2010 Mill River Invertebrate Monitoring Report

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Introduction

The invertebrate community in the Mill River downstream of Lake Whitney has been monitored twice per year (spring and summer) from 2000 through 2009 in an effort to discern any impact from changing flow patterns that might be induced by the South Central Connecticut Regional Water Authority's (SCCRWA) withdrawal of water from Lake Whitney for public water supply. Quantitative and qualitative data have been collected for habitat characteristics and benthic macroinvertebrate community structure at up to five stations along the lower Mill River in Hamden and New Haven, CT. The new water treatment facility came on line in April of 2005, although it has rarely operated near capacity through 2010; withdrawals have averaged 1.4 to 31% of capacity on an annual basis, with peak monthly withdrawal at 85% of capacity. After 10 years of study, including five years of pre-operational data and five years of post-operational data, comparisons between pre-operation years and post-operation years were made in late 2009 and are the subject of a detailed report (AECOM 2010).

Stations 1, 2 and 3 are near each other, and while not truly replicates, they offer similar habitat and represent a freshwater environment with flows from Lake Whitney as the dominant influence on habitat quality and quantity. Stations 4 and 5 are within the more strongly tidal zone, and have been subject to saltwater intrusion during high tides. Station 5 is routinely affected by saltwater, whereas Station 4 is less impacted by actual saltwater, but is hydrologically influenced by tidal effects. As the differences between stations became apparent and doing more at each station within the constraints of the budget was requested, Station 5 was dropped from the sampling routine in 2006. Consequently, there are very few post-operational data for Station 5 and it was not considered in the 2009 analysis. Additionally, Station 4 was considered separately from Stations 1-3 for most assessments, as the habitat is quite different (e.g., less riffle zone, more rooted plants, slower water velocity, tidal influence).

The examination of ten years of data for the lower Mill River generated the following observations and conclusions:

1. In general, the macroinvertebrate assemblage observed in the Mill River since 2000 is indicative of intermediate stream community health. The taxa collected in the Mill River may be commonly found in a range of environments (e.g., worms, scuds, prosobranch snails, caddisflies, midgeflies). Most taxa found were typical of urban freshwater habitats, where water quality impacts are common. Midges (Diptera, Chironomidae) are common in a variety of freshwater habitats, but their dominance in a community is often regarded as a sign of degraded conditions. More detailed assessment of chironomid species in the Mill River supports this assessment.
2. Water quality indications of the biotic index are moderate overall, suggesting that water quality in the lower Mill River is suboptimal at all flow levels assessed. However, biotic index values declined with increasing average flow for the 10-week period preceding sampling at all stations, suggesting better water quality with higher flow (lower values for the index represent better water quality). While storm water runoff is a concern in the contributory watershed, water quality features of primary importance to invertebrates are apparently positively influenced by higher flows. This includes temperature and oxygen, and possibly pH, all of which can be altered by detention in upstream Lake Whitney. Note that a separate study indicates low dissolved oxygen at times in the vicinity of the footbridge downstream, but most invertebrate sampling effort is focused upstream of related influences.
3. Flow is a potentially important factor in shaping the invertebrate community of the lower Mill river, and some changes in the invertebrate community may be explained by key flow

events, usually high and low extremes. However, invertebrate community features do not closely track any flow gradient.

4. Abundance of the most common taxa observed does not appear to be related to flow. The most common taxa at Stations 1-3 for all years did not increase in abundance with increased flows. Invertebrate abundance at Stations 1-3 was highest under the lowest flow observed, but similar flow values did not necessarily result in high abundance of these species. At Station 4, the highest invertebrate abundances appear to occur under moderate flows, but increased abundances of some taxa have occurred under both lower and higher flows. Flow itself may be influential in setting habitat, affecting water quality, and washing invertebrates downstream, but is not the sole factor affecting abundance or composition of the invertebrate community, and may not be the primary factor.
5. There appears to be a pattern of alternating years of decreased and increased invertebrate abundance at station 1, with higher values in odd years. This instability has not been adequately explained by any factors we have examined. Increased abundance is usually linked to increases in just a few taxa, suggesting opportunistic activity when resources (space or food under favorable water quality) are available and substantial fluctuations in that availability.
6. No clear patterns are apparent in the analysis of feeding guilds versus flow. Increased flow did not result in increased presence of any one particular feeding group, although decreased flow may favor the scraper group. This is consistent with the ecology of that group, which scrapes attached algae and related organic matter off of rocks and other substrates. Such accumulations will be higher with low flows, while the quantity and quality of suspended particles may be reduced at low flows. However, there was not a clear increase in suspended particulate feeders at high flows, perhaps indicating a confining influence of flow (more specifically velocity) on abundance.
7. High values for any one feeding group are usually related to increased abundance of one or two particular taxa. Grouping the data as pre-operation and post-operation sets as relates to the water treatment facility does not suggest any patterns in feeding group abundance or indicate any shifts between feeding groups as a result of the treatment facility operation. A range of flows have been experienced in pre-operation and post-operation years, and the abundance of any one feeding group for a particular range of flows is variable.
8. Lack of stability may be a function of varying flows, but the influence of the water treatment facility withdrawal is very minor in that regard. Wide fluctuations in river flow overshadow any influence of withdrawal for water supply.

