AN ECOLOGICAL STUDY OF TIDAL POWELLS CREEK

AND THE ADJACENT POTOMAC RIVER

PRINCE WILLIAM CO., VIRGINIA

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EXECUTIVE SUMMARY

Powells Creek is a tidal embayment of the Potomac River located about 25 miles (40 km) downstream of the nation's capital in Prince William County, Virginia. Tidal Powells Creek is one of the smaller, shallower named embayments in the tidal Potomac with a mean depth of 0.8 m (2.6 ft) and a surface area of 155 hectares (383 acres). It is located in the freshwater portion of the tidal Potomac River and normally has a salinity less than 0.5 parts per thousand. Its watershed is mostly on the Piedmont, but the area immediately surrounding the tidal embayment is in the Coastal Plain.

This work's primary objective was to determine the status of biological communities and the physico-chemical environment in the Powells Creek area of the tidal Potomac River to provide a baseline against which to assess future conditions. Five sites along the length of tidal Powells Creek were sampled for water quality and plankton on a semimonthly basis from mid May through September 2001 and monthly in October and November. Adult and juvenile fish were sampled by seining at three sites on a similar frequency.

Air temperatures during 2001 displayed a normal seasonal pattern with the exception of a cooler than normal July and a warmer than normal November and December. June and July were wetter than normal, but the period of August through December was very dry. River and tributary flow followed a typical seasonal pattern of decreasing flows from spring through fall punctuated by short-term flow spikes from storms and frontal passages. A particularly strong tributary flow spike was observed in late July.

Water temperature reflected the typical seasonal pattern found in air temperature and included a response to the the cooler July weather. Conductivity (a measure of salinity) was generally typical of freshwater conditions, but increased greatly during the fall drought to a level characterized as oligohaline. Dissolved oxygen was generally greater than 6 mg/L in the range supportive of aquatic life. High values observed in June and July in tidal Powells Creek indicated high levels of photosynthesis. pH trends were also indicative of rapid phytoplankton photosynthesis during this period. Chlorophyll a, a direct measure of phytoplankton biomass, was also robust during this period. A marked decline in these photosynthetic indicators was observed immediately following the late July flow spike. The light environment declined substantially at this time as well. Turbidity, light attenuation coefficient, and total suspended solids all increased indicating a decrease in light penetration attributable to increased suspended sediment in the water column, probably washed in from heavy rains. Phytoplankton recovered within several weeks following this flow spike. Overall, tidal Powells Creek exhibited highly productive (eutrophic) conditions typical of the tidal Potomac River embayments. Suspended sediments constitute the greatest source of light attenuation with phytoplankton also important in most samples. Other components became more important moving up the creek.

Rotifers were the most abundant zooplankton as is typical in the tidal freshwater Potomac River and freshwater systems in general. There was a consistent early September maximum in rotifers, principally due to *Keratella* observed at all stations. *Brachionus* was also a contributor to this peak at the mid and inner Creek sites. An early June peak (attributable to *Filinia*) and a clear late July minimum were observed at mid and inner Creek sites corresponding to the chlorophyll decline at these sites. However, at the outer cove and river sites there was no late July decline and in fact a strong increase was observed in the outer Creek which may have been due to flushing of rotifers from the mid Creek area.

Crustacean zooplankton trends were similar to those found in other studies of the tidal freshwater Potomac River. *Bosmina* was the most numerous cladoceran, but is relatively small. The most abundant larger cladoceran, *Diaphanosoma*, was very abundant in tidal Powells Creek exceeding 30,000/m^3. *Ceriodaphnia* was also important. *Diaphanosoma* declined drastically in the wake of the late July flow spike. *Eurytemora*, *Diaptomus*, and cylopoids were the most numerous copepods.

Sampling of planktonic fish larvae (ichthyoplankton) began in the midst of high populations of clupeid (herring and shad) taxa and after the peak of *Morone* sp. (white perch and striped bass). The maximum densities observed were at the lower end of the range of observations from the long-term study at Gunston Cove, but populations may have been higher earlier in the year. The dominance of the ichthyoplankton by clupeids is typical in the tidal freshwater Potomac River as is their peak in May. Other taxa observed were also typical of the tidal

freshwater Potomac.

The array of fishes and their catch levels in the seines at Powells Creek in 2001 are comparable to seine catches observed at similar times of the year in Gunston Cove. The catch in Powells Creek was somewhat more dominated by a single species, white perch, but the subdominant species (banded killifish, alewife, and inland silverside) are similar to those observed in Gunston Cove. The three stations sampled produced a similar list of species with some variation in the order of abundance of individual species. Overall, the fish taxa collected are typical of the tidal freshwater Potomac River.

The outer portion of the embayment (outside the railroad bridge) is more open to the river and more easily flushed by river water and influenced by events in the river. The inner embayment (inside the bridge) is shallow of limited area, so it is easily flushed by creek runoff, but it is more protected from the open water outside the bridge. That should make it more subject to alternating blooms and flushes of the plankton community and to the development of degraded physicochemical conditions from changes in the immediate watershed.

INTRODUCTION

This work's primary objective was to determine the status of biological communities and the physico-chemical environment in the Powells Creek area of the tidal Potomac River to provide a baseline against which to assess future conditions. This will facilitate the formulation of well-grounded management strategies for maintenance and improvement of water quality and biotic resources in this area. Important byproducts of this effort are the opportunities for faculty research and student training which are integral to the educational programs at GMU.

