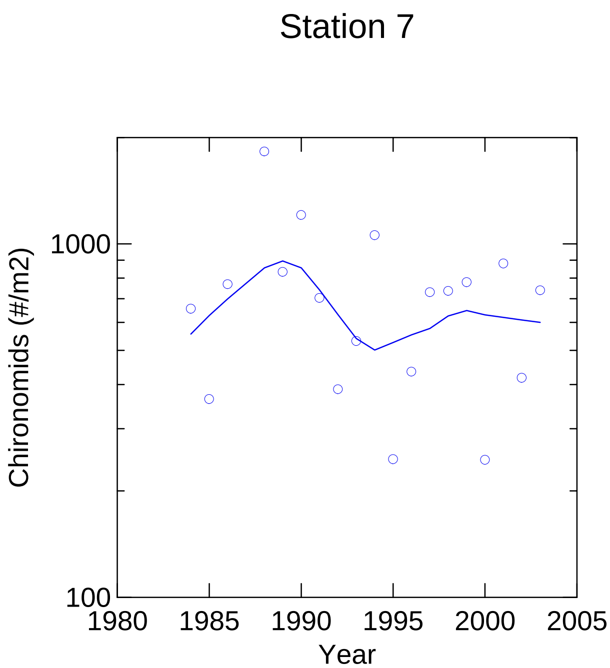
Oligochaetes demonstrated a strong increase during the late 1980's and were then relatively constant thorough the remainder of the study period (Figure 178). The trend line went from about 80/m^2 in 1984 to over 1000/m^2 in 2003. Methodological issues may be account for some of this increase as oligochaetes tend to fragment during processing.

Figure 178. Long term trends in Benthos: Oligochaetes. Gunston Cove.



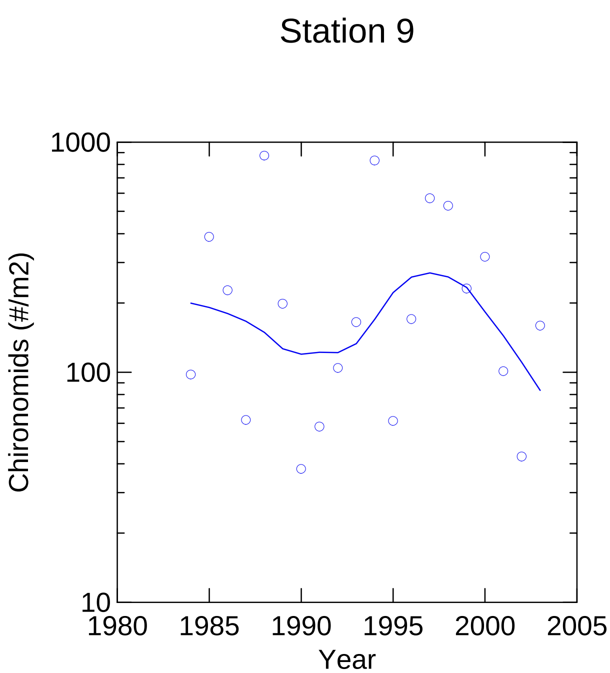
A similar pattern in long term trends was found for oligochaetes in the river (Figure 179). The increasing trend appeared to be somewhat more gradual than that found in the cove, but resulted in the trend line moving from about 100/m^2 in 1984 to 2000/m^2 by 2003.

Figure 179. Long term trends in Benthos: Oligochaetes. River mainstem.



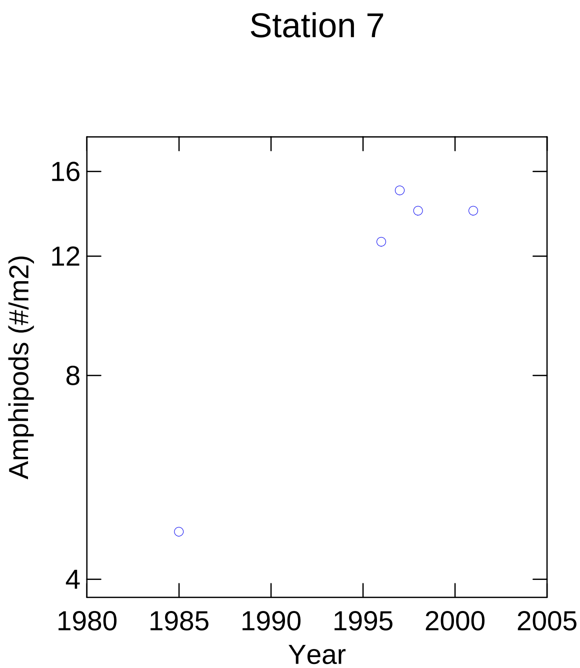
Chironomids found in the cove are the larvae (and sometimes pupae) of midges or gnats. Their density has shown some variation over time in the cove, but has generally remained in the range 500-1000/m^2 (Figure 180). Chironomids are an important food source for fish such as white perch.

Figure 180. Long term trends in Benthos: Chironomids. Gunston Cove.



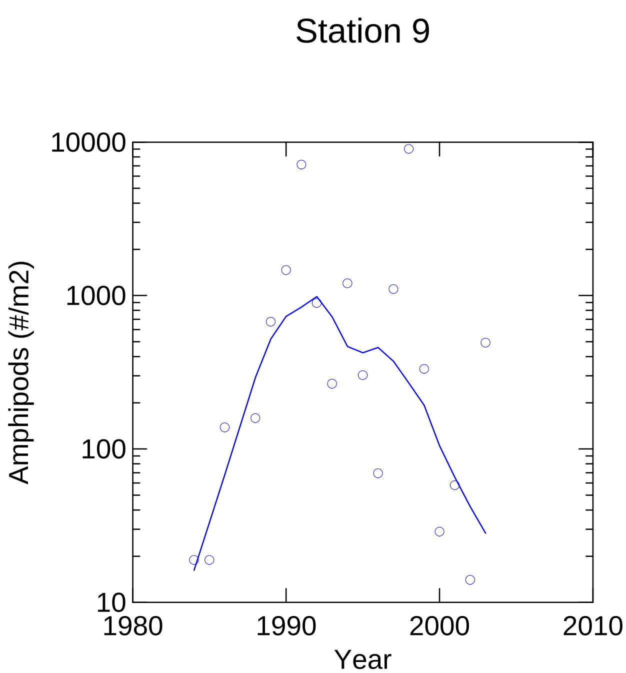
Chironomids have been found at a somewhat lower density in the river mainstem (Figure 181). There is some evidence of a decline in the late 1980's, a resurgence in the 1990's, and another decline recently.

Figure 181. Long term trends in Benthos: Chironomids. River mainstem.



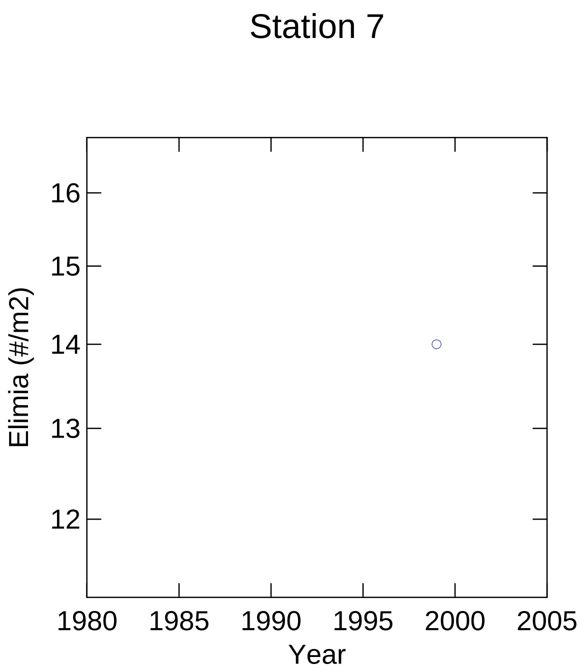
Amphipods are small crustacea that are often called scuds. They are generally about 5-10 cm in length. Their occurrence in the cove is sporadic (Figure 182), probably due to the fact the bottom of the cove is a relatively unfavorable habitat for them – homogeneous, fine grained sediment. They have occurred more in recent years than in the early years of the study.

