

Quantico Marine Corps Base Stream Monitoring

1998-1999

Final Report

to the
U.S. Navy

by

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Introduction

George Mason University has conducted a two-year biomonitoring of the streams of the Quantico Marine Corps Base. The purpose of the study was to provide baseline information on stream water quality and habitat quality in the streams and watersheds of the Marine Corps Base (MCB) north and west of Interstate Highway 95 and to compare the sites to other sites in northern Virginia.

Thirteen sites were selected for sampling, positioned at the lower end of each subwatershed to integrate ecological conditions in each subwatershed. The locations of the sampling sites are described in Table 1 and shown on Figure 1. Five of the sites (Stations 2, 3, 4, 5, and 6) were on small tributaries of Cedar Run, itself a tributary of the Occoquan River. One site (Station 8) was on the South Fork of Quantico Creek. Another five sites (Stations 7, 9, 10, 11, and 13) were located on tributaries or the main stream of Chopawamsic Creek. The last two sites (Stations 1 and 12) were on tributaries of Aquia Creek.

Each site was sampled for benthic macroinvertebrates and for fishes once in each year. The first year's field sampling was conducted during May, June and July of 1998, and the second year's sampling was during May, June and July of 1999. A habitat assessment was also conducted in each year.

Methods

Benthic Macroinvertebrate Sampling Methods

To assess benthic communities, a modified version of the EPA Rapid Bioassessment Protocol II (Plafkin et al. 1989) was used. A kick net, measuring 22 cm x 44 cm with a 0.5 mm mesh size, was used to sample benthic organisms. With the net held to the bottom facing upstream, the substrate was vigorously disturbed to a distance of one meter directly upstream of the net for one minute. Larger stones were manually picked when necessary. The sample was placed in a pan and rinsed through a 0.5 mm sieve. Large debris was examined for organisms and discarded. Organisms remaining on the net were placed into the sample jar. A kick sample was taken at a riffle and at a run area and combined into one jar. The sample was preserved in formalin to a concentration of five percent. Macroinvertebrates were sampled at each site once during each spring-early summer (May through July).

In the lab the sample was rinsed with tapwater to remove the formalin. The sample was spread evenly on a numbered grid of 0.5 mm mesh size and squares measuring 5 cm x 5 cm . Using a random number table, whole grids were selected and picked until 200 organisms were found or the entire sample was picked. The organisms and remaining sample were preserved in ethanol and glycerin. The organisms were identified to family and enumerated. The primary source for taxonomic identification was Merritt and Cummins (1995).

RBP II employs various metrics and indices to compare and rank sites through characterization of the benthic community. The protocol permits a choice of metrics dependent

Table 1. Sampling sites used for biomonitoring of streams in Quantico Marine Corps Base

Station Number	Site Description
1	Cannon Creek above Rt 644
2	Dorrells Run below MCB 3
3	Goslin Run above MCB 8
4	Lucky Run below MCB 8
5	South Mill Branch below MCB 8
6	East Mill Branch above MCB 8
7	North Branch of Chopawamsic Creek at Coop's Gobbler Road
8	South Fork of Quantico Creek above Rt. 619
9	North Branch of Chopawamsic Creek above confluence with Middle Branch
10	Middle Branch of Chopawamsic Creek above MCB 1
11	South Branch of Chopawamsic Creek below MCB 1
12	Beaverdam Run below Application Training area
13	Chopawamsic Creek below second crossing of Breckinridge Road

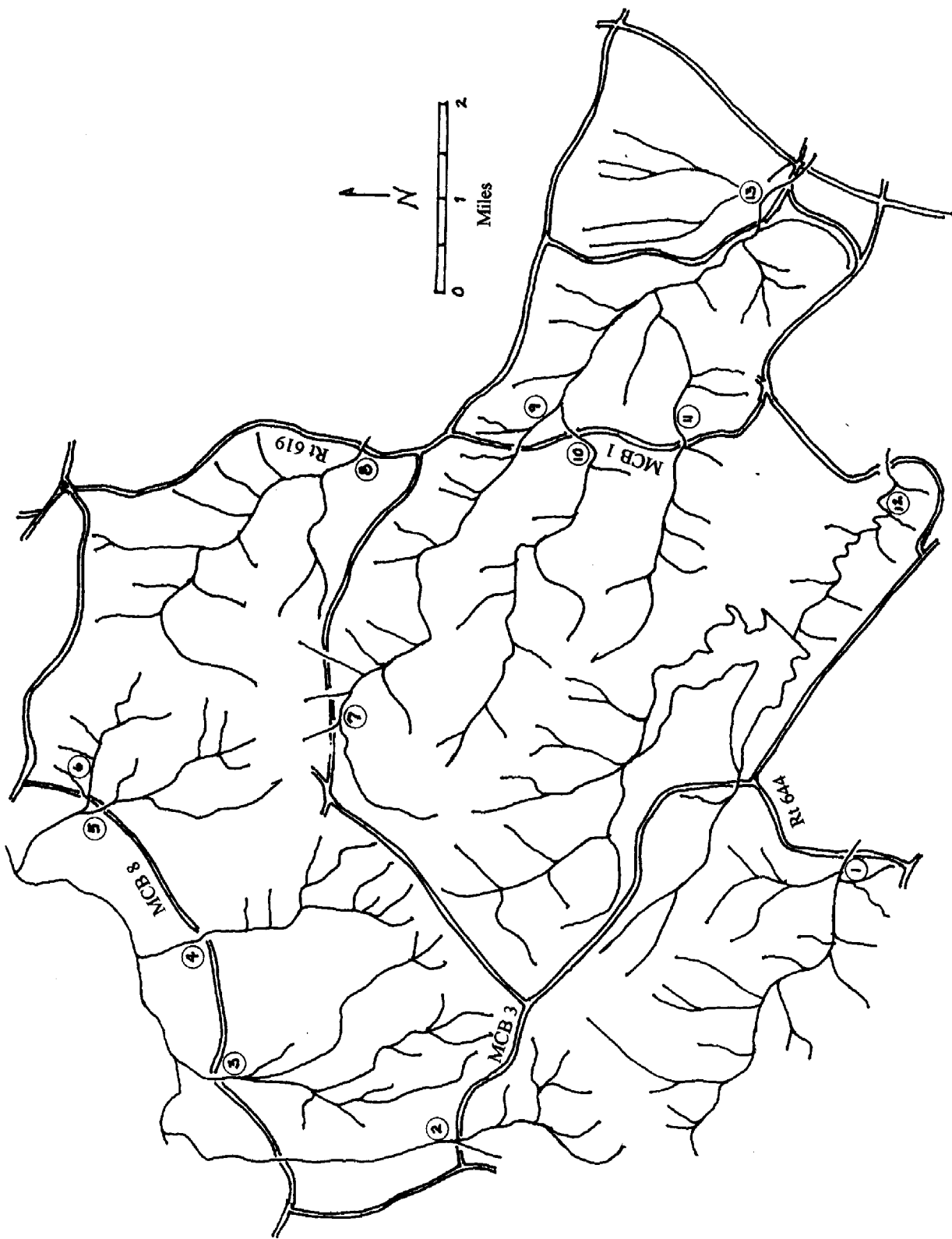


Figure 1. Sampling sites for biomonitoring of streams in Quantico Marine Corps Base.

upon the region sampled. The following six metrics were used to compare the sites: Family Richness, Family Biotic Index, Ephemeroptera-Plecoptera-Trichoptera (EPT)/Chironomidae abundance, Percent Dominant Family, EPT Index, Sorensen's Index. The metrics are briefly described in Table 2. These metrics were used by Jones and Kelso (1997) to compare three watersheds north of the Quantico Marine Corps Base (Neabsco Creek, Powells Creek and Quantico Creek), which are geographically and morphologically similar to the streams within Quantico Marine Corps Base.

Table 2. Metric definitions used in RBP II

Name of Metric	Definition
Sorensen's Index	measures similarity of two stations according to presence or absence of taxa
Taxa Richness	total number of unique taxa
Taxa Biotic Index	weighting numbers of individuals in a taxa by a tolerance value unique for that taxa
EPT Index	total number of distinct taxa within Ephemeroptera, Plecoptera and Trichoptera which are considered pollution sensitive
EPT/Chironomids	measures community balance; sensitive taxa/ tolerant taxa
Percent Dominant Taxa	indicates community balance, percent contribution of the dominant taxa to the total number of organisms

Fish Sampling Methods

The sampling of fish communities was accomplished following procedures outlined in Plafkin et al. (1989). At each predetermined sampling site, a 200 meter length of stream channel containing several riffles, runs and pools, was measured from a reference point, such as a road crossing or other easily distinguishable landmark, and served as the sampling area for the site. This sampling area was then divided into four 50 meter segments to reduce the handling time and mortality of the fishes. Boundary nets were set at either end of the stream reach when the reach boundaries coincided with deep pools or a wide channel. These nets were used to prevent fish from swimming upstream or downstream and escaping capture.

Sampling of the fish populations was accomplished using backpack-mounted, battery-powered or gas generator-powered electroshocking gear. Walking in an upstream direction with this gear, the sampling person sent an electrical current through the water column between a cathode and anode that were placed in the water. This current stunned the fish and allowed them to be collected with dip nets. Once collected, the fish were placed into a 5 gallon bucket containing streamwater, until all visible fish for a 50 meter segment were collected. Individuals less than 2 centimeters in standard length were not recorded, as recommended by Plafkin et al. (1989). The fishes were then identified to species, enumerated, and returned to a downstream

location. In addition, the incidence of hybrids and diseased or anomalous individuals was noted in the field log book. Those fishes that could not be identified with certainty in the field were preserved in 10 percent formalin and carried to George Mason University for identification. Keys and descriptions found in Jenkins and Burkhead (1993) were the primary means of identification. Upon completion of the first 50 meter segment, the remaining three 50 meter segments were sampled in the same manner. Typically, no more than two sampling locations were completed in any one day.