Powells Creek consists of both a free-flowing stream that begins in the Piedmont section of Prince William County, Virginia and a tidal embayment of the Potomac River. The headwaters of Powells Creek are found near the Coles School on Rt. 642 near its intersection with Rt. 234. From there it flows in a generally southeastern direction across the Piedmont. It has been impounded below Spriggs Road to form Lake Montclair. Approximately 2 miles downstream of the Lake Montclair dam Powells Creek flows under Interstate 95 which marks the approximate transition to the Coastal Plain. About 3/4 mile below I-95 the stream flows under U.S. Rt 1 and then enters a tidal marsh area which extends for about 0.8 miles before significant tidal open water is reached. The watershed is primarily residential at low to moderate densities.

The current study is focused on the tidal portion of Powells Creek which is bounded on the north by Leesylvania State Park and on the south by the Cherry Hill peninsula. The embayment has a constriction near its mouth which is spanned by a railroad bridge (Figure 1). The portion of the tidal creek inside the railroad bridge has an mean depth of 0.8 m (2.6 ft), a surface area of 155 hectares (383 acres), and a water volume of 1.18 million cubic meters making Powells Creek one of the smaller named embayments on the tidal Potomac River (Lippson et al. 1981). The 1 meter contour extends about a quarter mile further into the tidal river from the railroad bridge and this area too should probably be considered part of the embayment.

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METHODS

A. Profiles and Plankton: Sampling Day

Sampling was conducted on a semimonthly basis at stations along a transect from near the head of tide on Powells Creek to the Potomac mainstem (Figure 1). One station (PC-5) was located in the narrowed upstream channel of Powells Creek near the powerline crossing. A second site (PC-4) was located in the creek channel as the embayment begins to broaden. The next site (PC-3) was in the broad shallow part of the embayment inside the railroad bridge. A fourth site (PC-2) was just inside the mouth of the embayment and outside of the railroad bridge. The last site (PC-1) was located in the river outside the headlands of the embayment. Dates for sampling as well as weather conditions on sampling dates and immediately preceding days are shown in Table 1.

Sampling was initiated at 9:30-11:30 am. Three types of measurements or samples were obtained at each station : (1) depth profiles of temperature, conductivity, dissolved oxygen, pH, and light measured directly in the field; (2) water samples for GMU lab determination of pH, total alkalinity, suspended solids, turbidity, and chlorophyll a; (3) net sampling for 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, and at half-meter intervals thereafter to the bottom. Meters were checked for calibration before and after sampling. Light profiles (photosynthetically active radiation) were measured with a LI-COR PAR sensor and surface unit.

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. At shallower stations equal volumes were pooled from surface and bottom onl y. The sample was placed in an insulated cooler filled with river water to maintain *in situ* temperature until return to the lab.

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 :m mesh sieve. Two depths (0.3 m and 0.3 m off bottom) with 48 L per depth were used if water depth was less than 1.5 m. The sieve consisted of a 12-inch long piece of 6-inch diameter PVC pipe with a piece of 0.44 :m Nitex net glued to one end. The 0.44 :m 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 and ichthyoplankton were collected by towing a 202 :m net for 1 minute at each of three depths (near surface, middepth, and near bottom) or for 1.5 minutes at each of 2 depths if less than 1.5 m deep. The 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 twice 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%.

At GMU 10-15 mL aliquots of both depth-integrated and surface samples were filtered through 0.45 :m membrane filters (Gelman GN-6) at a vacuum of less than 10 lbs/in^2 for chlorophyll analysis. 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. Total suspended solids and volatile suspended solids (organic weight) were measured by filtering 200-400 mL of depth-integrated sample through a pre-tared glass fiber filter (Whatman 984AH). Turbidity was measured with a Hach 2100P turbidity meter.

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 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 1980). Acid titrant was calibrated with standard Na_2CO_3.

B. Profiles and Plankton: Followup Analyses

Chlorophyll 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 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* (:g/L) = $F_s R_s (R_b - R_a)/(R_s - 1)$

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.

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: Edmondson (1959), Pennak (1978), and Rutner-Kolisko (1974).

Zooplankton = { (N)(V SUB s)} OVER { (V SUB c)(V SUB f) }

Zooplankton counts were converted to number per liter with the following formula:

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 :m 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 in each sample was expressed as number per 10 m^3 using the following formula:

Ichthyoplankton= {(N)(10) } OVER { V }

where N=number of ichthyoplankton in the sample
V=volume of water filtered, (m^3)

C. Adult and Juvenile Finfish

Shoreline fishes were sampled by seining at 3 beach stations: outside the railroad bridge on the south shore of the embayment, outside the bridge on the north shore, and just inside the bridge on the north shore (Figure 1). The seine was 50 feet long, 4 feet high and made of knitted nylon with a 1/4 inch 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. The station just inside the bridge was obstructed by the remains of old bridge pilings and confined by a short beach, and seines there were pulled only about 50 feet. Dates of sampling and weather conditions are found in Table 1.

After the net was hauled in, the fishes were identified and 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 (1993), Hildebrand and Schroeder (1928), Loos et al. (1972), Dahlberg (1975), Scott and Crossman (1973), Bigelow and Schroeder (1953), and Eddy and Underhill (1978).

E. Data Analysis

Data for each parameter were entered into Quattro Pro spreadsheets for graphing of temporal and spatial patterns. Systat 9.0 was used for statistical calculations.