Figure 182. Long term trends in Benthos. Amphipods. Gunston Cove.



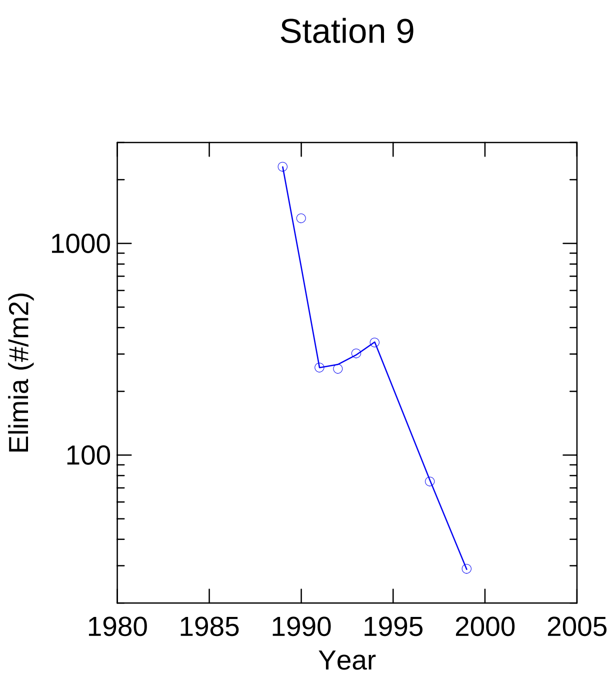
Amphipods are much more common in the river mainstem (Figure 183). Here the bottom tends to have more structure, with lots of mollusc shells and coarse organic matter. A distinct pattern seems to be emerging over the years with a distinct maximum in the early 1990's and minima in the mid 1980's and recently.

Figure 183. Long term trends in Benthos. Amphipods. River mainstem.



Elimia is a genus of snails that occurs in the study area. *Elimia* has been observed only in one year in the cove (Figure 184).

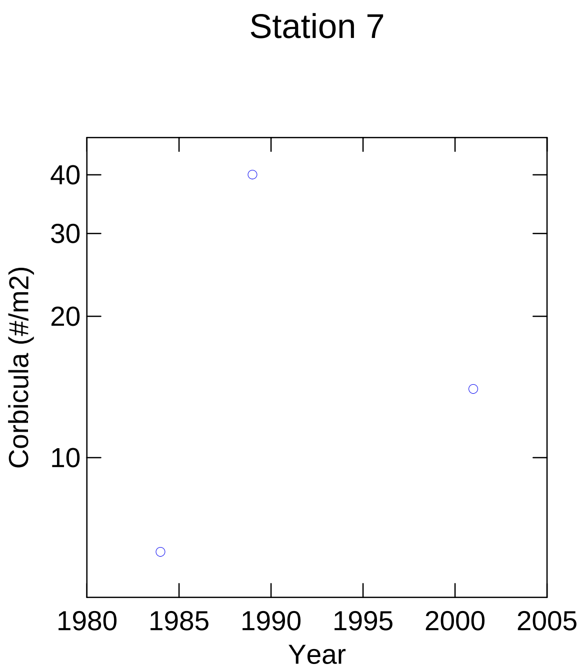
Figure 184. Long term trends in Benthos: *Elimia*. Gunston Cove.



The gastropod *Elimia* was not found in samples before 1989, but in that year appeared with a surprisingly strong abundance of about 2000/m^2 (Figure 185). Since that date its numbers have declined substantially so that by 1999 it had reached less than 30/m^2. Since 1999 it has not turned up in our samples.

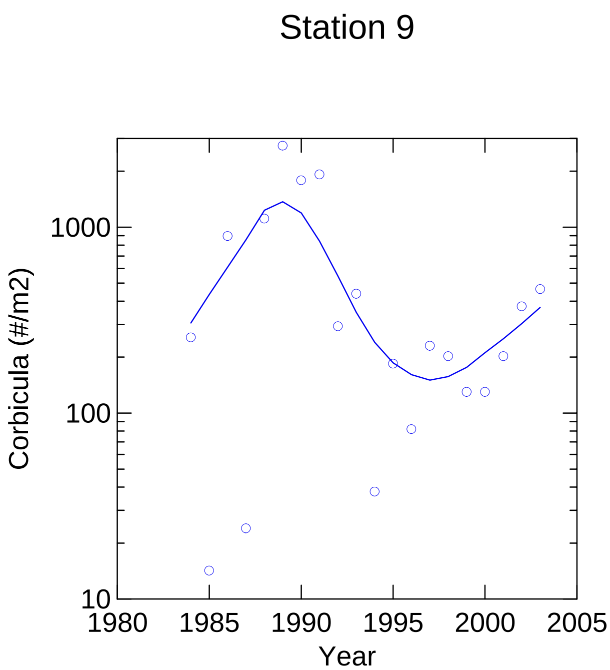
Figure 185. Long term trends in Benthos: *Elimia*. River mainstem.

Elimia, probably the most abundant native snail in the tidal Potomac River, was called Goniobasis in earlier reports. It first appeared in our benthic samples in 1989, but disappeared from collections by 2000. We do not have an obvious explanation for this appearance and disappearance, but this kind of pattern is sometimes seen, more commonly with introduced species.



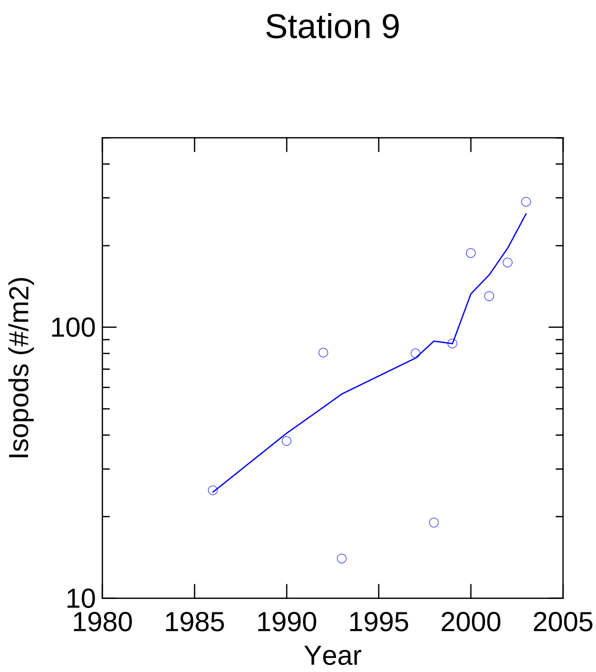
The Asiatic clam (*Corbicula*) is found sporadically in the cove without any real pattern over the years (Figure 186).

Figure 186. Long term trends in Benthos: *Corbicula*. Gunston Cove.



Corbicula has been consistently found in the cove at moderate to high abundances (Figure 187). The trend line indicates a rise from a few hundred in the early 1980's to over 1000/m^2 by 1990. This was followed by a decline during most of the 1990's and then a recent resurgence to moderate levels.

Figure 187. Long term trends in Benthos. *Corbicula*. River mainstem.



Isopods, also called aquatic sow bugs, are crustaceans which are about 5-10 mm long. They have never been found in the cove so no graph is presented. Like amphipods, their absence in the cove is probably due to the homogeneous substrate. Their densities have gradually increased during the study to current levels of about 300/m^2.

Figure 188. Long term trends in Benthos: Isopods. River mainstem.