The method chosen to analyze the fish sampling results was the EPA Rapid Bioassessment Protocol V (Plafkin et al., 1989), which is based on the Index of Biotic Integrity (IBI) developed by Karr (1981). Calculation of the IBI results from summation of rating values derived from 12 characteristics, called metrics, of the fish community. The 12 are grouped into three categories: species richness and composition, trophic composition, and fish abundance and condition. The metrics used are listed in Table 3. Information from each of these metrics is used to assign a rating value of 5, 3, or 1 for each metric for each fish collection. These rating values are assigned to each metric according to whether its value approximates (5), deviates somewhat from (3), or deviates strongly from (1) the value expected at a comparable site that is relatively undisturbed (Karr, 1991). The metric values which set the rating levels are shown in Table 4.

Metrics A, B, C, D, E, and L are thought to vary with the size of the stream, and hence must be adjusted to allow comparison of different stream sizes on the same scale. The adjustment involves plotting the values from each station for each metric on a separate graph. The X axis is the area of the watershed above the collecting site, using a log scale (base 10), and the Y axis is the value of the metric. A line is then drawn through the origin and sloped at an angle sufficient to include 95% of the plotted sites below the line. The angle of the line with the X axis is then trisected. Two lines are drawn from the origin along the two angles of trisection. Those station values which lie in or above the top third are given a rating value of 5. Those station values which lie within the middle third (between the two lower sloped lines) are given a rating value of 3. Those station values which lie within the bottom third (below the lowest sloped line) are given a rating of 1.

Metrics F, G, H, I, J, and K are assigned a rating value based on percentage ranges. The percentage ranges for each metric are shown in Table 4. After assignment of the rating values for each metric, the rating values are summed and give the total IBI score.

Habitat Assessment Procedure

The EPA Rapid Bioassessment Protocols (Plafkin et al., 1989) provide a procedure for classifying the physical quality of a stream and its riparian environment. The procedure asks the assessor to rate three attributes or parameters of stream substrate and in-stream cover on a scale of 0-20 each, three parameters of channel morphology on a scale of 0-15 each, and three parameters of riparian and bank structure on a scale of 0-10 each. This assessment was made for each site in each year.

Table 3. Metrics used to calculate the IBI values from the fish collection results

Species richness and composition metrics

- A. Number of native fish species
- B. Number and identity of darter species (*Etheostoma* sp. or *Percina* sp.)
- C. Number and identity of sunfish species (*Lepomis* sp.)
- D. Number and identity of sucker species (Catostomidae)
- E. Number and identity of intolerant species
- F. Proportion of individuals as green sunfish (*Lepomis cyanellus*)

Trophic composition metrics

- G. Proportion of individuals as generalist feeders
- H. Proportion of individuals as specialist feeders
- I. Proportion of individuals as top carnivores

Fish abundance and condition metrics

- J. Proportion of individuals as hybrids
- K. Proportion of individuals with disease or anatomical anomalies
- L. Total number of individuals in sample collection

Table 4. Ranges of values of IBI metrics used to assign ratings of 5, 3, or 1

Metric	Rating value		
	5	3	1
A. Number of native species	Determined from graphic analysis		
B. Number and identity of darter species	Determined from graphic analysis		
C. Number and identity of sunfish species	Determined from graphic analysis		
D. Number and identity of sucker species	Determined from graphic analysis		
E. Number and identity of intolerant species	Determined from graphic analysis		
F. Proportion of individuals as green sunfish	<5	5-20	>20
G. Proportion of individuals as generalist feeders	<20	20-45	>45
H. Proportion of individuals as specialist feeders	>45	45-20	<20
I. Proportion of individuals as top carnivores	>5	5-1	<1
J. Proportion of individuals as hybrids	0	1	>1
K. Proportion of individuals with disease or anatomical anomalies	0-2	3-5	>5
L. Total number of individuals in sample collection	Determined from graphic analysis		

Results

Benthic macroinvertebrate samples

A total of 5410 macroinvertebrate specimens were picked, identified and enumerated in the two years of this study (Table 5). Insects made up the vast majority of specimens, comprising almost 92% of all individuals. The most abundant insect order was Diptera (two-winged flies), which comprised almost 40% of all individuals identified. Most of the dipterans were chironomids (midges) with smaller, but still substantial numbers of simuliids (blackflies) and tipulids (craneflies) detected. Ephemeroptera (mayflies) was the second most numerous insect order, comprising over one quarter of all specimens. Six mayfly families were found with Heptageniidae and Isonychiidae being most important. The order Trichoptera (caddisflies) represented about 12% of individuals collected. The majority of the caddisflies were in the family Hydropsychidae with Philopotamidae also being well represented. Three other Trichoptera families were sporadically found. Other insect orders found in decreasing order of abundance were Plecoptera (stoneflies), Coleoptera (beetles), Megaloptera (helgrammites), Odonata (dragonflies), and Hemiptera (true bugs). Oligochaetes were the most numerous non-insect group comprising 5.8% of all individuals. The abundance of each family in each sample is tabulated in Appendix A.

The two years differed somewhat in taxonomic composition. Chironomids and thus total dipterans increased substantially in the second year. Megaloptera increased somewhat. Mayflies and beetles remained fairly constant in their contribution to the total. Trichoptera (caddisflies) and Plecoptera (stoneflies) showed a marked decline.

Chironomids attained substantial representation in almost all samples with a maximum of 66%. Only the 1999 Station 3 sample had no chironomids, and this sample had a total of only 58 organisms, far short of the target of 200. Heptageniids, isonychiids, hydropsychids, perlid stoneflies, and oligochaetes were also present in almost all samples.

Metric values computed for each sample are shown in Table 6. Taxa richness (the number of taxa found in a sample) averaged 17.3 and differed little between the two years. Family biotic index (an average measure of tolerance for the sample) averaged 4.2 and also was similar between years. EPT/chironomid abundance was much higher in 1998 (4.3) than in 1999 (1.32), due to the increase in chironomids and the decrease in some of the EPT groups in 1999. The increase in percent dominance and decrease in EPT index (the number of EPT taxa) in 1999 was also due to this factor.

Station 12 in 1998 had the lowest taxa richness and highest percent dominance of all samples, suggesting an impaired biota. EPT index was also low. EPT/chironomid abundance was very high, normally a sign of good conditions. However, this was mainly due to large numbers of hydropsychids, the most tolerant of the EPT group. The highest quality sites in 1998 appeared to be Stations 3, 6, 8, and 9. Station 6 had the highest taxa richness and EPT index. Station 8 had the lowest family biotic index. Station 9 tied for highest EPT index. In 1999 Station 12 again had a somewhat depressed macroinvertebrate community, although metrics were higher than in 1998. Other stations with impaired communities were Station 2 with high FBI and low EPT, Station 5

Table 5 - Macroinvertebrates identified and enumerated by family

Insects	1998		1999		both years	
	total	Percent	total	Percent	total	Percent
Coleoptera						
Dryopidae	32	1.2%	41	1.5%	73	1.3%
Dytiscidae	0	0.0%	1	0.0%	1	0.0%
Elmidae	78	2.8%	80	3.0%	158	2.9%
Gyrinidae	2	0.1%	1	0.0%	3	0.1%
Halipidae	1	0.0%	1	0.0%	2	0.0%
Hydrophilidae	0	0.0%	2	0.1%	2	0.0%
Peephenidae	3	0.1%	6	0.2%	9	0.2%
	116	4.2%	132	5.0%	248	4.6%
Diptera						
Ceratopogonidae	9	0.3%	18	0.7%	27	0.5%
Chironomidae	593	21.6%	1050	39.4%	1643	30.4%
Culicidae	0	0.0%	3	0.1%	3	0.1%
Dixidae	0	0.0%	1	0.0%	1	0.0%
Empididae	11	0.4%	19	0.7%	30	0.6%
Simuliidae	165	6.0%	81	3.0%	246	4.5%
Tipulidae	35	1.3%	44	1.7%	79	1.5%
	813	29.6%	1216	45.6%	2029	37.5%
Ephemeroptera						
Baetidae	211	7.7%	34	1.3%	245	4.5%
Caenidae	3	0.1%	5	0.2%	8	0.1%
Ephemereilidae	17	0.6%	19	0.7%	36	0.7%
Heptageniidae	312	11.4%	327	12.3%	639	11.8%
Isonychiidae	239	8.7%	278	10.4%	517	9.6%
Leptophlebiidae	27	1.0%	35	1.3%	62	1.1%
	809	29.5%	698	26.2%	1507	27.9%
Hemiptera						
Gerridae	1	0.0%	0	0.0%	1	0.0%
Saldidae	0	0.0%	5	0.2%	5	0.1%
	1	0.0%	5	0.2%	6	0.1%
Megaloptera						
Corydalidae	31	1.1%	67	2.5%	98	1.8%
Sialidae	0	0.0%	19	0.7%	19	0.4%
	31	1.1%	86	3.2%	117	2.2%
Odonata						
Aeshnidae	5	0.2%	25	0.9%	30	0.6%
Coenagrionidae	2	0.1%	0	0.0%	2	0.0%
Corduliidae	0	0.0%	5	0.2%	5	0.1%
Corduligastridae	3	0.1%	5	0.2%	8	0.1%
Gomphidae	21	0.8%	25	0.9%	46	0.9%
	31	1.1%	60	2.3%	91	1.7%
Plecoptera						
Leuctridae	15	0.5%	14	0.5%	29	0.5%
Nemouridae	23	0.8%	3	0.1%	26	0.5%
Perlidae	174	6.3%	88	3.3%	262	4.8%
Periodidae	10	0.4%	4	0.2%	14	0.3%
	222	8.1%	109	4.1%	331	6.1%
Trichoptera						
Brachycentridae	3	0.1%	4	0.2%	7	0.1%
Hydropsychidae	374	13.6%	80	3.0%	454	8.4%
Hydroptilidae	8	0.3%	0	0.0%	8	0.1%
Philopotamidae	82	3.0%	92	3.5%	174	3.2%
Psychomiidae	1	0.0%	1	0.0%	2	0.0%
	468	17.0%	177	6.6%	645	11.9%
Crustacea						
Gammaridae	14	0.5%	20	0.8%	34	0.6%
Cambaridae	3	0.1%	13	0.5%	16	0.3%
Hydracarina	11	0.4%	4	0.2%	15	0.3%
Gastropoda	4	0.1%	19	0.7%	23	0.4%
Pelecypoda	10	0.4%	11	0.4%	21	0.4%
Oligochaeta	207	7.5%	109	4.1%	316	5.8%
Planariidae	2	0.1%	0	0.0%	2	0.0%
Nemertea	3	0.1%	6	0.2%	9	0.2%
TOTAL	2745	100.0%	2665	100.0%	5410	100.0%