Light attenuation (extinction) due to chlorophyll (K_{chl}) and total suspended solids (K_{tss}) was derived by multiplying the concentration of each constituent by a specific attenuation coefficient derived from Table 5 of Gallegos (2001). Values were 0.0154 m^2/mg for chlorophyll a and 0.0806 m^2/g for total suspended solids. These were summed and subtracted from total attenuation to arrive at residual attenuation K_{res}.

RESULTS

A. Climate

April, May, and June experienced near normal temperatures (Table 2), but July was substantially cooler than normal. August was near normal and September slightly below normal. October was near normal, but November and December were about 3EC above normal. Precipitation was slightly below normal in April, normal in May, and substantially above normal in June and July. August was slightly below normal and led into an intensifying drought which lasted through the remainder of the year. For the period September through December, only 10.7 cm of precipitation were observed in 2001 compared to the average for that period of 31.9 cm. Solar radiation was reduced in late May during a period of consistent cloudy and rainy weather. It increased steadily through June reaching a peak in early July before gradually tapering off through the rest of the year.

Freshwater flow into the tidal Potomac at Little Falls was somewhat lower than normal in early to mid May, but increased substantially in late May to above 10,000 cfs (Figure 2). Two additional flow spikes were observed in early and late June followed by a steady decline through July reaching a seasonal low of about 2000 cfs in late July. Flows increased substantially during August to nearly 10,000 cfs on three occasions. Flow data was not available from Powells Creek, but data from several other area streams was examined to get some idea of tributary inflows into tidal Powells Creek (Figure 3). These showed that flows were high in late May, gradually decreased through most of June, spiked in late June, resumed the gradual decline through most of July, and spiked again in late July. August flows remained a little higher than July with assorted peaks which became less common moving into September.

B. Water Quality

All stations exhibited a similar seasonal increase in temperature (Figure 4). Temperature increased in the Potomac River (Station PC-1) from about 21EC in mid May to 27EC in late June. A slight decline was observed during July followed by an annual maximum of about 28EC in August. Temperature in the river declined steadily through the remainder of the year reaching nearly 12EC in late November. In outer Powells Creek (Station PC-2) temperatures were slightly warmer than the river in June and early August. In middle and inner Powells Creek (Stations PC-2 and PC-3) temperatures during the June and early August maxima were substantially higher than in the river exceeding 30EC. In innermost Powells Creek (PC-5) temperature was generally 2-5EC cooler than in the rest of the study area.

Conductivity was generally quite low at all sites through early September, indicative of freshwater conditions (Figure 5). Beginning in late September a rather pronounced increase in conductivity was observed such that by late November conductivity exceeded 3000 uS/cm at the river and outer and mid Powells Creek sites. This value roughly corresponds to a salinity of about 2 parts per thousand (ppt) which is indicative of oligohaline conditions. At inner Powells Creek station their was a milder increase while at the innermost site only a temporary blip in October was observed.

Dissolved oxygen concentrations were generally greater than 6 mg/L, in the range supportive of aquatic life (Figure 6). On the whole values were lowest at the inner Powells Creek sites. The lowest value observed was 4 mg/L at the innermost Powells Creek site in early September. When examined on a percent saturation basis (Figure 7) further trends are observed. First, dissolved oxygen was well above saturation in outer and mid Powells Creek from May through mid July. This indicates a high rate of photosynthetic production due to phytoplankton activity. High levels were also observed in June and early July in the river and inner Powells Creek. A dramatic decline at all of these sites occurred in late July with concentrations declining to 80-100% saturation. Dissolved oxygen rebounded in the mid and outer Creek in August, but in the other areas oxygen concentrations did not recover as strongly. Dissolved oxygen at the innermost station was rarely above 100% indicating the lack of strong photosynthetic activity at this site. However, respiration appeared to be notable at this site in late August and September as oxygen dropped below 60% saturation.

Field pH was very high in outer and mid Powells Creek from May to mid July, another manifestation of high photosynthesis rates (Figure 8). In the river and inner Creek pH also increased during June and early July to above 8.5. A dramatic decline was observed in late July with pH dropping below 7 in the mid and inner Creek and below 8 in the river and outer Creek. The river station continued to decline into August, but the Creek stations were again above 8 by early August and approaching 9 in some places by early September. A fairly steady decline was observed for the remainder of the year to less than 7.5 by late November. The innermost Creek station (PC-5) did not exhibit these drastic swings but remained between 6.7 and 7.7 for the entire year.

The most obvious signal in the turbidity data was a strong spike in late July (Figure 11). Values on this date were 120-140 NTU (nephelometric turbidity units) at the mid and inner Creek sites and 60-80 at the outer and innermost Creek sites. The river site was unchanged at about 30 NTU. These data suggest a major influx of suspended sediments into the water column at this time either from the washed in from the watershed or resuspended from the bottom of the Creek. Other than this spike turbidity was generally in the 10-40 NTU range with lowest values consistently observed at the innermost Creek station.

Secchi depth transparency also exhibited a strong decline on this late July sampling (Figure 12). Four of the sites exhibited secchi depth of less than 20 cm on this date whereas on other dates secchi depth exceeded 30 cm. In the spring the river and innermost Creek sites generally had the clearest water with secchi depths greater than 60 cm while the other Creek sites were in the range 35-50 cm. During August secchi depth at all sites increased, generally to the 30-50 cm range. Data at the innermost site was limited because it was often possible to observe the secchi disk clearly on the bottom of the water column. Data for light extinction coefficient mirrored that for secchi and turbidity with the greatest rate of light extinction with depth occurring on July 27 in mid Creek (Figure 13).