H. Synthesis to Date

Important trends in water quality and biotic variables for those subjected to both linear regression and Lowess analysis are summarized in Table 21. These results point to a general improvement in water quality in the cove and some improvements in the river mainstem. Plankton variables also show a shift to a more desirable state with a decrease in phytoplankton and an increase in zooplankton in the cove. The river exhibited less of a change.

Water quality and aquatic biota have been measured in Gunston Cove using a generally consistent monitoring protocol since the early 1980's. Major changes in the protocol include: (1) decrease in the number of stations monitored for water quality and plankton, (2) increased emphasis on biweekly/semimonthly sampling, (3) change in method for zooplankton. The current sampling protocol for plankton utilizes only two stations which are monitored on a biweekly/semimonthly basis. This sampling regime was based on the similarities observed between stations in the cove on any given date and the differences observed, especially in plankton, between monthly sampling dates. Three stations have been maintained for both trawl and seine sampling given the variability that is found between stations and the importance of fish to the management of the ecosystem. Since water quality, plankton, and fish sampling have been maintained at a consistent core of sampling sites using consistent methods, long term trends can be assessed over the entire sampling period. The exception to this is zooplankton which was originally sampled only by sieving 96 L with a 73 µm mesh net. This protocol was changed in 1990 to one in which a 202 µm tow net sample was collected for larger zooplankton (macrozooplankton) and a 44 µm sieve was instituted for smaller zooplankton (microzooplankton). This made

Table 21
Summary of Important Trends over Period 1984-2003
Gunston Cove Study

	Station 7		Station 9	
	Linear	Lowess	Linear	Lowess
Water Quality Parameters - GMU				
Conductivity	+	+	0	0
Dissolved oxygen, mg/L	0	0	+	C
Dissolved oxygen, % sat.	0	0	+	C
Secchi depth	+	+	0	C
Light Extinction Coeff.*	+	+	-	-
Alkalinity	0	C	+	C
Water Quality Parameters – Noman Cole Lab				
Chloride	+	0	+	0
Lab pH	-	C	-	C
Alkalinity	-	C	0	C
BOD	-	L	0	0
Total suspended solids	-	-	0	0
Volatile suspended solids	-	-	-	-
Total phosphorus	-	L	0	0
Soluble reactive phosphorus	0	L	+	C
Ammonia nitrogen	0	L	-	-
Unionized ammonia nitrogen	0	L	-	-
Nitrite-nitrogen	0	0	-	-
Nitrate-nitrogen	-	-	-	-
Organic nitrogen	-	L	0	0
N:P ratio	0	0	-	-
Biological Parameters – GMU				
Chlorophyll a, depth-int.	-	L	0	0
Chlorophyll a, surface	-	L	0	0
Photosynthetic rate	-	-	0	C
Most rotifers*	+	+	+	C
Bosmina*	+	C	+	C
Diaphanosoma*	+	C	0	C
Copepod nauplii*	+	+	+	+
Adult & copepodid copepods*	+	C	0	0

* parameter not available for entire study period
Linear column denotes significance of linear regression over entire period of record: + indicates an increase, - indicates a decrease and 0 indicates no change.
Lowess column denotes pattern suggested by lowess curve line: + indicates consistent positive trend, - indicates consistent negative pattern, L indicates a decrease following several years of increase, C indicates a complex pattern, 0 indicates no apparent pattern.

our methods more consistent with other Potomac monitoring programs and improved quantification of both macro- and microzooplankton. This change limited the period of record of strictly comparable zooplankton data to 1990-2003, although some comparisons with earlier data are warranted.

Analysis of this data has started to reveal some insights into the behavior of the system and the effects of management activities. Below we list what seem to be the most important generalizations that can be extracted from the data so far. It is important to remember that, while these conclusions seem reasonably solid, from a scientific point of view these represent working hypotheses which should continue to be tested with new analyses and new data.

First, in Gunston Cove there was a clear pattern of increase in chlorophyll a, a measure of phytoplankton biomass, from 1984 through 1988 followed by a decline through 1997. In fact, regression analysis indicates a significant decreasing linear trend in chlorophyll over the entire period of record in the cove. This same pattern was observed in BOD, total phosphorus, organic nitrogen, and volatile suspended solids. If we assume that phytoplankton compose the majority of BOD, total phosphorus, organic nitrogen, and volatile suspended solids in the cove, the similarity of these trends provides convincing evidence that phytoplankton biomass increased from 1984-88, then declined through 1997 in Gunston Cove and that there has been a significant decline over the entire period of record. Secchi depth indicates that most of the shallow cove water column has adequate light to support phytoplankton growth and, therefore, is not light limited. In fact Secchi depth has shown a significant linear increase over the period of record. N:P ratios indicate that phosphorus was the limiting nutrient during this period. Phosphorus loading from Noman M. Cole, Jr. Pollution Control Plant was greatly curtailed in the early 1980's. The observed pattern in phytoplankton biomass in the cove can be directly tied to the management action to decrease phosphorus loadings if we assume temporary storage of phosphorus during the pre-decrease period which continued to be released in significant amounts for several subsequent years until largely exhausted or covered by 1989. In addition to the decrease in phytoplankton biomass observed during the 1990's, large scale *Microcystis* blooms disappeared and diatoms, a preferred food source for larger herbivorous zooplankton like cladocera, increased in importance.

The increase in water clarity noted above opens the possibility that the cove will soon be able to support substantial stands of submersed aquatic vegetation (SAV). Light has probably been limiting SAV growth in the cove. The two main light absorbing constituents in the Bay are algae (as measured by chlorophyll a) and TSS. The decline in both of these noted above appears to be responsible for the observed improvement in light penetration and water clarity. Conditions are already favorable at depths up to 0.5 m for SAV colonization and growth (EPA 2003, p. 133). If chlorophyll a and TSS continue to drop, greater depths and more of the cove should be colonized by SAV. This could facilitate further improvements in water quality and living resources.

Second, there were significant changes in other water quality variables. Chlorine was eliminated from the Noman M. Cole, Jr. Pollution Control Plant discharge in the mid-1980's, removing a major factor inhibiting fish movement in Pohick Creek. Ammonia nitrogen in the cove increased from 1983 through 1989 after which a clear decline was observed through 1995. This has helped to decrease the possibility of un-ionized ammonia toxicity in Pohick Bay.

Third, zooplankton have generally increased in the cove over the 14 year period of consistent data. Total rotifers led by *Brachionus* and *Filinia* have shown a consistent steady increase over the period. Conochilidae and *Keratella* are other rotifer taxa that have shown a large net increase over the period. The herbivorous cladoceran *Diaphanosoma* has undergone a substantial increase over the period while other herbivorous cladocera have generally increased slightly. Copepods have also shown a clear net increase over the period. Since zooplankton are an important link in the food chain between primary production and fish, this suggests an strengthened food chain.

Fourth, the total catch of fish collected by trawling in the cove has generally declined since the mid-1980's, mainly due to the decline of blueback herring, alewife, gizzard shad, bay anchovy, and brown bullhead. White perch has remained the most abundant fish in the trawls, but its dominance has declined in the last few years.

Fifth, the total fish collected per seine in the cove has shown little net change, although a dip was observed in the mid-1990's. However, there has been a major change from strong dominance by white perch in the early period to shared dominance by white perch and banded killifish, and most recently dominance by banded killifish.

Sixth, the anadromous catch has increased partially due to increased frequency of sampling. The recent dramatic increase in alewife catches is well beyond that explained by increased sampling effort and reflects a major increase in anadromous fish usage of Pohick and Accotink Creeks.