Table 6 - Metric values for each sample

Station	1998					
	Taxa Richness	Family Biotic Index	EPT/Chir Abundance	Percent dominance	EPT Index	Sorensen's Index
1	15	4.47	2.44	34.7	7	0.600
2	17	4.59	1.68	24.4	6	0.571
3	19	3.25	10.13	25.1	9	0.682
4	16	3.82	2.51	41.6	8	0.537
5	20	4.13	1.72	27.2	6	0.622
6	22	4.31	1.16	34.6	10	0.638
7	17	4.56	0.82	40.5	8	0.571
8	18	3.18	8.12	29.3	9	0.512
9	19	3.56	6.04	31.6	10	0.591
10	17	3.66	2.65	23.8	8	0.524
11	18	4.30	1.36	37.2	7	0.512
12	9	4.05	15.08	66.7	4	0.471
13	13	4.48	2.38	31.1	7	0.526

Station	1999					
	Taxa Richness	Family Biotic Index	EPT/Chir Abundance	Percent dominance	EPT Index	Sorensen's Index
1	16	3.53	1.95	26.2	5	0.537
2	18	4.86	0.67	36.9	4	0.651
3	ould not be calculated due to small number of organisms in sample					
4	21	4.80	0.45	60.7	8	0.652
5	17	5.01	0.32	59.3	8	0.619
6	15	4.21	1.12	39.7	5	0.500
7	15	4.86	0.45	46.0	4	0.400
8	21	4.27	1.01	37.7	7	0.652
9	22	3.68	2.25	30.3	9	0.638
10	23	4.19	1.46	29.8	10	0.542
11	17	4.83	0.28	66.5	7	0.619
12	14	4.23	4.68	52.9	5	0.667
13	21	3.86	1.21	35.6	10	0.565

Sorensen's index computed using QA@7 - 6/27/96 as reference

with high FBI and high percent dominance, Station 7 with high FBI and low EPT, and Station 11 with high FBI and high percent dominance. Stations 8, 9, 10, and 13 were the highest quality sites in 1999.

Metric values were converted into metric scores using the ranges determined by Jones (1999) based on an extensive study of reference conditions in Prince William Forest Park just north of the study area. These individual metric scores (Table 7) were summed to arrive at an Index of Macroinvertebrate Integrity (IMBI). IMBI values were generally higher in 1998 than in 1999. Over half of the stations scored 100% of possible in 1998, while only two attained this value in 1999. Average score in 1998 was 93.5%, while in 1999 it was 87.5%. Sorensen's index was the metric most often below optimum in 1998. In 1999 EPT/Chironomid abundance, Percent dominance, and EPT index were also often suboptimal. In no cases were metric values in the lowest range of metric scores (0). Stations 4, 8, 10, 11, 12, and 13 were suboptimal in both years. Using Biological Condition Criteria defined in Plafkin et al. (1989), the vast majority of samples collected in this study would be considered Non-impaired. Station 12 in 1998 with a IMBI of 67% would be considered Moderately Impaired. Stations 5 and 7 would be on the border between Moderately Impaired and Non-impaired in 1999.

Fish sampling

A list of the names of all the fish species that were collected and their families is presented in Table 8. Forty species in eleven families were identified. A total of 6,484 fishes representing 33 species was sampled during the months of June and July, 1998. The number of individuals of each species collected at each site in 1998 is presented in Appendix B1. In 1999, fish sampling was conducted in May, June and July, and 7186 fishes in 36 species were caught. The number of individuals of each species collected at each site in 1999 is shown in Appendix B2. A summary table shows the total number of each species collected in each year (Table 9). Rosyside dace was the most abundant fish in both years. Blacknose dace was second in overall abundance, followed by swallowtail shiner, tessellated darter, creek chub, fallfish, and redbreast sunfish.

IBI calculation

Table 10. lists how each species was classified in each of the categories used in the IBI metrics. The classifications were determined from lists in Plafkin et al. (1989), Barbour et al. (1999), Smogor and Angemeier (1999) and information in Jenkins and Burkhead (1993).

The rating values for the 12 metrics for each station in 1998 are shown in Table 11. The total IBI values for each station ranged from 34 to 48 in 1998.

The rating values for the 12 metrics for each station for 1999 are presented in Table 12. The total IBI values for each station ranged from 32 to 50 in 1999.

Table 7 - Metric scores for each sample

Station	1998						
	Taxa Richness	Family Biotic Index	EPT/Chir Abundance	Percent dominance	EPT Index	Sorensen's Index	Index of Macrobenthic Integrity (% of possible)
1	6	6	6	6	6	6	100%
2	6	6	6	6	6	6	100%
3	6	6	6	6	6	6	100%
4	6	6	6	6	6	3	92%
5	6	6	6	6	6	6	100%
6	6	6	6	6	6	6	100%
7	6	6	6	6	6	6	100%
8	6	6	6	6	6	3	92%
9	6	6	6	6	6	6	100%
10	6	6	6	6	6	3	92%
11	6	6	6	6	6	3	92%
12	3	6	6	3	3	3	67%
13	3	6	6	6	6	3	83%

Station	1999							
	Taxa Richness	Family Biotic Index	EPT/Chir Abundance	Percent dominance	EPT Index	Sorensen's Index	Index of Macrobenthic Integrity (% of possible)	
1	6	6	6	6	3	3	83%	
2	6	6	6	6	3	6	92%	
3	Could not be calculated due to small number of organisms in sample							
4	6	6	3	3	6	6	83%	
5	6	3	3	3	6	6	75%	
6	6	6	6	6	3	3	83%	
7	6	6	3	6	3	3	75%	
8	6	6	6	6	6	6	100%	
9	6	6	6	6	6	6	100%	
10	6	6	6	6	6	3	92%	
11	6	6	3	3	6	6	83%	
12	6	6	6	6	3	6	92%	
13	6	6	6	3	6	6	92%	

Scoring Criteria from Jones (1999)

Table 8. List of species of fishes collected at Quantico MCB in 1998 and 1999

Family	Scientific name	Species abbreviation	Common name
Petromyzontidae	<i>Lampetra aepyptera</i>	Lam aep	least brook lamprey
Anguillidae	<i>Anguilla rostrata</i>	Ang ros	American eel
Cyprinidae	<i>Clinostomus funduloides</i>	Cli fun	rosyside dace
	<i>Cyprinella analostana</i>	Cyp ana	satinfin shiner
	<i>Cyprinella spiloptera</i>	Cyp spi	spotfin shiner
	<i>Exoglossum maxillingua</i>	Exo max	cutlips minnow
	<i>Luxilus cornutus</i>	Lux cor	common shiner
	<i>Notemigonus crysoleucas</i>	Not cry	golden shiner
	<i>Notropis amoenus</i>	Not amo	comely shiner
	<i>Notropis hudsonius</i>	Not hud	spottail shiner
	<i>Notropis procyne</i>	Not pro	swallowtail shiner
	<i>Phoxinus oreas</i>	Pho ore	mountain redbelly dace
	<i>Pimephales notatus</i>	Pim not	bluntnose minnow
	<i>Pimephales promelas</i>	Pim pro	fathead minnow
	<i>Rhinichthys atratulus</i>	Rhi atr	blacknose dace
	<i>Semotilus atromaculatus</i>	Sem atr	creek chub
	<i>Semotilus corporalis</i>	Sem cor	fallfish
Catostomidae	<i>Catostomus commersoni</i>	Cat com	white sucker
	<i>Erimyzon oblongus</i>	Eri obl	creek chubsucker
	<i>Hypentelium nigricans</i>	Hyp nig	northern hogsucker
Ictaluridae	<i>Ameiurus melas</i>	Ame mel	black bullhead
	<i>Ameiurus natalis</i>	Ame nat	yellow bullhead
	<i>Ameiurus nebulosus</i>	Ame neb	brown bullhead
	<i>Noturus insignis</i>	Not ins	marginated madtom
Esocidae	<i>Esox niger</i>	Eso nig	chain pickerel
Umbridae	<i>Umbra pygmaea</i>	Umb pyg	eastern mudminnow
Salmonidae	<i>Salvelinus fontinalis</i>	Sal fon	brook trout
Poeciliidae	<i>Gambusia holbrooki</i>	Gam hol	eastern mosquitofish
Centrarchidae	<i>Enneacanthus gloriosus</i>	Enn glo	bluespotted sunfish
	<i>Lepomis auritus</i>	Lep aur	redbreast sunfish
	<i>Lepomis cyanellus</i>	Lep cya	green sunfish
	<i>Lepomis gibbosus</i>	Lep gib	pumpkinseed
	<i>Lepomis gulosus</i>	Lep gul	warmouth
	<i>Lepomis macrochirus</i>	Lep mac	bluegill
	<i>Micropterus dolomieu</i>	Mic dol	smallmouth bass
	<i>Micropterus salmoides</i>	Mic sal	largemouth bass
Percidae	<i>Percina notogramma</i>	Per not	stripeback darter
	<i>Percina peltata</i>	Per pel	shield darter
	<i>Etheostoma flabellare</i>	Eth fla	fantail darter
	<i>Etheostoma olmstedi</i>	Eth olm	tessellated darter