Total suspended solids exhibited a trend similar to that in turbidity, secchi, and light extinction with highest values observed on July 27 especially at the mid Creek site (Figure 14). Otherwise, values at the outer, mid, and inner Creek stations were generally 20-40 mg/L and did not exhibit distinct spatial or seasonal trends. Values were generally lower at the innermost Creek site (PC-5).

Volatile suspended solids, a measure of organic matter content of suspended solids, did not exhibit any marked response on July 27 suggesting that the suspended solids responsible for the increased turbidity on that date were fine, inorganic particles (Figure 15). A general seasonal pattern was observed at most sites with highest levels in early July or August.

Chlorophyll concentration in the water column is a measure of phytoplankton density (Figure 16). Chlorophyll concentrations were quite high in May and June at the outer, mid, and inner Creek sites, exceeding 80 :g/L on occasion. On July 27 a marked decline in chlorophyll was observed at the inner and mid Creek sites, but chlorophyll actually increased at the outer Creek and river sites. This behavior is consistent with a flushing of phytoplankton from the middle and inner Creek areas to the outer Creek and river sites due to a strong rainstorm with resulting runoff. Chlorophyll rebounded strongly at the mid Creek site in August and more slowly at the inner Creek site. Pheopigment, a measure of dead and dying phytoplankton, followed patterns similar to those in chlorophyll (Figure 17).

C. Zooplankton

Zooplankton were sampled in two ways. For the smaller zooplankton, including rotifers, the small cladoceran *Bosmina*, and immature copepods, water was pumped through a 44 :m mesh sieve. For larger cladocerans and copepods, a 202 :m net was towed through the water.

Rotifers are the smallest and usually most numerous zooplankton in the freshwater tidal Potomac River, as in most freshwater systems. In the river rotifers were found at only moderate densities of less than 1000/L for much of the year (Figure 18). Much higher numbers were observed late in the year with a maximum in early September exceeding 3000/L. *Keratella* was generally the most important genus, but *Polyarthra* was co-dominant in early September and *Synchaeta* was dominant in late November. In the outer Creek (Figure 19) rotifers were much more common earlier in the year. *Keratella* was consistently associated with the peaks in abundance which occurred in mid May, late July, and early September. In the mid creek area (Figure 20) there were two distinct maxima. In early June *Filinia* was responsible for a maximum and in early September *Brachionus* and *Keratella* were most important. On both cases densities exceeded 3000 animals/L. A marked decline was observed in late July at the same time that the chlorophyll levels declined dramatically at this site. At the inner Creek site (Figure 21) there were again peaks in early June and early September. The early June peak was again dominated by *Filinia*, but *Brachionus* also contributed. The early September peak was higher than at the other sites with *Brachionus* playing more of a role along with *Keratella*.

In summary there was a consistent early September maximum in rotifers, principally due to *Keratella* observed at all stations. *Brachionus* was also a contributor to this peak at the mid and inner Creek sites. An early June peak (attributable to *Filinia*) and a clear late July minimum were observed at mid and inner Creek sites corresponding to the chlorophyll decline at these sites. However, at the outer cove and river sites there was no late July decline and in fact a strong increase was observed in the outer Creek which may have been due to flushing of rotifers from the mid Creek area.

The small cladoceran *Bosmina* was also quantified from the microzooplankton samples. *Bosmina* densities were generally greatest in the late spring or summer, exceeding 100/L at three of the four sites (Figure 22). The river site also exhibited a maximum in the fall. *Bosmina* declined at all sites on July 27. the hypothesized flushing event.

A final group whose abundance was determined in the microzooplankton samples was the immature stage of copepods, the nauplius. Copepod nauplii exhibited a single major peak in October at most sites (Figure 23). In the river November was actually the highest.

The larger cladocerans, quantified in macrozooplankton samples, exhibited distinct spatial and temporal patterns (Figures 24-27). Both *Ceriodaphnia* and *Diaphanosoma* were dominant at the river site while *Diaphanosoma* was by far most important in the outer and mid Creek sites. *Diaphanosoma* reached a maximum at most sites on July 13. Maximum numbers were over 30,000/m^3 (30/L) at outer and mid Creek sites and nearly 10,000/m^3 (10/L) in the river. At the river site *Ceriodaphnia* peaked at about 7500/m^3 (7.5/L) in early June. At the inner cove site *Diaphanosoma* was greatly reduced, not exceeding 1000/m^3. *Ceriodaphnia* attained over 5000/m^3 on July 27 at the inner cove site. *Ceriodaphnia* actually increased on July 27 (the date of hypothesized flushing) at all stations while *Diaphanosoma* declined drastically.

Copepods attained their greatest density in the river, exceeding 20,000/m^3 (20/L) in early July (Figure 28). The calanoid *Eurytemora* was the most important taxon in May and early June, but cyclopoids took over in July. Copepods declined drastically in the river in late July and remained low until a peak in *Diaptomus*, another calanoid, was found in October. Copepod populations followed a similar seasonal pattern at the outer Creek site (Figure 29), but at reduced levels. Again *Eurytemora* was important initially, and cyclopoids become more important by July. At the mid Creek site (Figure 30), *Eurytemora* was not as important and, again cyclopoids became dominant in July reaching a maximum of 10,000/m^3 (10/L). There was no substantial fall peak. At the inner Creek site copepod abundance was relatively low and the dominant taxon was *Diaptomus* with peaks in both late May and late July.