There are some potential linkages between these six general patterns. The link between phosphorus and phytoplankton seems strong. The decreased biomass and shift to diatoms in phytoplankton populations and general improvement in water quality should promote a general increase in zooplankton as has been observed for most taxa. Another factor which is consistent with the general increase in zooplankton is the reduction in top-down control caused by the decrease in planktivorous fish (less predation pressure on zooplankton) suggested by the trawl samples, although this decrease in planktivores may have been mostly completed by the time the increase in zooplankton was first noted. Further evidence for this linkage was found in 2001 when strong populations of blueback herring, alewife, and bay anchovy may have been responsible for the reduced abundance of *Diaphanosoma*. The changes in fish taxa are a bit harder to explain. The consistent performance of white perch in the cove is encouraging and consistent with the cove being a supportive environment. The decline of other fish taxa in trawls is unclear, but many of these species are migratory and may be exposed to increased mortality or other factors in other areas. The increase in banded killifish may simply reflect an increase in habitat as SAV has gradually increased in the cove.

The ecological community that inhabits Gunston Cove and the adjacent Potomac River has clearly been altered by human activity and management. These alterations include changes in fish species and their abundance, changes in watershed characteristics and resulting tributary water quality, discharge of municipal and industrial waste, and dredging and filling activities. It is certainly beyond the scope of this project to comprehensively assess the extent and impact of these changes, but listing of a few examples may be useful.

The fish fauna of the tidal freshwater Potomac has been substantially altered. Historically, large numbers of anadromous shad and herring species frequented the area in spring during spawning. The great numbers of fish involved in these springtime river herring runs must have had a major impact through their feeding, the feeding activities of their offspring as well as the nutrients left in the tidal freshwater area by the death of many after their spawn. Anadromous fish spawning is considered insignificant now relative to its historical importance. Another alteration of the fish community is the disappearance in the early 20th century of the sturgeon, a primary benthic feeder in the river channel. Finally, several species common in the study area today are not native and were introduced at various times during the last several hundred years. These include most centrarchids (bluegill, crappies, small-mouth bass, large-mouth bass), channel cat, blue catfish, carp, and goldfish. Despite these introductions the most abundant fishes in the Gunston Cove area are the natives white perch and banded killifish. In addition to introduction of fish species, a number of molluscs including the common Asiatic clam (*Corbicula*) have been introduced.

Over the period of European settlement almost all of the Potomac watershed was cleared of forest cover for at least some time. In the immediate Gunston Cove watershed much of the land was cleared in the late 1600's for tobacco farming. This resulted in extensive soil erosion and sediment accumulation in tributary embayments. Of note here is the fact that the town of Dumfries was once a leading colonial port and is now separated from navigable waters by a large expanse of marsh, apparently the result of sediment deposition from upstream land erosion. The exact impact of early tobacco land use on Gunston Cove is not known. Land was largely cleared in the watershed around the time of the Civil War, but forest regrew in the early 20th century as farming was abandoned. Since World War II the Gunston Cove watershed has again experienced extensive clearing, this time attributable to suburban development. This has led to changes in the hydrology of tributary streams and probable increases in sediment, nutrients, metals, and other contaminants.

The suburbanization of the watershed also led to the need for sewage treatment facilities. These facilities were consolidated into a single plant, the Noman M. Cole, Jr. Pollution Control Plant, which discharges into Pohick Creek just above the head of tide. While the volume of waste handled by the plant has steadily increased, the quality of the effluent has improved to the extent that loadings have remained relatively constant or decreased since 1983. Nonetheless, significant quantities of nitrogen, phosphorus, and other substances enter Gunston Cove from this source. There is also a major influx of treated sewage down the Potomac from Blue Plains treatment plant upstream. This may have an impact on the cove due to tidal mixing. There is no direct industrial discharge to Gunston Cove currently, but there may have been historical releases from Fort Belvoir or there may be upstream sources. Historic discharges may still have impacts through sediment storage and release.

Dredging and filling have substantially altered the shoreline of the tidal freshwater Potomac River in the District of Columbia and nearby areas of Virginia and Maryland. For example, much of the current National Mall was tidal marsh or mud flats before being filled. A dredged channel is maintained throughout the tidal river and local dredging is done in selected embayments and warf areas. The elimination of marsh areas and shallow weedbed areas through dredging and filling have certainly decreased available habitat in the tidal freshwater Potomac. Submersed aquatic vegetation (SAV) has changed greatly in aerial extent even in the last few decades and we have no clear idea of what is was like in the pre-European settlement period. While dredging and filling activities are not known to have had a major impact on Gunston Cove, the extensive work in the larger area has certainly impacted the availability of marsh areas for biotic habitat and biogeochemical cycling.

Based on the extent of these impacts and the lack of knowledge of pre-European conditions of water quality and biotic abundances, it is impossible to assess how different conditions are today from earlier times. We can only speculate that water quality and biotic abundances could be substantially different now. The tidal freshwater Potomac can clearly not be restored in all aspects to pre-European conditions. For example, introduced centrarchids and other fishes cannot be eliminated from the river. Given the dynamic nature of ecosystems and the complexity of physicochemical and biological factors that promote change, it is unrealistic to expect an ecosystem to remain static. Our goal should be to eliminate those anthropogenic stresses that we can, reduce or manage those that we cannot eliminate, and encourage the development of a biological community that functions to cycle nutrients and transfer energy among as many native species as possible. Specific management practices which seek to control point and non point sources, protect and enhance stream buffers and tidal wetlands, and avoid further exotic species introductions are expected to further this goal.

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Anadromous Fish Survey

Pohick, Accotink, and Dogue Creeks

2003 and 2004

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Submitted to

Department of Public Works
County of Fairfax, Virginia

June, 2005

Introduction

The commercially valuable anadromous fishes in the herring family (Clupeidae) live as adults in the coastal ocean, but return to freshwater creeks and rivers to spawn. In the mid-Atlantic region, four species are present. The American shad grows to be the largest and spawns in the Potomac River channel between Piscataway Creek and Mason Neck. We do not normally catch this species as either adults, juveniles, or larvae. The alewife enters creeks tributary to the tidal freshwater Potomac River and travels further into these creeks to spawn than do the other species. In recent years we have regularly caught larval, juvenile, and adult alewife in Gunston Cove and in Pohick, Acccotink, and Dogue Creeks. The blueback herring also enters creeks to spawn,, but penetrates less far and apparently often spawns in tidal embayments. This species has been fairly regularly taken in our samples as larvae, juveniles, and adults. The final species is the hickory shad. This species is less common than the other river herrings, and less is known about its habits. We have had difficulty distinguishing the juveniles of this species from those of alewife and blueback herring, and are working to establish better recognition characters. A few juvenile specimens have been tentative identified as hickory shad.

Another set of valuable fishes are the semi-anadromous white perch and striped bass, which are sought after by both the commercial fishery and the sport-fishery. The adults of these species may remain in an estuary as adult, while some individuals of striped bass, in particular, may continue on out into the coastal ocean. Both spawn in the Potomac River. Striped bass spawn primarily in the river channel between Mason Neck and Maryland Point, while white perch spawn primarily further upriver, from Mason Neck to Alexandria, and also in the adjacent tidal embayments.

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

For several years, we have focused a monitoring program on the spawning of these species in Gunston Cove and Pohick Creek, Accotink Creek, and, less regularly, Dogue Creek. We have sampled for adult individuals each spring since 1988 and for eggs and larvae since 1992. After 16 years of using hoop nets to capture adults, we shifted in the spring of 2004 to visual observations and seine, dip-net, and cast-net collections. This change in procedures was done to allow more frequent monitoring of spawning activity and to try to determine the length of time the spawning continued.