Table 9. List of species of fishes collected at Quantico MCB in 1998 and 1999

Common name	Sci nam	Number caught			Distribution notes	
		1998	1999	Total		Rank
least brook lamprey	<i>Lam aep</i>	12	4	16		present only at Stations 1 and 13
American eel	<i>Ang ros</i>	130	77	207		present only in Chop. & Quantico
rosyside dace	<i>Cli fun</i>	1363	1564	2927	1	absent only from Station 7
satinfin shiner	<i>Cyp ana</i>	1	178	179		present only in Aquia (Sta.
spotfin shiner	<i>Cyp spi</i>	123	1	124		present only in Aquia
cutlips minnow	<i>Exo max</i>	166	313	479	10	absent at Stations 2, 3, 5, 7, & 11
common shiner	<i>Lux cor</i>	231	273	504	8	absent at Stations 7, 11, 12, & 13
golden shiner	<i>Not cry</i>	16	12	28		
comely shiner	<i>Not amo</i>	2	33	35		present only in Aquia
spottail shiner	<i>Not hud</i>	64	7	71		
swallowtail shiner	<i>Not pro</i>	664	874	1540	3	absent at Stations 7 and 11
mountain redbelly dace	<i>Pho ore</i>	3	3	6		present only at Station 2
bluntnose minnow	<i>Pim not</i>	22	24	46		
fathead minnow	<i>Pim pro</i>		21	21		
blacknose dace	<i>Rhi atr</i>	689	938	1627	2	absent only at Stations 1, 3, and 7
creek chub	<i>Sem atr</i>	650	383	1033	5	present at all stations
fallfish	<i>Sem cor</i>	367	472	839	6	absent at Stations 7 and 11
white sucker	<i>Cat com</i>	296	199	495	9	absent at Station 7
creek chubsucker	<i>Eri obl</i>	98	58	156		
northern hogsucker	<i>Hyp nig</i>	8	3	11		
black bullhead	<i>Ame mel</i>		1	1		present only at Station 13
yellow bullhead	<i>Ame nat</i>	1	31	32		
brown bullhead	<i>Ame neb</i>	7		7		
margined madtom	<i>Not ins</i>	148	252	400	11	absent at Stations 2, 4, 5, 6, & 11
chain pickerel	<i>Eso nig</i>	22	55	77		
eastern mudminnow	<i>Umb pyg</i>	4		4		present only at Stations 5, 6, & 13
brook trout	<i>Sal fon</i>	1		1		present only at Station 9
eastern mosquitofish	<i>Gam hol</i>		5	5		present only at Station 13
bluespotted sunfish	<i>Enn glo</i>	20	32	52		
redbreast sunfish	<i>Lep aur</i>	417	411	828	7	absent only at Station 3
green sunfish	<i>Lep cya</i>	46	14	60		
pumpkinseed	<i>Lep gib</i>	44	27	71		
warmouth	<i>Lep gul</i>	2	1	3		present only at Station 13
bluegill	<i>Lep mac</i>	140	103	243		
smallmouth bass	<i>Mic dol</i>		1	1		present only at Station 6
largemouth bass	<i>Mic sal</i>	15	5	20		present only at Station 13
stripeback darter	<i>Per not</i>		3	3		present only at Station 1
shield darter	<i>Per pel</i>	4		4		present only at Stations 1 and 3
fantail darter	<i>Eth fla</i>	97	47	144		present only in Occoquan & Sta. 11
tessellated darter	<i>Eth olm</i>	611	734	1345	4	present at all stations

Table 10. List of IBI category classifications of fish species.

Key to species abbreviations	Common Name	Trophic Level	Tolerance	Origin
<i>Lampetra aepyptera</i> - <i>Lam aep</i>	Least Brook Lamprey	Detritivore	intermediate	native
<i>Anguilla rostrata</i> - <i>Ang ros</i>	American Eel	Omnivore	intermediate	native
<i>Clinostomus funduloides</i> - <i>Cli fun</i>	Rosyside Dace	Insectivore	intolerant	native
<i>Cyprinella analostana</i> - <i>Cyp ana</i>	Satinfin Shiner	Insectivore	intermediate	native
<i>Cyprinella spiloptera</i> - <i>Cyp spi</i>	Spotfin Shiner	Insectivore	intermediate	native
<i>Exoglossum maxillingua</i> - <i>Exo max</i>	Cutlips Minnow	Insectivore	intermediate	native
<i>Luxilus cornutus</i> - <i>Lux cor</i>	Common Shiner	Insectivore	intermediate	native
<i>Notemigonus crysoleucas</i> - <i>Not cry</i>	Golden Shiner	Invertivore	tolerant	native
<i>Notropis amoenus</i> - <i>Not amo</i>	Comely Shiner	Invertivore	intermediate	native
<i>Notropis hudsonius</i> - <i>Not hud</i>	Spottail Shiner	Invertivore	intermediate	native
<i>Notropis procne</i> - <i>Not pro</i>	Swallowtail Shiner	Invertivore	intermediate	native
<i>Phoxinus oreas</i> - <i>Pho ore</i>	Mountain Redbelly Dace	Omnivore	intermediate	native
<i>Pimephales notatus</i> - <i>Pim not</i>	Bluntnose Minnow	Omnivore	tolerant	exotic
<i>Pimephales promelas</i> - <i>Pim pro</i>	Fathead Minnow	Omnivore	tolerant	exotic
<i>Rhinichthys atratulus</i> - <i>Rhi atr</i>	Blacknose Dace	Omnivore	tolerant	native
<i>Semotilus atromaculatus</i> - <i>Sem atr</i>	Creek Chub	Omnivore	tolerant	native
<i>Semotilus corporalis</i> - <i>Sem cor</i>	Fallfish	Omnivore	tolerant	native
<i>Catostomus commersoni</i> - <i>Cat com</i>	White Sucker	Invertivore	tolerant	native
<i>Erimyzon oblongus</i> - <i>Eri obl</i>	Creek Chubsucker	Invertivore	intermediate	native
<i>Hypentelium nigricans</i> - <i>Hyp nig</i>	Northern Hog Sucker	Invertivore	intermediate	native
<i>Ameiurus melas</i> - <i>Ame mel</i>	Black Bullhead	Invertivore	tolerant	native
<i>Ameiurus natalis</i> - <i>Ame nat</i>	Yellow Bullhead	Invertivore	tolerant	native
<i>Ameiurus nebulosus</i> - <i>Ame neb</i>	Brown Bullhead	Invertivore	tolerant	native
<i>Noturus insignis</i> - <i>Not ins</i>	Margined Madtom	Invertivore	intolerant	native
<i>Esox niger</i> - <i>Eso nig</i>	Chain Pickerel	Piscivore	intermediate	native
<i>Umbra pygmaea</i> - <i>Umb pyg</i>	Eastern Mudminnow	Invertivore	intermediate	native
<i>Salvelinus fontinalis</i> - <i>Sal fon</i>	Brook Trout	Piscivore	intolerant	exotic
<i>Gambusia holbrooki</i> - <i>Gam hol</i>	Eastern Mosquitofish	Insectivore	tolerant	native
<i>Enneacanthus gloriosus</i> - <i>Enn glo</i>	Bluespotted Sunfish	Insectivore	intermediate	native
<i>Lepomis auritus</i> - <i>Lep aur</i>	Redbreast Sunfish	Insectivore	intolerant	native
<i>Lepomis cyanellus</i> - <i>Lep cya</i>	Green Sunfish	Invertivore	tolerant	exotic
<i>Lepomis gibbosus</i> - <i>Lep gib</i>	Pumpkinseed	Insectivore	intermediate	native
<i>Lepomis gulosus</i> - <i>Lep gul</i>	Warmouth	Invertivore	intermediate	native
<i>Lepomis macrochirus</i> - <i>Lep mac</i>	Bluegill	Insectivore	intermediate	exotic
<i>Micropterus dolomieu</i> - <i>Mic dol</i>	Largemouth Bass	Piscivore	tolerant	exotic
<i>Micropterus salmoides</i> - <i>Mic sal</i>	Largemouth Bass	Piscivore	tolerant	exotic
<i>Percina notogramma</i> - <i>Per not</i>	Stripeback Darter	Insectivore	intolerant	native
<i>Percina peltata</i> - <i>Per pel</i>	Shield Darter	Insectivore	intolerant	native
<i>Etheostoma flabellare</i> - <i>Eth fla</i>	Fantail Darter	Insectivore	tolerant	native
<i>Etheostoma olmstedi</i> - <i>Eth olm</i>	Tessellated Darter	Insectivore	Intolerant	native

Table 11. IBI metric values and calculations using 1998 sampling results

Station Number	Site Code	Total IBI Score	Area Km2	log km2	Total # of Species	# Native Sp.	#exotic sp.	IBI Score	# Darter Sp.	IBI Score	# Sunfish Sp.	IBI Score
1	CC@644	46	19.81	1.30	20	19	1	5	2	3	3	5
2	DR@3	48	6.48	0.81	16	13	3	5	2	5	4	5
3	GR@8	46	12.43	1.09	18	15	3	5	3	5	3	5
4	LR@8	48	9.45	0.98	17	15	2	5	2	5	4	5
5	SMB@8	48	4.92	0.69	15	14	1	5	3	5	2	5
6	EMB@8	44	5.7	0.76	16	13	3	5	3	5	3	5
7	NBC@CGR	48	4.66	0.67	8	7	1	3	1	3	3	5
8	SFQC@619	46	20.2	1.31	16	14	2	3	1	1	4	5
9	NBC@MB	38	16.96	1.23	15	13	2	3	1	1	2	3
10	MBC@I	46	11.66	1.07	16	15	1	5	1	3	3	5
11	SBC@1	48	6.86	0.84	8	7	1	3	2	5	2	5
12	BR@AT	40	33.93	1.53	16	15	1	3	1	1	2	3
13	CC@BR	34	57.89	1.76	19	17	2	3	2	3	4	3

# Sucker Sp.	IBI Score	# Intolerant Sp.	IBI Score	#green SF	% Green Sunfish	IBI Score	#gen	% Generalists	IBI Score	#spec	% Specialists	IBI Score	#top
2	3	5	5	0	0.00%	5	33	14.47%	5	195	85.53%	5	3
2	5	3	5	9	2.29%	5	145	36.90%	3	248	63.10%	5	1
3	5	4	5	10	5.68%	5	113	64.20%	1	63	35.80%	3	10
3	5	3	5	14	2.69%	5	247	47.41%	1	274	52.59%	5	0
3	5	3	5	6	1.42%	5	209	49.29%	1	215	50.71%	5	0
2	5	3	5	6	0.90%	5	422	63.27%	1	245	36.73%	3	0
1	3	3	5	0	0.00%	5	17	9.19%	5	168	90.81%	5	14
2	3	4	5	1	0.09%	5	196	17.39%	5	931	82.61%	5	1
2	3	5	5	0	0.00%	5	185	28.77%	3	458	71.23%	5	1
2	3	4	5	0	0.00%	5	180	28.85%	3	444	71.15%	5	4
1	3	3	5	0	0.00%	5	204	34.93%	3	380	65.07%	5	0
2	3	4	5	0	0.00%	5	116	23.11%	3	386	76.89%	5	2
3	3	3	3	0	0.00%	5	205	50.00%	1	205	50.00%	5	2