D. Fish

Sampling of planktonic fish larvae (ichthyoplankton) began in the midst of high populations of clupeid taxa (Figures 32-35). Clupeid larvae observed included various river herrings (*Alosa* sp.) as well as threadfin and gizzard shad (*Dorosoma* sp.). They are lumped together because many younger clupeid larvae cannot be identified to species. The highest densities were observed at PC-2 reaching nearly 60 larvae per 10 m^3 on May 15. Numbers were somewhat lower (25-40 per 10 m^3) at the other stations on this date. Clupeids declined steadily through May and June and disappeared from samples by July 13. *Morone* sp. (white perch or striped bass) larvae were found only at PC-1, the river site, and only on May 15. *Menidia beryllina* (silverside) was found at all stations, but was most abundant and observed most frequently at PC-3 where it reached a maximum of about 4 per 10m^3 on July 13. *Lepomis* sp. (sunfish) and Ictaluridae (catfish) larvae were observed only at PC-4.

The array of fishes collected in the seines at Powells Creek in 2001 was typical of the tidal freshwater Potomac River (Jones and Kelso 2001). The most abundant fish collected in the seines at Powells Creek was the white perch (*Morone americana*) which composed almost 50% of all individuals collected overall and was the most abundant species at all three collection sites (Table 3). Banded killifish (*Fundulus diaphanus*) was the second most abundant fish at about 12% of all fishes, followed by alewife (*Alosa pseudoharengus*) at 10.7% and inland silverside *(Menidia beryllina)* at 8.6%. (All of the *Alosa* sp. were young juveniles, and the species are difficult to distinguish one from another. The determination that some of the juveniles were hickory shad (*Alosa mediocris*) caused some additional confusion, but we feel that most of our identifications were correct.) Banded killifish was more abundant at the site inside the railroad bridge, while alewife was more numerous at the two sites outside the bridge. Inland silverside was slightly more abundant inside the railroad bridge. Three other species comprised at least 2% of the collections: spottail shiner (*Notropis hudsonius*) 3.3%, bay anchovy (*Anchoa mitchilli*) 2.75% and striped bass (*Morone saxatilis*) at 1.95%.

White perch collections reached a maximum on June 15 as did alewife (Figures 36-39), when young-of-the-year juveniles grew large enough to be caught in the seine. Banded killifish were most abundant in the first sample on May 23, but were nearly as abundant on August 31. Inland silverside were less abundant during the summer months, and spottail shiner were more numerous during the summer, but bay anchovy were concentrated in very late summer and fall.

The seine station just inside the railroad bridge on the north shore of the embayment produced the largest catches, despite the fact that the site allowed only half the seine tow distance of the other stations. The abundance of fishes may have been because of the protective cover provided by the old pilings and the shade of overhanging trees. The order of abundance of species was almost the same as the overall order at all stations combined: white perch first, followed by banded killifish, inland silverside, and alewife. Species that were collected at this station more than others were blueback herring, brown bullhead, goldfish, tessellated darter, golden shiner, and spottail shiner. The station on the south shore outside the bridge produced almost as many fish individuals. After white perch, the most abundant species there were, in declining order, alewife, inland silverside, striped bass, banded killifish, and bay anchovy. Alewife, American eel, white perch, striped bass, and hogchoker were more abundant here than at other stations. Finally, the north shore beach station outside the bridge produced the lowest catch. White perch again were most numerous, followed by alewife, banded killifish, and bay anchovy. Hickory shad, bay anchovy, common carp, gizzard shad, Eastern silvery minnow, channel cat, largemouth bass, and yellow perch were all taken here in numbers greater than at the other two stations.

DISCUSSION

The year 2001 was characterized by relatively normal temperatures from April through June, a markedly cool July, and relatively normal temperatures from August October. November and December were substantially warmer than normal. Precipitation was near normal through May, well above normal in June and July, and well below normal for the remainder of the year. Light (photosynthetically active radiation) was depressed in late May and June, peaked in July, and declined steadily for the remainder of the year.

Water temperature followed the expected spring increase at all stations through mid June, but in July there was a marked drop in July. This decrease corresponded with the below normal air temperatures for July noted above. By early August temperatures had returned to their June levels before beginning the fall decline. Conductivity was generally very low in the study area reflecting the lack of intrusion of brackish water from downstream portions of the tidal Potomac. However, by October and even more so in November, there was a marked increase in conductivity at the river and outer tidal creek stations (PC-1, PC-2, and PC-3) which indicated that brackish water was starting to enter the area. The lower summer freshwater flow into the river had resulted in greater movement of the brackish water upstream.

Dissolved oxygen concentrations were generally highest in the mid-tidal creek sites (PC-2, PC-3, and PC-4) where chlorophyll was generally quite high. This strongly suggests that phytoplankton photosynthesis was a major factor. There was a decrease in dissolved oxygen in late May, which corresponds to the time of decreased light (PAR) availability, again implicating photosynthesis. The rising light concentrations of June through early July coincided with some of the highest dissolved oxygen. By late July a marked decline in oxygen was found at all stations except PC-5. The observations in the tidal creek were made on July 27, which was right on the heels of precipitation of almost 3.5 cm (at National Airport). This rainfall resulted in a marked flow spike in Quantico Creek (the nearest USGS gauge) on July 26, the date of highest flow during the entire summer for this gauge. Thus, it appears that the decline in oxygen in Powells Creek was due in large part to the flushing and dilution of the phytoplankton that had accumulated in the tidal creek. Interestingly, oxygen concentrations increased somewhat at PC-5 on that date. Since PC-5 oxygen had actually been slightly below saturation, the flushing may actually have diluted the oxygen depletion processes occuring at this site.