Methods

Beginning on March 7, 2004 and at least weekly until May 10, an observer visited Pohick Creek at the outfall of the Noman M. Cole, Jr., Pollution Control Plant, Dogue Creek at either Rt. 1 or at Washington’s Gristmill National Park, and less regularly Accotink Creek at Rt .1, and Pohick Creek below Lorton Road. When schools of herringsized fishes were seen, an attempt was made to capture some of the individuals for identification. We first tried to sample with a small seine net and met with moderate success. Then we tried a wire mesh dip-net, but that proved wholly inadequate. Finally, we used a monofilament hand cast-net, which produced good catches. As was done in previous years, eggs and larvae in the creek water were sampled by holding a conical plankton net with a mouth diameter of 0.3 m and a square mesh size of 0.333 mm in the stream current for 15 minutes. The samples were preserved with 5% formalin and transported to the GMU laboratory for identification and counting of the fish eggs and larvae.

Results

The total number of visits to observe and collect adult fishes in each creek in 2004 and also in previous years are presented in Table 1. The results of the observations and collections made on those visits are summarized in Table 2. Collections were focused on Pohick Creek below the outfall, with visits to Accotink Creek and Dogue Creek for visual observation of schools of clupeids. Plankton net collections of fish eggs and larvae were done only at Pohick Creek. Eighteen samples were taken from March 8 through May 10, 2004.

Table 1. Sampling period and frequency of effort and sampling gear in each year for adult anadromous fishes in Pohick, Accotink, and Dogue Creeks

Year	Sampling period	Pohick	Accotink	Dogue	Sampling gear
2004	Mar 7-May 10	22 (cast net)	10 (visual)	12 (visual)	Cast net, seine, visual
2003	Apr 6-May 31	7 (1 net)	7 (1 net)	0	Hoop nets
2002	Mar 30-Jun 1	9 (1 net)	9 (1 net)	0	Hoop nets
2001	Mar 3-May 25	12 (1 net)	12 (1 net)	0	Hoop nets
2000	Mar 12-May 27	11 (2 nets)	11 (1 net)	0	Hoop nets
1999	Mar 21-May 30	11 (2 nets)	11 (1 net)	0	Hoop nets
1998	Mar 3-May 26	13 (2 nets)	13 (1 net)	9 (1 net)	Hoop nets
1997	Mar 7-Jun 10	15 (2 nets)	15 (1 net)	15 (1 net)	Hoop nets
1996	Mar 29-Jun 6	11 (2 nets)	11 (1 net)	6 (1 net)	Hoop nets
1995	Apr 15-May 26	6 (2 nets)	6 (1 net)	0	Hoop nets
1994	Apr 23-May 28	6 (2 nets)	6 (1 net)	0	Hoop nets
1993	Apr 2-Jun 4	7	9	0	Hoop nets
1992	Mar 6-May 30	10	10	0	Hoop nets
1991	Mar 26-Jun 1	10	10	0	Hoop and gill nets
1990	Apr 20-May 25	6	6	0	Hoop and gill nets
1989	Apr 9-May 8	6	5	0	Hoop and gill nets
1988	Mar 11-Jun 10	4	2	1	Gill nets

Table 2. Sampling period and frequency of effort in each year for eggs and larvae of anadromous fishes in Pohick, Accotink, and Dogue Creeks

Year	Sampling period	Pohick Cr.	Accotink Cr.	Dogue Cr.
2004	Mar 8-May 10	18	0	0
2003	Apr 6-May 31	8	9	0
2002	Mar 30-Jun 1	9	9	0
2001	Mar 3-May 25	12	12	0
2000	Mar 12-May 27	11	11	0
1999	Mar 21-Jun 15	13	13	0
1998	Mar 3-May 26	13	13	9
1997	Mar 10-Jun 1	14	14	14
1996	Apr 19-Jun 5	7	7	7
1995	Apr 14-May 26	6	6	0
1994	Apr 22-May 27	6	6	0
1993	Apr 2-Jun 4	9	9	0
1992	May 2-May 29	5	5	0

The results of the fish egg and larva sampling of the spring of 2003 were reported in the 2002 Anadromous Fish Survey. Those results are repeated in Tables 3 and 4 for reference. No ichthyoplankton sample was collected in Pohick Creek on May 16, 2003, because of very high water flow. Very young alewife larvae were collected on the first day we sampled and on two succeeding weeks in April in Pohick Creek. Two older yolk sack larvae tentatively identified as alewife were caught in Pohick in May 23. Larvae of common carp were caught in Pohick Creek on April 26 and May 3. Numerous newly hatched gizzard shad larvae were caught on May 10 in Pohick Creek, and five more were caught on the same date in Accotink Creek. Gizzard shad larvae were also collected on May 23 and May 31 in Pohick Creek. One sunfish larva (perhaps a pumpkinseed) was collected in Accotink Creek on May 10. A few fish eggs were collected in most samples in both creeks, and larger numbers were collected from Pohick Creek on April 6, May 3, and May 10. The eggs were not identified to a species, because of debris that adheres to the adhesive eggs and obscures identifying features.

Table 3. Fish eggs and larvae collected on each sampling date in Pohick and Accotink Creeks in 2003

Date	Taxon identity	Larvae from Pohick	Larvae from Accotink	Unidentified Eggs from Pohick	Unidentified Eggs from Accotink
Apr 6	Alewife	5	0	28	1
Apr 12	Alewife	2	0	5	0
Apr 19		0	0	2	1
Apr 26	Alewife	5	0	2	1
	Common carp	3	0		
May 3	Common carp	3	0	29	2
May 10	Gizzard shad	75	5	149	3
	Sunfish	0	1		
May 16		--	0	--	0
May 23	Alewife	2	0	6	2
	Gizzard shad	1	0		
May 31	Gizzard shad	2	0	0	0

Table 4. Summary of number of fish eggs and larvae collected in Pohick and Accotink Creeks in 2003 sampling season

Taxon identity	Total	Pohick	Accotink	Total No./ 10^3m	Pohick No./ 10^3m	Accotink No./ 10^3m
Unidentified eggs	231	221	10			
Gizzard shad	85	80	5			
Alewife	14	14	0			
Common carp	6	6	0			
Sunfish	1	0	1			

The results of the 2003 samples from Gunston Cove were not reported in the 2002 Anadromous Survey, but are presented in Table 5. A total of 1544 fish larvae were collected, 1065 from the river station and 479 from the Cove station. Most of the larvae caught in the river (54.4%) were *Dorosoma* sp. larvae and were probably gizzard shad. A collection of 205 clupeid larvae from the river on July 10 were not identifiable to genus with certainty, but based on time of the year were probably *Dorosoma* sp. also. *Alosa* sp. larvae were also abundant (239 larvae) in the river channel. The most abundant kind of larvae caught in the cove were *Alosa* sp. larvae (49.5% of the total). *Morone* sp. larvae and *Dorosoma* sp. larvae were also abundant (118 and 64 larvae, respectively) in the cove collections.

Table 5. Collections of fish larvae from Station 7 in Gunston Cove and Station 9 in the Potomac channel in 2003.*

Day	St	Clupe-idae	*Alosa* sp.	Alewife	Blue-back herring	*Doro-soma* sp.	*Morone* sp.	Yellow perch	Inland silver-side
Mar 27	7		1 (0.26)						
	9								
Apr 10	7	11 (2.35)	3 (0.64)	13 (2.78)			48 (10.27)	27 (5.78)	
	9		1 (0.17)	4 (0.67)			4 (0.67)		
Apr 29	7		76 (14.98)			10 (1.97)	70 (13.6)		
	9		145 (25.75)			12 (2.13)	16 (2.84)		
May 15	7		105 (20.63)			44 (10.32)	1 (0.23)		
	9		24 (5.24)			54 (11.8)	2 (0.44)		7 (1.53)
May 29	7		18 (5.63)		2 (0.63)	8 (2.5)			
	9		37 (9.92)			288 (74.37)			
Jun 12	7		17 (4.66)			1 (0.27)			
	9		11 (3.24)			173 (50.93)	8 (2.36)		
Jun 24	7		17 (5.27)			1 (0.31)			
	9		8 (3.1)			40 (15.52)			1 (0.39)
Jul 10	7								2 (0.47)
	9	205 (44.52)							
Jul 24	7								4 (1.39)
	9		10 (2.8)						
Aug 8	7								
	9								
Aug 21	7								
	9								