% Top Carnivores	IBI Score	#HorE	% Hybrids or Exotics	IBI Score	#DorA	% with Disease or Anomalies	IBI Score	Total # Individuals	IBI Score	TOTAL IBI Score
1.32%	3	12	5.26%	1	0	0.00%	5	228	1	46
0.25%	1	74	18.83%	1	0	0.00%	5	393	3	48
5.68%	5	24	13.64%	1	0	0.00%	5	176	1	46
0.00%	1	18	3.45%	1	1	0.19%	5	521	5	48
0.00%	1	6	1.42%	1	2	0.47%	5	424	5	48
0.00%	1	29	4.35%	1	7	1.05%	3	667	5	44
7.57%	5	3	1.62%	1	0	0.00%	5	185	3	48
0.09%	1	9	0.80%	3	3	0.27%	5	1127	5	46
0.16%	1	15	2.33%	1	10	1.56%	3	643	5	38
0.64%	1	7	1.12%	1	4	0.64%	5	624	5	46
0.00%	1	2	0.34%	3	0	0.00%	5	584	5	48
0.40%	1	2	0.40%	3	0	0.00%	5	502	3	40
0.49%	1	23	5.61%	1	0	0.00%	5	410	1	34

Table 12. IBI metric values and calculation using 1999 sampling results

Station Number	Site Code	Total IBI Score	Area km2	log km2	Total # of Species	# Native Sp.	IBI Score	# Darter Sp.	IBI Score	# Sunfish Sp.	IBI Score	# Sucker Sp.	IBI Score
1	CC@644	46	19.81	1.30	18	17	5	2	5	4	5	2	3
2	DR@3	46	6.48	0.81	15	14	5	1	3	3	5	2	5
3	GR@8	32	12.43	1.09	8	7	3	2	5	1	1	1	3
4	LR@8	44	9.45	0.98	17	14	5	2	5	3	5	3	5
5	SMB@8	50	4.92	0.69	15	14	5	2	5	2	5	2	5
6	EMB@8	48	5.7	0.76	18	14	5	2	5	3	5	2	5
7	NBC@CGR	36	4.66	0.67	4	4	3	0	1	1	3	1	3
8	SFQC@619	46	20.2	1.31	16	14	3	1	3	3	3	2	3
9	NBC@MB	48	16.96	1.23	16	15	5	1	3	2	3	2	5
10	MBC@1	44	11.66	1.07	16	15	5	1	3	3	5	1	3
11	SBC@1	46	6.86	0.84	8	7	3	1	3	2	5	1	3
12	BR@AT	42	33.93	1.53	15	15	3	1	3	1	1	1	1
13	CC@BR	38	57.89	1.76	22	19	3	1	1	6	5	2	3

	IBI	# Intolerant Sp. Score	#green SF	% Green Sunfish	IBI Score	#gen	% Generalists	IBI Score	#spec	% Specialists	IBI Score	#top	% Top Carnivore	IBI Score	#HorE
3	3	0	0.00%	5	42	19.72%	5	171	80.28%	5	1	0.47%	1	1	
3	5	0	0.00%	5	71	36.22%	3	125	63.78%	5	0	0.00%	1	1	
2	3	4	12.50%	3	15	46.88%	1	17	53.13%	5	0	0.00%	1	1	
3	5	8	2.90%	5	136	49.28%	1	140	50.72%	5	3	1.09%	3	3	
3	5	0	0.00%	5	132	42.44%	3	179	57.56%	5	0	0.00%	1	1	
3	5	1	0.17%	5	297	51.65%	1	278	48.35%	5	1	0.17%	1	4	
1	3	0	0.00%	5	49	92.45%	1	4	7.55%	1	47	88.68%	5	0	
4	5	0	0.00%	5	165	14.71%	5	957	85.29%	5	0	0.00%	1	2	
4	5	0	0.00%	5	289	27.39%	3	766	72.61%	5	2	0.19%	1	1	
4	5	0	0.00%	5	255	32.82%	3	522	67.18%	5	4	0.51%	1	1	
3	5	0	0.00%	5	530	38.94%	3	831	61.06%	5	0	0.00%	1	1	
4	5	0	0.00%	5	130	14.86%	5	745	85.14%	5	1	0.11%	1	0	
4	3	1	0.29%	5	118	34.71%	3	222	65.29%	5	2	0.59%	1	3	

% Hybrids or Exotics	IBI Score	#DorA	% with Disease or Anomalies	IBI Score	Total # Individuals	IBI Score	Total IBI Score
0.47%	3	0	0.00%	5	213	1	46
0.51%	3	0	0.00%	5	196	1	46
3.13%	1	0	0.00%	5	32	1	32
1.09%	1	1	0.36%	3	276	1	44
0.32%	3	0	0.00%	5	311	3	50
0.70%	3	0	0.00%	5	575	3	48
0.00%	5	0	0.00%	5	53	1	36
0.18%	3	0	0.00%	5	1122	5	46
0.09%	3	0	0.00%	5	1055	5	48
0.13%	3	2	0.26%	3	777	3	44
0.07%	3	0	0.00%	5	1361	5	46
0.00%	5	0	0.00%	5	875	3	42
0.88%	3	0	0.00%	5	340	1	38

Habitat assessment

The habitat assessment values for each parameter in each year are shown in Table 13. The theoretical score totals at a site with excellent ranking would lie between 103 and 135. Good rankings would lie between 67 and 102, fair scores between 31 and 66, and poor scores between 0 and 30. The assessments in 1999 were generally higher than those of 1998, with ten sites ranking higher and three sites ranking lower. The difference appears to be attributable to the fact that different personnel made the assessments in the two years.

In 1998, the assessment score totals ranged from 38 for Station 11 to 123 for Station 10. Five sites rank Excellent (Stations 2, 4, 9, 10, and 13). Three sites are classified as Good (Stations 1, 8, and 12), while five sites were Poor (Stations 3, 5, 6, 7, and 11). Low scores are mostly caused by siltation.

In 1999, the assessment scores ranged from 88 for Station 5 to 126 for Station 9. Five stations rank Excellent (Stations 2, 3, 9, 10, and 12), and eight rank as Good (Stations 1, 4, 5, 6, 7, 8, 11, and 13). The elevation in scores over those of 1998 are mostly the effect of higher evaluations of the quality of siltation parameters and channel morphology parameters.

Discussion

Benthic macroinvertebrates

The taxonomic composition of the collections show a fairly high degree of similarity across stations and in both years. Midges and other flies (Diptera) were the most abundant component of the community, as is the case in many watersheds which have been studied. However, these streams are distinctly different in the almost equal abundance of mayflies (Ephemeroptera), and the presence of significant numbers of helgrammites, stoneflies, and a variety of other invertebrates.

There is little difference between 1998 and 1999 in the Taxa Richness and Family Biotic Index metrics, but the EPT/Chironomid abundance and EPT Index decreased in the second year and the Percent Dominance increased in 1999. The changes mostly reflect the marked increases in 1999 of Diptera and decreases of Hydropsychid caddisflies (Trichoptera), but Megaloptera, Odonata, and Crustacea also increased, and Plecoptera and Oligochaeta declined in the second year.

A major ecological change struck the streams between 1998 and 1999. Beginning in July of 1998, a major drought developed and persisted through the summer of 1999. The monthly rainfall totals (Fig. 2.) for Sept, 1997 through August, 1999 illustrates this graphically. This undoubtedly had strong effects on the macroinvertebrate populations.

The highest quality sites in 1998 were Stations 3, 6, 8, and 9; Station 12 was somewhat lower than other sites in its scores. The highest quality sites in 1999 were Stations 8, 9, 10, and 13, and Stations 2, 5, 7, 11, and 12 were lower in quality. Nevertheless, as the summary IMBI values show, most of the sites ranked as Non-impaired in 1998 and 1999, with only one (Station 12)

Table 13. Habitat assessment scores for each collecting station

Station	Habitat Parameters*									Total Score
	1	2	3	4	5	6	7	8	9	
1998										
1	8	13	13	5.5	5.5	5.5	4	9.5	8	72
2	16	18	18	13.5	13.5	9.5	7	9.5	7	112
3	2.5	2.5	11.5	1.5	5.5	5.5	4	9.5	9.5	52
4	18	18	18	13.5	13.5	13.5	4	9.5	9.5	117.5
5	8	8	13	5.5	5.5	5.5	1	4	4	54.5
6	8	8	13	5.5	5.5	5.5	4	7	7	63.5
7	2.5	2.5	8	5.5	5.5	5.5	4	7	4	44.5
8	13	18	18	9.5	9.5	9.5	4	9.5	9.5	91
9	19	15	20	14	13	12	8	10	8	119
10	19	19	19	18	11	14	6	9	8	123
11	3	3	6	4	2	4	3	7	6	38
12	18	12	17	11	10	9	8	9	8	102
13	18	18	16	13	11	11	4	9	8	108
1999										
1	15	17	15	11	15	8	6	7	7	101
2	15	20	16	14	14	17	8	7	7	118
3	11	18	15	9	11	20	3	8	8	108
4	11	11	16	11	14	8	6	8	6	91
5	11	11	11	8	13	11	8	7	8	88
6	12	16	16	12	12	11	6	9	6	100
7	10	17	15	7	15	6	8	10	9	97
8	11	15	16	11	15	8	6	10	8	100
9	16	17	18	15	15	15	10	10	10	126
10	15	16	18	10	14	13	8	10	8	112
11	11	20	16	12	12	7	4	7	8	97
12	16	16	18	13	13	14	10	10	9	119
13	19	16	17	12	12	4	4	8	8	100
* Assessment Parameters				Excellent	Good	Fair	Poor			
1	bottom substrate/ available cover			16-20	11-15	6-10	0-5			
2	embeddedness			"	"	"	"			
3	stream flow and/or stream velocity			"	"	"	"			
4	channel alteration			12-15	8-11	4-7	0-3			
5	bottom scouring and deposition			"	"	"	"			
6	pool/ riffle : run/ bend			"	"	"	"			
7	bank stability			9-10	6-8	3-5	0-2			
8	bank vegetation stability			"	"	"	"			
9	streamside cover			"	"	"	"			
Total score				103-135	67-102	31-66	0-30			