Dissolved oxygen rebounded during August and September, but did not reach the highest levels found in the spring and early summer. As in the spring the mid tidal creek station (PC-3) had the highest concentrations. The most upstream station exhibited renewed and intensified depletion in late August and September. The depletions at this site may be due to the beginnings of decomposition of the annual marsh vegetation.

pH followed a very similar pattern to dissolved oxygen with high values in the spring, a strong decline in late July and recovery in August and September. In fact pH and dissolved oxygen were very strongly correlated.

The three measures of water clarity and light penetration (secchi depth, light extinction coefficient, and turbidity) were highly intercorrelated and were strongly correlated with two measures of particle concentration (total and volatile suspended solids) (Table 4). All exhibited a strong spike in late July on the date when oxygen decline noted above occurred. An decrease in water clarity due to flushing of suspended sediments into the tidal creek would be expected as a result of rainstorms and high runoff from the watershed. Turbidity, a measure of light scattering by particles, increased strongly in late July, greatly above values on any other date. This increase was most strongly observed in the tidal creek and there was little indication of it at the river site (PC-1). Turbidity was generally lowest at the most upstream site (PC-5). Secchi depth also decreased much more markedly at tidal creek sites than at the river site. And light was extinguished at a much higher rate with depth on this date.

Interestingly there was a poor correlation between chlorophyll levels (a measure of phytoplankton algae) and water clarity and light penetration. To examine the relative importance of suspended solids vs. phytoplankton to light penetration in Powells Creek we were able to partition the light extinction coefficient, k, into components related to suspended solids (K_{tss}), that related to phytoplankton (K_{chl}), and that from other components (K_{res}). These values are graphed for each station by sample date in Figures 41 to 44. In these graphs the greater the K value, the greater the light attenuation by the particular component. It can be seen that on all dates at all stations, K_{tss} is greater than K_{chl} meaning that nonalgal suspended sediments are more important than algae as a cause of light attenuation in the study area. In most cases K_{tss} was double or triple K_{chl}. This would help explain the poor correlation between chlorophyll concentration and light penetration in Powells Creek. It also suggests that attempts to increase light penetration in Powells Creek will need to address nonalgal suspended sediments. Other sources of light attenuation (K_{res}) varied in importance between the stations. At PC-1 K_{res} was small and hovered around 0 indicating little contribution from other sources. Proceeding upstream along the tidal creek, K_{res} was consistently positive, generally increased, and became more variable. This suggests that other light absorbing materials such as dissolved organics become more important in these areas. Also, it is possible that inorganic particles were present that were not retained on the filters we used for TSS determination. This may particularly explain the large K_{res} values on July 27 and PC-3 and PC-5. On these dates K_{res} may actually have been the result of very fine clay particles washed in by the storm flows.

Chlorophyll levels were generally higher in the tidal creek than in the river channel during the spring. Chlorophyll began to increase in the river channel during late June and actually peaked there on July 27. This was the same date that chlorophyll dropped sharply at the inner tidal creek stations (PC-3 and PC-4). Interestingly, chlorophyll actually continued to increase on this date at the outer creek station PC-2. This may be accounted for partially by the flushing of algae from the inner creek stations by the storm flows. Chlorophyll bounced back at the inner tidal creek stations in August and then began a fall decline at both tidal creek and river stations through November. Lowest chlorophyll values were consistently observed at the farthest upstream site (PC-5) and showed much less seasonal pattern at this site. This is probably due to the sheltered nature of the creek at this point from both overhanging and emergent vegetation and the continual flushing of the small water volume at this site.

Rotifer populations in the tidal creek (Figs 20, 21) exhibited a bimodal population curve with peaks in spring (June 13) and fall (September 7). *Filinia* was the dominant in spring, while *Brachionus* and *Keratella* was most important in the fall. Decline of the spring peak was underway for several weeks before the July 27 flushing event, although seems to have further depleted populations. Populations in the river and outer cove sites followed a different pattern. In the river peak densities were observed on July 13, September 7, and November 28. At the outer tidal creek site there were high densities on the first sampling date (May 15) and peaks on July 27 and September 7. The July 27 peak corresponds with the flushing event in the inner tidal river and may again be evidence of flushing of animals from the inner tidal creek (PC-3 and PC-4) to the outer tidal creek (PC-2). Maximum densities were greater in the inner tidal creek sites than at the outer tidal creek and river sites. The maximum observed densities of over 5000/L are consistent with the maximum densities observed in Gunston Cove (Jones and Kelso 2001). The same taxa are generally dominant in both areas.