Total	7	11 (2.35)	237 (56.07)	13 (2.78)	2 (0.63)	64 (15.37)	119 (24.1)	27 (5.78)	6 (1.86)
Total	9	205 (44.52)	239 (50.22)	4 (0.67)		579 (154.75)	30 (6.31)		8 (1.92)
Total	7 & 9	216 (46.87)	476 (106.29)	17 (3.45)	2 (0.63)	643 (170.12)	149 (30.41)	27 (5.78)	14 (3.78)

* Numbers in parentheses are calculated No. of larvae/10m^3

The summary of the results of the seine, cast net and visual surveys for adult anadromous and semi-anadromous fish spawning in the creeks in 2004 are shown in Table 6. A record by each sampling date is presented in Table 7. In Pohick Creek, 29 adult alewife were caught and many more observed. None were seen in Accotink Creek at the Route 1 bridge. In Dogue Creek at Washington's Gristmill, 35 alewife were caught, and in Quantico Creek above I-95, 21 alewife were caught. Blueback herring were seen only in Quantico Creek, where 22 were caught. Gizzard shad were caught in Pohick Creek (5 adults) and Dogue Creek (3 adults). A flashing white school of adult fishes that were almost undoubtedly alewife were seen in Pohick Creek on the first day of sampling, March 7. No more were seen until April 4, when 28 (11 males and 17 females) were caught. None were seen the following week on April 11, but on April 16 a swarm of 75-100 alewife and 75-100 gizzard shad were present in Pohick. The following day none were present at Pohick, but 32 (18 males and 14 females) alewife and two gizzard shad were caught in Dogue Creek. On April 18 50-60 alewife were seen in Pohick at the wastewater outfall and another 30-40 alewife upstream of that location at the first waterfall in the creek, just downstream of the Lorton Road bridge. The series of small waterfalls at this last site appears to block the upstream migration of the alewife and the gizzard shad, and spawning adults have been observed here in previous years. On April 19, one alewife was seen at the outfall in Pohick Creek. On April 25 we were notified by a homeowner on Quantico Creek, that alewife were present in the creek behind his house. Sampling caught 21 (19 males and 2 females) alewife and 22 (22 males) blueback herring. After April 19, no more alewife were seen in Pohick Creek and after April 22, no clupeid fishes were seen.

Table 6. Catch of adult anadromous and semi-anadromous fishes in Pohick, Accotink, Dogue, and Quantico Creeks in 2004

Fish species	Pohick Creek	Accotink Creek	Dogue Creek	Quantico Creek
Anadromous species Alewife	29 caught 100-200 seen	0	35 caught	21 caught
Anadromous species Blueback herring	0	0	0	22 caught
Semi-anadromous Gizzard shad	5 caught, 100-150 seen	0	2 caught	0

Table 7. Adult anadromous and semi-anadromous fishes seen or caught on each sampling date in Pohick, Accotink, Dogue, and Quantico Creeks in 2004

Date	Fish species	Pohick Creek	Accotink Creek	Dogue Creek	Quantico Creek
Mar 7	clupeids	~25 seen	0	0	Not visited
Mar 8		0	0	0	Not visited
Mar 9		0	0	0	Not visited
Mar 10		0	0	0	Not visited
Mar 15		0	0	0	Not visited
Mar 21		0	0	0	Not visited
Mar 28		0	Not visited	0	Not visited
Apr 4	Alewife	28 caught	0	0	Not visited
Apr 11		0	Not visited	0	Not visited
Apr 16	Alewife	75-100 seen, 1 caught	0	0	Not visited
	Gizz. shad	75-100 seen, 3 caught	0	0	Not visited
Apr 17	Alewife	0	Not visited	32 caught	Not visited
	Gizz. shad	1 seen	-	2 caught	Not visited
Apr 18	alewife	50-60 seen at outfall, 30-40 seen below Lorton Rd	0	0	Not visited
	Gizz. shad	2 caught below Lorton Rd			
Apr 19	alewife	1 seen	Not visited	Not visited	Not visited
Apr 20		0	Not visited	Not visited	Not visited
Apr 21	Gizz. shad	~80 seen	Not visited	Not visited	Not visited
Apr 22	Gizz. shad	~70 seen	Not visited	Not visited	Not visited
Apr 23		0	Not visited	Not visited	Not visited
Apr 25	alewife	0	Not visited	Not visited	21 caught
	Blueback herring	0			22 caught
Apr 27		0	Not visited	Not visited	Not visited
Apr 28		0	Not visited	Not visited	Not visited
May 2		0	Not visited	Not visited	Not visited
May 10		0	Not visited	Not visited	Not visited

Discussion

2003 Fish Spawning

The results of sampling fish larvae and adult fishes in Pohick and Accotink Creeks in the spring of 2003 were presented in the Anadromous Fish Survey 2002. In this report, we add the results of fish larvae sampling in Gunston Cove and the Potomac River in 2003 and the sampling of adult fishes in the creeks in 2004.

All available information on the spawning activity of alewife in the Gunston Cove area in 2003 is gathered in Table 8. Adult alewife were not caught or seen in Pohick Creek on March 27, but were present on April 6. *Alosa* sp. yolk sack larvae were caught in the creek on April 6, so spawning activity must have begun a few days prior to that date. In fact one *Alosa* sp. post-yolk sack larva was caught in the Cove at Station 7 on March 27. Larvae of *Alosa* sp. that were predominantly yolk sack larvae were taken in the cove and the river on April 10. Adult alewife were last seen in Pohick Creek on April 12, and two post-yolk sack larvae were caught on the same date. Yolk sack larvae of Alosa sp. were also caught in Pohick Creek on April 26 that possibly were alewife. On April 29, numerous post-yolk sack larvae were caught in the cove and the river. On May 15, sampling caught abundant *Alosa* sp. larvae in the cove. These may have been late alewife or blueback herring. However, the two yolk sack larvae collected on May 23 in Pohick Creek were surely blueback herring. Juvenile alewife appeared in abundance in the seine and trawl samples in Gunston Cove on June 12 and June 26 and continued to be caught through October 9. Alewife spawning must have begun in late March and perhaps continued until mid April. Spawning definitely occurred in Pohick Creek.

Table 8. Summary of alewife spawning data for Gunston Cove and Pohick and Accotink Creeks in 2003. Catch data from Pohick Creek and Accotink Creek have been combined.

Date….	Adult alewife In creeks	Eggs* in Creeks	Larval *Alosa*** in creeks	Larval *Alosa*** In cove	Larval *Alosa*** In channel	Juvenile Alewife ***
Mar 27				1	0	0
Apr 6	48	29	5			
Apr 10				16	5	0
Apr 12	2	5	2			
Apr 19	--	3	0			
Apr 26	0	3	5			
Apr 29				76	145	0
May 3	0	31	0			
May 10	--	152	0			
May 15				105	24	0
May 16	0	--	--			
May 23	0	8	2			
May 29				20	40	0
May 31	0	0	0			
Jun 12				17	11	8+43
Jun 26				17	8	58+28
Jul 7						8+2
Jul 10				0	0	
Jul 24				0	10	2+1
Aug 8				0	0	
Aug 21				0	0	0+13
Sep 4						5+34
Sep 22						7+36
Oct 9						16+2
Nov 24						0
Dec 10						0

*No. of fish eggs caught
** No. of *Alosa* larvae caught
***Newly transformed alewife juveniles caught in trawls and seines, respectively, in Gunston Cove and the river

The accumulated data on spawning activity of blueback herring are presented in Table 9. No adult blueback herring were caught in either of the creeks in 2003. Of the *Alosa* sp. larval captures described above, only those caught in Pohick Creek on April 26, April 23, and May 23 are likely to have been blueback herring. *Alosa* sp. larvae that could have been blueback herrings were caught in the cove and the river on May 15, May 29, June 12, and June 26. Juvenile blueback herring were first caught in seines and trawls in Gunston Cove on June 26. They remained in abundance in the cove through September

22. Spawning must have occurred from late April or early May to mid to late May, with a possibility that some spawning took place in Pohick Creek.