Total Monthly Rainfall 1997-1999

(From Quantico MCB Weather Station-Quantico, VA)

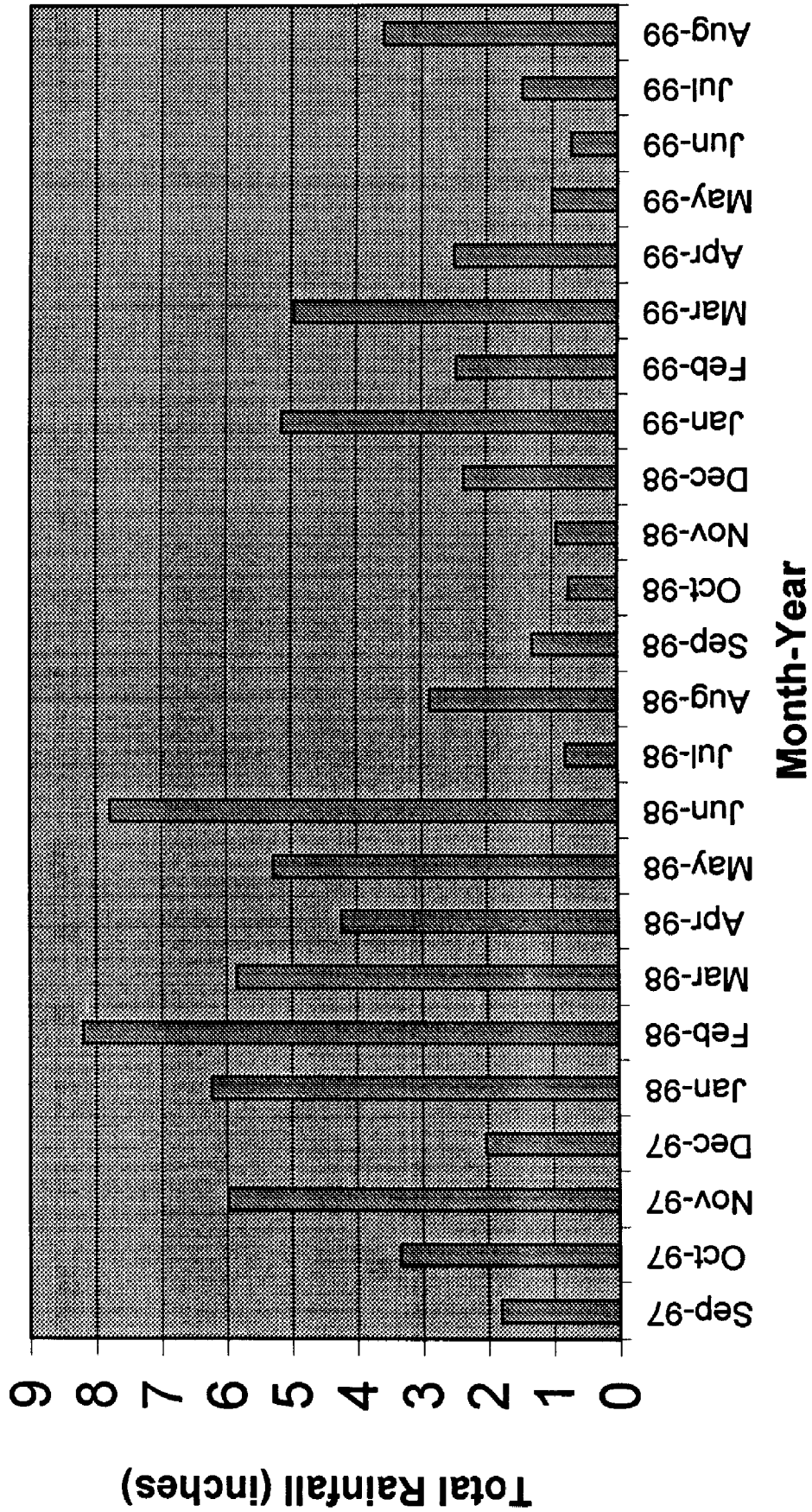


Fig. 2. Monthly rainfall totals for Quantico, Virginia September, 1997-August, 1999

scoring as Moderately impaired in 1998 and only two sites (Stations 5 and 7) scoring in the transitional values between Moderately impaired and Non-impaired in 1999. Plafkin et al. (1989) describe Non-impaired as “comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure for stream size and habitat quality”. Moderately impaired implies “Fewer species due to loss of most intolerant forms. Reduction in EPT Index.”.

Station 12 is downstream of Lunga Reservoir, which is probably a source of plankton import into the creek and a consequent change in the food web of the stream, which creates subtle shifts in the kinds of invertebrate species which are most successful there. Most of the streams have forested watersheds, and the base of the food web is leaf litter. Below reservoirs and lakes the base shifts to plankton, and animals such as hydropsychid caddisflies and simuliid fly larvae become dominant. The shift may occur to some degree below small ponds and beaverdams, if water retention time is long enough and if exposure to sunlight is allowed by loss of tree shade.

Fish communities

The occurrence of fishes in a particular stream is determined by a number of factors. First are the geologic and climatological events which provide access to the stream for the ancestral fishes and the evolutionary changes which enable the ancestral fishes to survive under the prevailing physicochemical and biological environmental conditions. This creates the community of fishes which could potentially occur in a particular stream system. The actual community of fishes reflects the quality of the water, the quality of the watershed land cover, the quality of the instream habitat, and the occurrence of natural and anthropogenic disturbances.

A total of 48 species of fishes have been collected from piedmont streams in the Potomac drainage system in the vicinity of Quantico (Fairfax, Prince William, Fauquier, and Stafford Counties) (Jenkins and Burkhead, 1993) and thus make up the current potential fish community. A list of eight species not collected in this study is shown in Table 14. None of the eight species were collected in a study in Prince William County of Neabsco, Powells and Quantico Creeks (Jones and Kelso, 1994).

The common carp and goldfish are usually found in quiet waters with soft bottoms. These conditions do occur in the ponds and reservoirs on the MCB, and I would not be surprised to catch a few individuals of carp, in particular, at the stations we sampled, but both species are rarely common in small streams. The eastern silvery minnow and the river chub are more typical of larger streams than we sampled and were not collected in the Prince William County streams along the Potomac (Jones and Kelso, 1994), but both have been taken in some Fairfax County streams and upper Occoquan drainage streams (Jenkins and Burkhead, 1993). Silverjaw minnow are usually an uncommon species, but do occur in Fairfax and Loudoun Counties. Rosyface shiner can be confused with comely shiner. They are thought to be intolerant of turbidity and siltation, but they have been collected in the upper Occoquan drainage. Longnose dace are fairly common bottom dwellers of fast flowing areas of northern Virginia streams. It occurs in the upper Occoquan drainage, so I am surprised at its absence in this study. The redbfin pickerel typically occurs in the same habitat conditions as the chain pickerel and is common in upper Occoquan drainage streams.

Table 14. Fish species found in many streams in the piedmont of northeastern Virginia, but not collected in this study

Family	Scientific name	Common name
Cyprinidae	<i>Cyprinus carpio</i>	common carp
	<i>Carassius auratus</i>	goldfish
	<i>Hybognathus regius</i>	eastern silvery minnow
	<i>Nocomis micropogon</i>	river chub
	<i>Notropis buccatus</i>	silverjaw minnow
	<i>Notropis rubellus</i>	rosyface shiner
	<i>Rhinichthys cataractae</i>	longnose dace
Esocidae	<i>Esox americanus</i>	redfin pickerel

Apparently it is not found in the relatively small creeks which drain directly into the Potomac, and proper quiet-water habitat with vegetation was not present in the Occoquan drainage streams sampled on the MCB. Thus, it appears that the absence of these species cannot be readily ascribed to losses caused by degraded stream conditions. Perhaps this is true of rosyface shiner and longnose dace, but not obviously so.

In a study of stream fishes of Fairfax County conducted in 1989 and 1990, Kelso, Yarrington and Zylstra (1991) collected only 34 species in the piedmont, even though 119 stream samples were collected at 23 sites. Species that were caught in this study but missing in the Fairfax County collections include least brook lamprey, comely shiner, mountain redbelly dace, fathead minnow, black bullhead, chain pickerel, eastern mudminnow, brook trout, bluespotted sunfish, warmouth, stripeback darter, and shield darter. Of these, the comely shiner, chain pickerel, stripeback darter, and shield darter are native stream fishes that might be expected to occur in Fairfax County, and their presence in the MCB is perhaps indicative of anthropogenic degradation in Fairfax. On the other hand, eastern silvery minnow and river chub were collected in Fairfax but not in this study. In the Prince William County watersheds study of the fish fauna of Neabsco, Powells, and Quantico Creeks, 30 species were taken in 20 collections at 20 sites (Jones and Kelso, 1994). Only the non-native longear sunfish, *Lepomis megalotis*, was collected in the Prince William study but was not taken in the present study. Thus, the creeks of the MCB are rich in species.

The US Fish and Wildlife Service conducted fish sampling trips on the MCB in the 1970s and 1980s. The list of species that were caught was made available by the Natural Resources and Environmental Affairs Branch. No piedmont stream species were listed which were not also taken in the current study, although collections from the coastal plain and tidal water and reservoirs did catch several fish species which are characteristic of these habitats, and which were not collected in 1998-1999.

A summary listing of the total scores of the Index of Macroinvertebrate Integrity, the Index of Biotic Integrity (fish), and the Habitat Assessment scores at each station for the two years is presented in Table 15. Comparing the three indices shows that there are differences between years for each index. The variation in the Habitat Assessment is largely the result of different personnel conducting the field measurements. The process involves qualitative judgements, and wide variation is often the result. A second factor is certainly the strong drought which developed between the two sampling periods. This is probably responsible for much of the variation between years in the macroinvertebrate and fish results. If this is true, then it appears that the drought has not had universally negative effects, since the IMBI values for three stations (Stations 8, 12, and 13) rose in 1999. These three sites have the largest watersheds that were sampled, and this implies, in agreement with general logic, that the drought has had a more severe effect on the macroinvertebrate populations in the smaller streams. An exception is Station 1, which has an only slightly smaller watershed and showed a decline in IMBI value in 1999.