The small cladoceran *Bosmina* was generally more abundant in the spring and early summer and less abundant in the late summer and early fall. This is a pattern typical of the tidal freshwater Potomac (Jones and Kelso 2001). Peak density of 200/L is also fairly typical. *Diaphanosoma* was the most abundant larger cladoceran in Powells Creek as in Gunston Cove. Maximum densities of *Diaphanosoma* in Gunston Cove are generally about 20,000 to 30,000/m^3 which is similar to that found in the tidal Powells Creek sites. In the river channel near Gunston Cove the maximum density of *Diaphanosoma* is generally about 10,000/m^3, again similar to that found in the river outside of Powells Creek. *Diaphanosoma* declined precipitously on July 27, the day of the summer flushing event. While this event may have hastened its decline, it decreased at the river site as well which did not seem to be greatly affected by the flushing event otherwise. *Ceriodaphnia* was also important in the river and the inner tidal creek, though on different dates. The peak values reached of about 6000/m^3 was higher than normally observed in Gunston Cove (Jones and Kelso 2001).

Copepod nauplii were present at moderate levels during most of the year, but increased dramatically in October to over 1000/L. This is an unusually high density compared to Gunston Cove stations which generally peaked at a few hundred per liter. It could be due to a synchronized spawning event since nauplii are the first stage of copepod growth. The dominance of *Eurytemora* and cyclopoid copepods at the river and tidal creek stations is typical of patterns observed in Gunston Cove (Jones and Kelso 2001). The higher numbers of these copepods observed in the river as opposed to the tidal creek is also typical as are the general magnitude of the population densities. *Diaptomus*, the dominant at the inner tidal creek site, is also common at Gunston Cove and can attain similar densities.

The dominance of planktonic fish larvae collections by clupeids is typical in the tidal freshwater Potomac River. The density of clupeid larvae generally peaks during May, and the May 15 collection may have been at about maximum density, though we can't tell for sure since samples were not collected before that time. Since *Alosa* sp. spawn mostly in March and April and *Dorosoma* sp. spawn mostly in May, the bulk of the larvae in May are probably *Dorosoma* sp.. The maximum densities collected at Powells Creek in 2001 are about a third to a quarter of the maximum densities typical for the Gunston Cove area. The second most abundant group of fish larvae found in Gunston Cove, *Morone* sp. (white perch and striped bass), were found only at the river station (PC-1) in Powells Creek and only on May 15. Though the densities are comparable to long term monthly averages in Gunston Cove, *Morone* larvae are frequently at their maximum in April (or even March) in Gunston Cove, which is before sampling was initiated in Powells Creek. *Menidia* larvae, found in few and scattered numbers throughout the summer in Powells Creek data, are present in a similar densities and seasonal distribution in the Gunston Cove data (Jones and Kelso 2001).

The seine catches at Powells Creek in 2001 seemed to produce about the same numbers of fishes as have comparable seines in Gunston Cove in 2000 (Jones and Kelso 2001). The catch at Powells Creek is more dominated by a single species, white perch. The other subdominant species (banded killifish, alewife, and inland silverside) are usually among the most abundant species in Gunston Cove seines also. As is the case in Gunston Cove, almost all of the white perch and alewife that are caught were young-of-the-year juveniles and almost all of the banded killifish and inland silverside were a mix of some juveniles and many adults. This results in a strong seasonality to the catches, with the largest numbers taken in June and July.

The three seine stations produced about the same list of numerically dominant species, with some change of sequence. White perch and inland silverside were most abundant at the stations outside the railroad bridge on the south shore and inside the bridge and were less abundant at the station outside the bridge on the north shore. Banded killifish and spottail shiner were more abundant at the station inside the railroad bridge. Alewife were more abundant at the station outside of the railroad bridge on the south shore. The number of species represented in the catch at each station was high at all stations: 23 at the station inside the bridge, 22 at the station outside the bridge on the north shore and 19 at the station outside the bridge on the south shore. The collection of species caught at the south shore station consisted of species most characteristic of the river and more saline water (white perch, alewife, striped bass, bay anchovy, hogchoker). The collection of species at the station inside the bridge were most characteristic of creeks and inner parts of embayments (banded killifish, brown bullhead, goldfish, golden shiner). The species caught at the station outside the bridge on the north shore were a mixture of river (bay anchovy, channel cat) and creek species (common carp, Eastern silvery minnow, largemouth bass).

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Table 1

Powell's Creek Study - 2001

			Avg Daily			Total Precip			Solar Radiation	
	Type of	Temp (EC)			(cm)			(E/m^2/day)		
Date	Sampling		1-day	3-day		1-day	3-day		1-day	3-day
May 15 WP		16.7	20.9		0	T		33.3	34.1	
May 23	F	18.9	17.6		0	2.56		38.7	20.0	
May 29 WP		15.5	16.1		T	0.28		25.5	24.4	
June 13 WP		21.7	26.3		0.08	0.08		27.1	32.3	
June 15	F	24.4	22.2		0.51	0.58		20.3	26.7	
June 23	F	25.0	25.2		0.02	2.08		11.6	22.5	
June 27 WP		26.7	27.2		0	0		38.9	36.2	
July 6		F	24.4	25.4		0	2.95		50.1	41.7
July 13 WP		22.2	23.3		0	T		49.7	46.2	
July 20	F	21.7	23.5		0	0.51		41.4	28.1	

July 27	WP		23.3	21.8		0	3.38		40.7	35.0	
Aug 3			F	25.0	25.7		0	0		38.9	42.5
Aug 8		WP		27.8	26.1		0	0		39.1	41.5
Aug 21	WP		20.6	21.1		0	0.86		38.1	29.9	
Aug 31		F	25.0	24.3		T	0.24		33.0	27.8	
Sep 7		WP		18.3	17.8		0	0		39.1	40.2
Sep 14		F	22.2	23.9		0.38	0.38		22.6	33.3	
Sep 26	WP		10.6	15.9		0	1.55		28.2	18.1	
Sep 28		F	17.2	14.3		0	0.08		25.0	24.8	
Oct 12		WP		15.6	13.9		T	T		23.0	26.5
Oct 25			F	17.8	15.0		0	0		25.5	22.5
Nov 14		F	8.9	9.3		0	0		31.0	28.0	
Nov 28	WP		7.8	9.8		0	T		13.2	12.1	

Type of sampling: WP=water quality, profiles, and plankton. F=fish seining.
1-day values are day of sampling. 3-day values are day of sampling plus previous 2 days.
“T” means “trace”.