Table 9. Summary of blueback herring spawning data for Gunston Cove and Pohick and Accotink Creeks in 2003. Catch data from Pohick Creek and Accotink Creek have been combined.

Date….	Adult herring In creeks	Eggs* in Creeks	Larval *Alosa*** in creeks	Larval *Alosa*** In cove	Larval *Alosa*** In channel	Juvenile herring ***
Mar 27				1	0	0
Apr 6	0	29	5			
Apr 10				16	5	0
Apr 12	0	5	2			
Apr 19	--	3	0			
Apr 26	0	3	5			
Apr 29				76	145	0
May 3	0	31	0			
May 10	--	152	0			
May 15				105	24	0
May 16	0	--				
May 23	0	8	2			
May 29				20	40	0
May 31	0	0	0			
Jun 12				17	11	0
Jun 26				17	8	251+5
Jul 7						0
Jul 10				0	0	
Jul 24				0	10	121+1
Aug 8				0	0	
Aug 21				0	0	8+0
Sep 4						125+45
Sep 22						147+92
Oct 9						0
Nov 24						0
Dec 10						0

*No. of fish eggs caught

** No. of *Alosa* larvae caught

***Newly transformed blueback herring juveniles caught in trawls and seines, respectively, in Gunston Cove and the river

Spawning information on gizzard shad in 2003 are gathered in Table 10. No adult gizzard shad were caught in Pohick or Accotink Creeks in 2003. Eighty yolk sack larvae were collected in Pohick Creek on May 10, and three more were caught in late May in Pohick. Several yolk sack larvae and three post-yolk sack larvae were caught in both the cove and the river on April 29. Larger numbers were caught at these sites on May 15. A few more showed up in cove collections in late May and June, but the largest numbers of yolk sack larvae were caught in the river on May 29 and June 12. A large number of post-yolk sack larvae they were probably gizzard shad were collected in the river on July 10. No juveniles were caught in the seines and trawl collections made in the cove and the river. Spawning probably began in the cove and river in mid to late April. In Pohick Creek, spawning occurred in early May and may have continued to mid May. Spawning in the cove and river seems to have continued into late June. The larvae and juveniles apparently suffered high mortality or perhaps moved out of the area early.

Table 10. Summary of gizzard shad spawning data for Gunston Cove and Pohick and Accotink Creeks in 2003. Catch data from Pohick Creek and Accotink Creek have been combined.

Date….	Adult gizzard shad In creeks	Eggs* in Creeks	Larval *Dorosoma*** in creeks	Larval *Dorosoma*** In cove	Larval *Dorosoma*** In channel	Juvenile Gizzard shad ***
Mar 27				0	0	0
Apr 6	0	29	0			
Apr 10				0	0	0
Apr 12	0	5	0			
Apr 19	--	3	0			
Apr 26	0	3	0			
Apr 29				10	12	0
May 3	0	31	0			
May 10	--	152	80			
May 15				44	54	0
May 16	0	--				
May 23	0	8	1			
May 29				8	300	0
May 31	0	0	2			
Jun 12				1	173	0
Jun 26				1	40	0
Jul 7						0
Jul 10				0	(205 Clupeidae)	
Jul 24				0	0	0
Aug 8				0	0	
Aug 21				0	0	0
Sep 4						0
Sep 22						0
Oct 9						0
Nov 24						0
Dec 10						0

*No. of fish eggs caught

** No. of *Dorosoma* larvae caught

***Newly transformed gizzard shad juveniles caught in trawls and seines, respectively, in Gunston Cove and the river

The information that pertains to spawning activity by white perch is shown in Table 11. White perch adults were not caught in either creek in 2003. Neither were any white perch larvae caught in the creeks. Moderate numbers of yolk sack larvae were taken in the cove and the river on April 10, and larger numbers of post-yolk sack larvae were caught on April 29 in the cove and, in smaller numbers, in the river. Eight yolk sack larvae were taken on June 12 in the river. Juvenile white perch began to be collected in the seines and trawls in the cove on June 12 and in the river on June 26. Spawning appears not to have occurred in the creeks, but began in the cove and river in late March or early April. It must have continued until late May in the tidal area.

Table 11. Summary of white perch spawning data for Gunston Cove and Pohick and Accotink Creeks in 2003. Catch data from Pohick Creek and Accotink Creek have been combined.

Date….	Adult white perch In creeks	Eggs* in Creeks	Larval Morone** in creeks	Larval *Morone*** In cove	Larval *Morone*** In channel	Juvenile White perch ***
Mar 27				0	0	0
Apr 6	0	29	0			
Apr 10				48	4	0
Apr 12	0	5	0			
Apr 19	--	3	0			
Apr 26	0	3	0			
Apr 29				70	16	0
May 3	0	31	0			
May 10	--	152	0			
May 15				1	2	0
May 16	0	--				
May 23	0	8	0			
May 29				0	0	0
May 31	0	0	0			
Jun 12				0	8	1+0
Jun 26				0	0	31+2
Jul 7						3+0
Jul 10				0	0	
Jul 24				0	0	14+8
Aug 8				0	0	
Aug 21				0	0	13+29
Sep 4						0
Sep 22						1+3
Oct 9						13+130
Nov 24						22+39
Dec 10						0

*No. of fish eggs caught
** No. of white perch larvae caught
***Newly transformed white perch juveniles caught in trawls and seines, respectively, in Gunston Cove and the river

A comparison of the number of larvae of *Alosa* sp., gizzard shad, white perch, and all species combined that were caught in each year in Pohick and Accotink Creeks is gathered in Table 12. In 2003, the catch of *Alosa* sp. larvae was greater than in any previous year. Based on the capture of adults and the time of capture of the larvae, most of these were probably alewife, but some blueback herring probably also spawned in the lower reaches of Pohick Creek in 2003. Gizzard shad also spawned in Pohick Creek in 2003 and in greater numbers than the previous two years. White perch do not ascend Pohick or Accotink Creeks above tidal water. Thus, the water quality and habitat conditions in Pohick Creek continue to be adequate for anadromous fish spawning.

Table 12. Catches of larvae of anadromous and semi-anadromous fish species in Pohick and Accotink Creeks, 1992-2003. Catch effort was not equal in each year nor in each creek

Fish species	Year	No. larvae Pohick Cr.	No. larvae Accotink Cr.	No. eggs Pohick Cr.	No. eggs Accotink Cr.
Alosa sp.	2003	14	0		
(blueback herring, alewife, hickory shad)	2002	0	4		
	2001	0	0		
	2000	7	2		
	1999	5	5		
	1998	0	18		
	1997	1	53		
	1996	5	2		
	1995	0	1		
	1994	0	9		
	1993	0	0		
	1992	0	0		

Fish species	Year	No. larvae Pohick Cr.	No. larvae Accotink Cr.	No. eggs Pohick Cr.	No. eggs Accotink Cr.
Gizzard shad	2003	78	5		
	2002	0	2		
	2001	0	0		
	2000	1	0		
	1999	105	3		
	1998	50	347		
	1997	147	53		
	1996	919	186		
	1995	2	4		
	1994	109	64		
	1993	1	32		
	1992	128	31		