The situation is less clear for the fish community. The IBI scores of three stations (Stations 6, 9, and 13) rose by four or more units in 1999, and an additional two (Stations 5 and 12) rose by two units. Stations 9, 12, and 13 have large watersheds, and so probably enjoyed the benefit of

Table 15. Quantitative measures of ecological condition at each station in 1998 and 1999

Station Number	Index of Macroinvertebrate Integrity		Index of Biotic Integrity (RBP V)		Habitat Assessment	
	1998	1999	1998	1999	1998	1999
1	100%	83%	46	46	72	101
2	100%	92%	48	46	112	118
3	100%	—	46	32	52	108
4	92%	83%	48	44	117.5	91
5	100%	75%	48	50	54.5	88
6	100%	83%	44	48	63.5	100
7	100%	75%	48	36	44.5	97
8	92%	100%	46	46	91	100
9	100%	100%	38	48	119	126
10	92%	92%	46	44	123	112
11	92%	83%	48	46	38	97
12	67%	92%	40	42	102	119
13	83%	92%	34	38	108	100

persistent stream flow despite the drought. On the other hand, Stations 5 and 6 have very small watersheds. They are adjacent to one another, so there may be some geologic or geographic factor which allowed the streams to develop improved fish communities. Another explanation might be simply the natural variation in the kinds of fishes present in the stream section on the day of sampling.

At three sites (Stations 3, 4, and 7) the IBI value for 1999 dropped by four or more units, and at three sites (Stations 2, 10, and 11) the value declined two units. All of these sites except Station 10 experienced declines in the IMBI values, too. This is possibly related to the common effects of the drought.

Stations 2, 9, and 10 appear to rank highest across the three measurements. Stations 11, 12, and 13 appear to rank lowest across the three measurements. However, if only the 1998, pre-drought IMBI and IBI values are examined, then Stations 2, 5, and 7 seem to be the best quality, and Stations 12 and 13 rank lowest. Nevertheless, I feel that there is general agreement that the quality of almost all sites is very good and perhaps is the best found in northern Virginia. Together with Quantico Creek in Prince William Forest Park, these streams seem to be the best reference sites available in this area.

The IBI values determined by Jones and Kelso for Neabsco Creek range from 26 to 48 and are mostly in the 30s (12 sites) in Jones and Kelso (1994) and range from 20 to 36 with most of the values in the 30s (18 sites) in Jones and Kelso (1997). The IBI values for Powells Creek range from 40 to 46 (4 sites) in Jones and Kelso (1994) and range from 36 to 46 (5 sites) in Jones and Kelso (1997). The IBI values for Quantico Creek range from 34 to 46 (4 sites) in Jones and Kelso (1994) and range from 24 to 50 (12 sites) in Jones and Kelso (1997), with half the values in the 40s. In the present study, only two IBI values were in the 30s in the 1998 collections and only three were in the 30s in 1999. The rest were in the 40s, with one 50.

Plafkin et al. (1989) suggest that IBI values between 28 and 34 rate as Poor, between 40 and 44 as Fair, and between 48 and 52 as Good. Values above 58 rate Excellent. However, they also describe the fish community comparable to each of these rate classes. Excellent is described as "Comparable to pristine conditions, exceptional assemblage of species", and Good has "Decreased species richness, intolerant species in particular; sensitive species present". I think this last class titled "Good" describes the fish community of most of the sites within the MCB. A few of the sites are "Fair", especially after the drought started.

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Appendix A

YR	98	98	98	98	98	98	98	98	98	98	98	98	98
Station	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	Sta. 13
Date	20-May	20-May	20-May	21-May	21-May	21-May	21-May	21-May	30-Jun	09-Jul	09-Jul	09-Jul	09-Jul
Analyst	AJM	AJM	AJM	AJM	AJM	AJM	AJM	AJM	AJM	AJM	AJM	AJM	AJM
Insects													
Coleoptera													
Dryopidae	0	0	9	0	13	6	0	2	0	0	2	0	0
Dytiscidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Elmidae	0	32	3	1	1	5	17	1	14	2	2	0	0
Gyrinidae	0	0	0	0	0	0	1	0	0	0	0	0	1
Halipidae	0	1	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Psephenidae	0	0	0	0	0	0	0	0	3	0	0	0	0
Diptera													
Ceratopogonidae	4	0	0	0	1	1	3	0	0	0	0	0	0
Chironomidae	32	47	15	35	53	79	90	17	25	49	84	12	55
Culicidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Dixidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Empididae	2	0	0	0	0	0	0	0	4	0	0	0	5
Simuliidae	66	18	12	8	11	7	16	4	2	7	4	2	8
Tipulidae	0	0	2	5	3	1	8	0	0	5	11	0	0
Ephemeroptera													
Baetidae	6	1	37	33	42	25	21	26	4	4	3	2	7
Caenidae	0	0	0	1	0	0	1	1	0	0	0	0	0
Ephemereidae	6	0	4	0	3	1	0	2	1	0	0	0	0
Heptageniidae	7	21	24	8	8	23	1	24	68	37	22	41	28
Isonychidae	38	8	4	20	7	16	0	60	22	45	16	0	3
Leptophlebiidae	0	0	0	0	0	4	23	0	0	0	0	0	0
Hemiptera													
Gerridae	0	0	0	0	1	0	0	0	0	0	0	0	0
Saldidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Megaloptera													
Corydalidae	2	1	0	3	1	1	0	4	8	7	1	3	0
Sialidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Odonata													
Aeshnidae	0	0	0	0	0	2	0	0	0	0	2	1	0
Coenagrionidae	0	0	0	0	0	0	0	0	0	0	2	0	0
Corduliidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Corduligastridae	0	0	1	0	2	0	0	0	0	0	0	0	0
Gomphidae	0	1	0	2	6	4	1	2	2	2	0	0	1
Plecoptera													
Leuctridae	0	0	0	0	0	2	2	0	6	4	1	0	0
Nemouridae	0	0	5	1	13	2	1	1	0	0	0	0	0
Perlidae	3	0	52	14	18	17	20	9	12	7	18	2	2
Perlodidae	0	0	5	0	0	0	5	0	0	0	0	0	0
Trichoptera													
Brachycentridae	0	0	0	0	0	0	0	0	2	1	0	0	0
Hydropsychidae	8	44	4	3	0	1	0	10	29	21	53	136	65
Hydroptilidae	0	2	0	0	0	0	0	0	5	0	0	0	1
Philopotamidae	10	3	17	8	0	1	0	5	2	11	0	0	25
Psychomiidae	0	0	0	0	0	0	0	0	0	0	1	0	0
Crustacea													
Gammaridae	0	0	1	0	2	2	8	0	0	0	1	0	0
Cambaridae	0	1	1	0	1	0	0	0	0	0	0	0	0
Hydracarina	1	0	0	1	1	3	0	0	2	1	2	0	0
Gastropoda	0	2	1	0	0	0	0	1	0	0	0	0	0
Pelecypoda	3	7	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta	0	3	10	102	8	25	4	35	4	2	1	5	8
Planariidae	0	1	0	0	0	0	0	1	0	0	0	0	0
Nemertean	2	0	0	0	0	0	0	0	0	1	0	0	0
TOTAL	190	193	207	245	195	228	222	205	215	206	226	204	209

Appendix A

YR	99	99	99	99	99	99	99	99	99	99	99	99	99
Station	Sta. 1	Sta. 2	Sta. 3	Sta. 4	Sta. 5	Sta. 6	Sta. 7	Sta. 8	Sta. 9	Sta. 10	Sta. 11	Sta. 12	Sta. 13
Date	11-Jun	03-Jun	05-Jul	25-May	26-May	04-Jun	15-Jun	04-Jun	16-Jun	15-Jun	01-Jun	26-May	01-Jun
Analyst	KDB	KDB	KDB	KDB	KDB	KDB	KDB	KDB	KDB	KDB	KDB	KDB	KDB
Insects													
Coleoptera													
Dryopidae	0	2	25	1	0	1	1	8	0	2	0	0	1
Dytiscidae	0	0	1	0	0	0	0	0	0	0	0	0	0
Elmidae	17	11	2	0	5	0	0	2	9	12	1	1	20
Gyrinidae	0	0	0	0	0	0	1	0	0	0	0	0	0
Halipidae	0	0	0	1	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	0	1	0	1	0	0	0	0	0	0	0	0
Psephenidae	0	0	0	0	0	0	0	0	2	3	0	0	1
Diptera													
Ceratopogonidae	0	0	0	1	4	0	1	2	3	5	2	0	0
Chironomidae	60	76	0	181	121	83	86	81	57	65	139	28	73
Culicidae	0	0	0	0	0	0	3	0	0	0	0	0	0
Dixidae	0	0	0	1	0	0	0	0	0	0	0	0	0
Empididae	1	0	0	2	0	0	0	4	1	5	1	5	0
Simuliidae	0	34	6	13	7	6	0	5	1	1	1	6	1
Tipulidae	6	3	4	5	0	6	0	4	2	1	13	0	0
Ephemeroptera													
Baetidae	0	0	0	1	9	0	6	0	0	0	8	1	9
Caenidae	0	0	0	0	0	0	0	0	2	1	0	0	2
Ephemerellidae	0	0	0	9	1	0	0	1	1	1	0	1	5
Heptageniidae	34	41	0	6	12	33	2	22	31	26	4	109	7
Isonychidae	47	0	0	2	6	36	0	51	67	15	6	0	48
Leptophlebiidae	0	0	0	2	0	1	30	0	0	0	1	0	1
Hemiptera													
Gerridae	0	0	0	0	0	0	0	0	0	0	0	0	0
Saldidae	1	0	0	0	0	0	4	0	0	0	0	0	0
Megaloptera													
Corydalidae	14	10	0	6	9	8	0	4	2	0	1	5	8
Sialidae	0	0	0	0	0	0	18	0	0	0	0	1	0
Odonata													
Aeshnidae	5	2	1	0	3	2	0	1	1	6	0	0	4
Coenagrionidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Corduliidae	0	0	0	0	0	0	5	0	0	0	0	0	0
Corduligastridae	0	1	0	1	0	0	0	0	1	0	2	0	0
Gomphidae	1	2	0	1	0	1	1	3	2	4	9	1	0
Plecoptera													
Leuctridae	0	0	0	0	0	0	1	1	2	1	9	0	0
Nemouridae	0	0	0	0	1	0	0	0	0	0	0	0	2
Perlidae	22	1	0	22	2	0	0	2	5	14	6	5	9
Perlodidae	0	0	0	0	4	0	0	0	0	0	0	0	0
Trichoptera													
Brachycentridae	0	0	0	0	0	0	0	0	2	2	0	0	0
Hydropsychidae	7	7	1	15	0	1	0	3	5	18	5	15	3
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Philopotamidae	7	2	0	24	4	22	0	2	13	16	0	0	2
Psychomyiidae	0	0	0	0	0	0	0	0	0	1	0	0	0
Crustacea													
Gammaridae	0	4	1	0	0	0	15	0	0	0	0	0	0
Cambaridae	2	3	0	0	0	1	0	4	0	1	0	2	0
Hydracarina	1	1	0	0	1	0	0	0	0	0	0	0	1
Gastropoda	0	0	8	1	0	1	0	3	0	0	1	0	5
Pelecypoda	0	1	0	0	0	0	0	4	4	0	0	0	2
Oligochaeta	4	5	8	3	14	7	13	8	8	12	0	26	1
Planariidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemertean	0	0	0	0	0	0	0	0	0	6	0	0	0
TOTAL	229	206	58	298	204	209	187	215	221	218	209	206	205