Table 2.
Meteorological Data for 2001. Monthly Summary.
Air Temperature and Precipitation are from National Airport.
Photosynthetically Active Radiation is from GMU Campus in Fairfax.

MONTH	Air Temp (^oC)		Precipitation (cm)		Psyn Active Radiation ($E/m^2/day$)
January	1.9	(1.4)	5.6	(6.9)	------
February	4.9	(3.0)	4.6	(6.9)	------
March	6.6	(8.4)	9.8	(8.0)	------
April	14.2	(13.6)	4.3	(6.9)	25.9
May	18.8	(19.1)	9.4	(9.3)	26.4
June	24.0	(24.4)	11.9	(8.6)	30.5
July	24.0	(26.7)	12.1	(9.6)	37.4
August	26.0	(25.8)	7.6	(9.9)	32.3
September	20.5	(21.8)	3.6	(8.4)	30.1
October	15.4	(15.4)	1.8	(7.7)	27.8
November	12.7	(9.9)	1.4	(7.9)	20.7
December	7.5	(4.1)	3.9	(7.9)	------

Note: 2001 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. LiCor logger at GMU pond in Fairfax, VA for solar radiation.

Table 3

Total Fish by Station
Tidal Powells Creek Study - 2001

		Station			
	OutNorth	OutSouth	InNorth	Total	% of Tot
Alosa aestivalis (Blueback herring)	3	6	8	17	0.36
Alosa mediocris (Hickory shad)	32	26	4	62	1.30
Alosa pseudoharengus (Alewife)	158	231	120	509	10.69
Alosa sapidissima (American shad)	0	0	0	0	0.00
Ameiurus catus (White catfish)	1	0	1	2	0.04
Ameiurus nebulosus (Brown bullhead)	0	0	3	3	0.06
Anchoa mitchilli (Bay anchovy)	67	43	21	131	2.75
Anguilla rostrata (American eel)	0	2	0	2	0.04
Carassius auratus (Goldfish)	0	0	8	8	0.17
Catostomus commersoni (White sucker)	0	0	0	0	0.00
Cyprinus carpio (Common carp)	2	0	1	3	0.06
Dorosoma cepedianum (Gizzard shad)	59	20	1	80	1.68
Etheostoma olmstedi (Tessellated darter)	10	8	58	76	1.60
Fundulus diaphanus (Banded killifish)	132	59	399	590	12.39
Fundulus heteroclitus (Mummichog)	30	9	35	74	1.55
Hybognathus regius (Eastern silvery minnow)	46	2	35	83	1.74
Ictalurus furcatus (Blue catfish)	0	0	0	0	0.00
Ictalurus punctatus (Channel catfish)	1	0	0	1	0.02
Lepisosteus osseus (Longnose gar)	0	1	0	1	0.02
Lepomis gibbosus (Pumpkinseed)	23	9	23	55	1.15
Lepomis macrochirus (bluegill)	14	2	14	30	0.63
Menidia beryllina (Inland silverside)	61	166	181	408	8.57
Micropterus salmoides (Largemouth bass)	5	1	1	7	0.15
Morone americana (White perch)	495	1055	799	2349	49.33
Morone saxatalis (Striped bass)	13	61	19	93	1.95
Notemigonus chrysoleucus (Golden shiner)	1	0	6	7	0.15
Notropis hudsonius (Spottail shiner)	39	38	79	156	3.28
Perca flavescens (Yellow perch)	3	0	1	4	0.08
Trinectes maculatus (Hogchoker)	0	1	0	1	0.02
Unknown juvenile	1	0	9	10	0.21
	1196	1740	1826	4762	100.00

Table 4
Correlations among Light-related Water Quality Variables

		DO	pH	Secchi	Ext. coef.	Turb.	VSS	TSS	Chl a
DO (% saturation)	----								
pH, Field		**0.783** {60}	----						
Secchi depth	-0.132	-0.157 {48}	---- {48}						
Extinction coefficient	-0.183	-0.066 {57}	**0.763** {57}	---- {47}					
Turbidity		0.077 {60}	-0.047 {60}	**-0.698** {48}	**-0.850** {57}	----			
Volatile suspended solids		**0.508** {58}	**0.454** {58}	**-0.621** {46}	**-0.595** {55}	**0.430** {58}	----		
Total suspended solids	**0.378**	0.276 {58}	**-0.744** {58}	**-0.834** {46}	**0.846** {55}	**0.675** {58}	---- {58}		
Chlorophyll a	**0.541**	**0.614** {56}	-0.302 {56}	-0.315 {46}	0.085 {53}	**0.701** {56}	**0.460** {54}	---- {54}	

Pearson correlation coefficient shown with number of data pairs in brackets. For n=46, coefficients with absolute values greater than 0.29 are significant at the 0.05 level and those with absolute values greater than 0.37 are significant at the 0.01 level (shown in bold).