Fish species	Year	No. larvae Pohick Cr.	No. larvae Accotink Cr.	No. eggs Pohick Cr.	No. eggs Accotink Cr.
White perch	2003	0	0		
	2002	0	0		
	2001	0	0		
	2000	1	8		
	1999	4	0		
	1998	20	174		
	1997	7	1		
	1996	17	8		
	1995	5	0		
	1994	1	0		
	1993	0	2		
	1992	0	0		

Fish species	Year	No. larvae Pohick Cr.	No. larvae Accotink Cr.	No. eggs Pohick Cr.	No. eggs Accotink Cr.
All species	2003	98	6	221	10
	2002	2	6	6	46
	2001	2	0	442	28
	2000	15	18	179	34
	1999	174	26	3549	188
	1998	71	604	767	1837
	1997	158	97	2383	1178
	1996	988	453	4917	4876
	1995	15	36	Many	Many
	1994	123	132	133	173
	1993	6	64	129	829
	1992	180	45	1624	430

The annual collection records of adult alewife, blueback herring, hickory shad, and gizzard shad in the creeks aregathered in Table 13 for the years from 1988 through 2004. This corroborates the spawning evidence provided by the fish larvae in Pohick Creek. Since we no longer can gain regular access to Accotink Creek within Fort Belvoir, our sampling site was moved upstream in 2003 to a location far above tidewater. This site proved unsuitable and in 2004, observations were made further downstream at the Route 1 bridge or whenever possible, even further downstream at the foot bridge on the nature trail on Fort Belvoir. However, no sightings of schools of clupeids were seen in 2004 either. Accotink Creek lacks a definitive location where the fish congregate to spawn, making it more difficult to document spawning in this creek.

Table 13. Catches of adult clupeid fishes in Pohick and Accotink and Dogue Creeks, 1988-2003. Catch effort was not equal in each year nor in each creek

Fish species	Year	Pohick Creek	Accotink Creek	Dogue Creek
Alewife	2004	29 caught, ~60 seen	0	32
	2003	50	0	
	2002	0	22	
	2001	50	210	
	2000	107	182	
	1999	9	0	
	1998	5	15	12
	1997	6	21	16
	1996	5	34	0
	1995	0	2	
	1994	0	4	
	1993	0	0	
	1992	0	0	
	1991	0	14	
	1990	0	2	
	1989	1	10	
	1988	0	0	0
Blueback herring	2004	0	0	0
	2003	0	0	
	2002	0	0	
	2001	0	2	
	2000	0	0	
	1999	0	0	
	1998	0	0	0
	1997	0	0	0
	1996	0	0	0
	1995	0	0	
	1994	0	0	
	1993	0	0	
	1992	0	0	
	1991	0	0	
	1990	0	0	
	1989	0	0	
	1988	0	9	17

Fish species	Year	Pohick Creek	Accotink Creek	Dogue Creek
Hickory shad	2004	0	0	0
	2003	0	0	
	2002	0	0	
	2001	0	1	
	2000	0	0	
	1999	0	0	
	1998	0	0	0
	1997	0	0	0
	1996	0	0	0
	1995	0	0	
	1994	0	0	
	1993	0	0	
	1992	0	0	
	1991	0	0	
	1990	0	0	
	1989	0	0	
	1988	0	0	0
Gizzard shad	2004	4 caught, ~80 seen	0	2
	2003	29	1	
	2002	5	103	
	2001	107	37	
	2000	138	118	
	1999	66	14	
	1998	50	24	87
	1997	91	66	88
	1996	257	59	60
	1995	183	23	
	1994	96	13	
	1993	322	21	
	1992	410	24	
	1991	52	3	
	1990	67	20	
	1989	131	15	
	1988	4	11	46

Appendix A

Phytoplankton Species	Dimensions (um)	CellVolume (um3)
Cyanobacteria		
Anabaena circinalis	6u	113
Anabaena sp.	6x4	113
Aphanocaspa del.	0.5-0.8u	0.144
Arthospira jeneri	5x2.5	24.5
Chroococcus dispersus	2.25u	5.96
Chroococcus sp.	2u	4.19
Chroococcus turgidus	11u	697
Dactylococcopsis acicularis	80x2	72.3
Merismopedia minima	0.5u	0.0654
Merismopedia tenuissima	1.0u	0.523
Microcystis aeroginosa	2.5u	8.18
Microcystis incerta	0.5u	0.0654
Oscillatoria planktonica	5x2.5	24.5
Oscillatoria sp.1		30
Oscillatoria Lacustris	5X5	98.1
Rhaphidiopsis sp.	6x3	42.4
Synechococcus sp.	10X3	70.6
Unknown bga (spherical)	1.5u	1.77
Green Algae		
Actinastrum hantzchii	40x6	517
Ankistrodesmus falcatus (>50)	190x6	1790
Ankistrodesmus convolutus	20x1	5.23
Carteria globosa	20u	4187
Chlamydomonas globosa9X7.	9x7	231
Chlamydomonas globosa12-16X9-12.	16x12	1206
Chlorogonium euchlorum	7X5	91.6
Closteriopsis longissima	100x2	235
Coelastrum reticulatum	16X4	134
Crucigenia sp		4.19
Franceia droescheria	12x9	509
Kirchneriella elongata	20X2	20.9
Pediastrum duplex	18x8	80
Scenedesmus acuminatus	6x6	109
Scenedesmus abundans	6x4	75.4
Scenedesmus bicaudatus	6x4	50.2
Scenedesmus quardracauda	6x4	57.7
Selenastrum minutum	14x3	57.9
Selenastrum westii	18x3	42.4
Spermatozoopsis exult.	7x5	137.4
Tetraedron regul.	20u	3052
Diatoms		
Asterionella formosa	75x10	1104
Cocconeis diminuta	20x14	429
Coscinidiscus sp.	50u	9243
Cyclotella glomerata	10u	236
Cyclotella meneg.	20u	1884
Cyclotella 10-15		491

Appendix A

Cyclotella 15-20		907
Cyclotella 20-25		1900
Cymbella affinis	20x11	720
Diploneis sp	25u	628
Fragilaria sp.	60X20	1800
Gomphonema acuminatus	40X20	2512
Gyrosigma sp.	120X60	16485
Melosira ambigua	15x10	1178
Melosira herzo	20x10	1626
Melosira italica	18x10	2640
Melosira 5-10x5		147
Melosira sp.10-15x7.5		552
Melosira 15-20x7.5		773
Melosira 20-25x12.5		2760
Melosira 25-30x12.5		3373
Melosira islandica	17.5x10	1374
Navicula sp. 1<50	20x10	285
Navicula zanoni	50X20	3062
Neidium sp.	24X12	678
Nitzschia angustata	40X22.5	1413
Nitzscia hung.	80x30	3768
Nitzschia paradoxa	50x6	706
Nitzschia sp.	60x20	1884
Pennate.2		118
Pennate.4		75.4
Rhizosolenia eriensis	110X25	5500
Stauroneis sp.	35x15	1884
Synedra acus	100x2	353
Synedra nana	100x1	76.5
Synedra tabulata	60X5	471
Synedra sp	100x40	4710
Synedra ulna	120x1	78.5
Cryptophytes		
Chroomonas amphioxeia8.25X5	7x5	91.6
Chroomonas minuta5X3	5x3	23.6
Chroomonas minuta3X2	3x2	6.28
Cryptomonas erosa	26X10	2749
Cryptomonas erosa reflexa	26x16	3483
Cryptomonas marsonii	12x9	509
Cryptomonas ovata	16x12	1206
Cryptomonas pussilla	7x5	91.6
Sennia parvula6X3	5x3	23.6
Other		
Chromulina microplankton6X3	5x3	23.6
Dinobryon divergens	15X6	283
Euglena acus	80x27.5	31662
Euglena sp.	40x20	5272
Mallomonas sp.	30X20	4409
Phacus sp.	30x18	2700
Trachelomonas sp.	20u	4187