Appendix B1. Fish sampling results for 1998

Station Number	Site	Site Code	Date	Lam aep	Ang ros	Cli fun	Cyp ana	Cyp spi	Exo max	Lux cor	Not cry
1	Cannon Creek above Rt. 644	CC@644	06/01/98	8	0	3	1	4	3	6	0
2	Dorrells Run below MCB 3	DR@3	06/04/98	0	0	23	0	0	0	0	2
3	Goslin Run above MCB 8	GR@8	06/22/98	0	0	3	0	0	0	2	4
4	Lucky Run below MCB 8	LR@8	06/03/98	0	0	120	0	0	1	20	6
5	South Mill Branch below MCB 8	SMB@8	06/02/98	0	0	117	0	0	0	0	2
6	East Mill Branch above MCB 8	EMB@8	06/02/98	0	0	148	0	0	0	2	1
7	North Branch of Chopawamsic Creek below Coop' Gobbler Road	NBC@CCGR	06/23/98	0	0	0	0	0	0	0	0
8	South Fork of Quantico Creek above Rt. 619	SFQC@619	07/01/98	0	3	398	0	0	68	0	0
9	North Branch of Chopawamsic Creek above confluence with Middle Branch	NBC@MB	07/07/98	0	4	61	0	0	54	87	0
10	1	IMBC@1	07/20/98	0	4	150	0	0	27	114	1
11	South Branch of Chopawamsic Creek below MCB	SBC@1	06/30/98	0	0	331	0	0	0	0	0
12	Beaverdam Run below Application Training Chopawamsic Creek below second crossing of Breckinridge Road	BR@AT	07/14/98	0	0	9	0	119	6	0	0
13		CC@BR	07/06/98	4	119	0	0	0	7	0	0
Totals				12	130	1363	1	123	166	231	16

<i>Not amo</i>	<i>Not hud</i>	<i>Not pro</i>	<i>Pho ore</i>	<i>Pim not</i>	<i>Rhi atr</i>	<i>Sem atr</i>	<i>Sem cor</i>	<i>Cat com</i>	<i>Eri obl</i>	<i>Hyp nig</i>	<i>Ame nat</i>	<i>Ame neb</i>	<i>Not ins</i>	<i>Eso nig</i>	<i>Umb pyg</i>	<i>Sal fon</i>	<i>Emm glo</i>	<i>Lep aur</i>	<i>Lep cya</i>	<i>Lep gib</i>
2	0	47	0	0	0	2	15	4	1	0	0	1	6	3	0	0	0	46	0	16
0	0	29	3	0	18	94	0	19	17	0	1	0	0	0	0	0	0	94	9	8
0	0	1	0	0	0	58	7	21	4	4	0	3	1	0	0	0	0	0	10	2
0	0	22	0	0	83	103	23	21	16	3	0	0	0	0	0	0	0	20	14	2
0	14	39	0	0	75	87	12	27	1	0	0	0	0	0	2	0	0	4	6	0
0	0	31	0	22	103	236	22	32	2	0	0	0	0	0	1	0	0	4	6	0
0	0	0	0	0	0	3	0	0	30	0	0	0	9	14	0	0	0	107	0	11
0	0	316	0	0	49	25	80	37	9	0	0	0	13	1	0	0	0	31	1	2
0	0	28	0	0	92	1	52	36	1	0	0	0	25	0	0	1	0	32	0	0
0	0	0	0	0	118	9	16	29	4	0	0	0	26	4	0	0	0	12	0	2
0	0	0	0	0	128	31	0	45	0	0	0	0	0	0	0	0	0	9	0	0
0	11	120	0	0	19	1	84	9	6	0	0	1	39	0	0	0	0	48	0	1
0	39	31	0	0	4	0	56	16	7	1	0	2	29	0	1	0	10	0	0	
2	64	664	3	22	689	650	367	296	98	8	1	7	148	22	4	1	20	417	46	44

<i>Lep</i> <i>gul</i>	<i>Lep</i> <i>mac</i>	<i>Mic</i> <i>sal</i>	<i>Per</i> <i>pel</i>	<i>Eth</i> <i>fla</i>	<i>Eth</i> <i>olm</i>	Total
0	12	0	3	0	45	228
0	64	1	0	1	10	393
0	4	10	1	9	32	176
0	4	0	0	42	21	521
0	0	0	0	19	19	424
0	1	0	0	23	33	667
0	3	0	0	0	8	185
0	8	0	0	0	86	1127
0	14	0	0	0	155	643
0	7	0	0	0	101	624
0	2	0	0	3	35	584
0	0	2	0	0	27	502
2	21	2	0	0	39	410
2	140	15	4	97	611	6484

Appendix B2 . Fish sampling results for 1999

Station Number	Site	Site Code	Date	Lam aep	Ang ros	Cli fun	Cyp ana	Cyp spi	Exo max	Lux cor	Not cry	Not amo	Not hud
1	Cannon Creek above Rt. 644	CC@644	05/25/99	4	0	0	0	0	4	1	0	27	0
2	Dorrell's Run below MCB 3	DR@3	06/09/99	0	0	4	0	0	0	1	3	0	0
3	Goslin Run above MCB 8	GR@8	05/17/99	0	0	1	0	0	0	0	0	0	0
4	Lucky Run below MCB 8	LR@8	05/18/99	0	0	51	0	0	0	26	0	0	1
5	South Mill Branch below MCB 8	SMB@8	06/30/99	0	0	64	0	0	0	1	5	0	0
6	East Mill Branch above MCB 8	EMB@8	07/06/99	0	0	120	0	0	1	0	2	0	0
7	North Branch of Chopawamsic Creek below Coop's Gobbler Road	NBC@CGR	06/21/99	0	0	0	0	0	0	0	0	0	0
8	South Fork of Quantico Creek above Rt. 619	SFQC@619	06/08/99	0	2	325	0	0	86	1	0	0	0
9	North Branch of Chopawamsic Creek above confluence with Middle Branch	NBC@MB	06/16/99	0	2	115	0	0	135	178	1	0	0
10	Middle Branch of Chopawamsic Creek below MCB 1	MBC@1	06/14/99	0	1	139	0	0	70	65	0	0	26
11	South Branch of Chopawamsic Creek below MCB 1	SBC@1	06/22/99	0	2	696	0	0	0	0	0	0	0
12	Beaverdam Run Below Application Training	BR@AT	06/23/99	0	0	44	178	1	11	0	1	6	0
13	Chopawamsic Creek below second crossing of Breckenridge Road	CC@BR	05/19/99	0	70	5	0	0	6	0	0	0	6
Totals				4	77	1564	178	1	313	273	12	33	33

Not pro	Pho ore	Pim not	Pim pro	Rhi atr	Sem atr	Sem cor	Cat com	Eri obl	Hyp nig	Ame mel	Ame nat	Not ins	Eso nig	Gam hol	Enn glo	Lep aur	Lep cya	Lep gib	Lep gul	Lep mac	Mic dol	Mic sal
34	0	0	0	0	1	24	9	5	0	0	3	18	1	0	1	25	0	15	0	5	0	0
6	3	0	0	5	48	1	2	4	0	0	12	0	0	0	0	75	0	3	0	12	0	0
1	0	0	0	0	5	6	0	1	0	0	0	0	0	0	0	0	4	0	0	0	0	0
9	0	0	0	23	27	60	11	12	3	0	1	0	0	0	0	8	8	0	0	2	0	3
38	0	4	0	29	70	17	11	1	0	0	1	0	0	0	0	4	0	1	0	0	0	0
45	0	17	21	78	134	20	19	1	0	0	6	0	0	0	3	2	1	0	0	0	1	0
0	0	0	0	0	2	0	0	3	0	0	0	0	47	0	0	1	0	0	0	0	0	0
354	0	3	0	88	14	45	13	17	0	0	0	29	0	0	0	38	0	2	0	10	0	0
48	0	0	0	152	2	97	36	3	0	0	0	44	2	0	0	65	0	0	0	30	0	0
26	0	0	0	115	11	68	57	0	0	0	0	25	4	0	0	25	0	5	0	18	0	0
0	0	0	0	430	66	0	32	0	0	0	0	0	0	0	0	48	0	0	3	0	0	0
302	0	0	0	12	0	112	3	0	0	0	2	73	1	0	0	100	0	0	0	0	0	0
11	0	0	0	6	3	23	6	11	0	1	6	63	0	5	28	20	1	1	1	23	0	2
874	3	24	21	938	383	473	199	58	3	1	31	252	55	5	32	411	14	27	1	103	1	5

<i>Per not</i>	<i>Eth fla</i>	<i>Eth olm</i>	Total
3	0	33	213
0	0	17	196
0	6	8	32
0	8	23	276
0	12	53	311
0	21	83	575
0	0	0	53
0	0	95	1122
0	0	145	1055
0	0	122	777
0	0	84	1361
0	0	29	875
0	0	42	340
3	47	734	7186