As noted in the summary report for the 2000-2004 pre-operational monitoring program (ENSR 2005), changes in the invertebrate community over time may be a consequence of many environmental factors, including the desiccation of the stream during the dry summer months, changes in water quality, altered food abundance and quality, and predation effects. Flow is only one factor, and is likely to have more indirect effects at low levels. Variability in flow, inducing instability, may be a potent factor in structuring the benthic macroinvertebrate community of the lower Mill River, and is linked to water quality issues (including dilution of contaminants from upstream and salinity from downstream), altered physical habitat, and available food resources. Post-operational data support that conclusion and suggest no detectable influence by the water withdrawal since operation of the treatment facility commenced. The withdrawals have simply been too small relative to the other sources of flow fluctuation in the Mill River watershed.

Given the wide variability of river flows, it appears unlikely that operation of the treatment facility in accordance with the SCCRWA's Management Plan has significant potential to result in measurable changes to the invertebrate community. Yet monitoring opportunities during extended dry, low flow periods with the treatment facility operating near full capacity have been very limited. Additional data under both operating and non-operating conditions during these dry weather events may provide more conclusive evidence as to the adequacy of the Management Plan to minimize water withdrawal impacts.

Based on the results of monitoring for a decade, sampling at Station 4 (footbridge) was discontinued and spring sampling at Stations 1, 2 and 3 also ceased as of the end of 2009. Beginning in 2010, monitoring focuses on Stations 1-3 during August, with an emphasis on detecting any impacts of treatment facility operation during a period of typically lower river flows. These three stations are similar and best represent the impact of flow from Lake Whitney on the lower Mill River. This report is the first under the new, reduced monitoring program, but takes advantage of data collected for Stations 1-3 over the last decade to continue to examine any trends and detect any flow impacts.

Methods

General methods were consistent with previous years, beginning in 2000. Samples were collected on August 30, 2010, at the peak of the tidal outflow (low tide). Sampling locations (Figure 1) included only Stations 1, 2 and 3 from previous years. General habitat features were surveyed and metered water quality (temperature, oxygen, conductivity, turbidity and pH) was assessed to ensure no major changes from previous years, but these are not used in the main analysis of data, which focuses on possible relationships between invertebrates and flow.

Flow is estimated by the SCCRWA using automated lake level measurements at the Lake Whitney spillway. Flow values were recorded as daily means from SCCRWA flow records from the Whitney Dam. As flow on the day of the survey is not an indication of antecedent conditions, SCCRWA flow records were used to derive an average flow for ten weeks (2.5 months) prior to each sampling. Note that drawdown and use of the bypass system through most of the summer of 2004 precluded accurate measures of flow for that period, but flows were obtained for all other summers in the monitoring period. Variation in flow from Lake Whitney is the dominant influence on water velocity at Stations 1 and 2. Water level changes may occur with tidal influences at Station 3, but saltwater does not intrude this far upstream.

Timed (two minutes) D-frame dip-net sampling was used to collect macroinvertebrates. This method is commonly used as a multi-habitat rapid bioassessment technique (Barbour et al. 1999). Riffle habitats were sampled at stations where riffle habitat is available. Macroinvertebrates were captured in the net by dislodging the substrate up to 1 ft (0.3 m) upstream of the dip-net. Two subsamples per sampling station were collected. Each subsample consisted of a two-minute collection, itself comprised of four 30-second collection efforts at four nearby locations within the site, all in riffle habitat. Subsamples were preserved in 70% ethanol for laboratory analysis. Macroinvertebrates were sorted, identified to the lowest practical taxonomic level, and counted. Primary references include Simpson and Bode (1980), Peckarsky et al. (1993), Merritt and Cummins (1996), and Epler (2001).

The two macroinvertebrate subsamples were analyzed separately, but combined into a single sample per station for data analysis. Variability among subsamples was evident, as is expected for such samples, but was not striking in most cases. For example, the subsamples for stations 1, 2 and 3 in 2010 had percent similarity index values of 81, 86 and 63%, respectively; for macroinvertebrate samples, these are very similar. Combining four subsamples for each of the two replicate samples and then pooling the replicate sample data helped minimize spatial variability, which can be naturally very high for macroinvertebrates. Variability not related to flow can obscure flow impacts, so such compositing of samples and results is desirable in this case.

Numerical analysis included relative abundance and dominance patterns for taxonomic and feeding groups, plus species richness and evenness. Species richness was expressed as number of separate, identified taxa. Species evenness quantifies the degree of dominance (or lack thereof) of taxa within a community; it measures the distribution of individuals among taxa present. It is calculated as the ratio of diversity to the maximum diversity achievable for the number of taxa present, and is therefore a number between 0 and 1. Diversity is calculated as the summation for all species of the fraction of the total number of invertebrates represented by each species times the natural logarithm of that fraction. When one or a few taxa dominate a community, diversity is low. The modified Hilsenhoff Biotic Index (HBI), based on a quality value of 0-10 assigned to each taxon multiplied by the abundance of each corresponding taxon and divided by the total number of individuals, was calculated for each station and date. The index was modified to include non-arthropod species (Mandeville 2002).

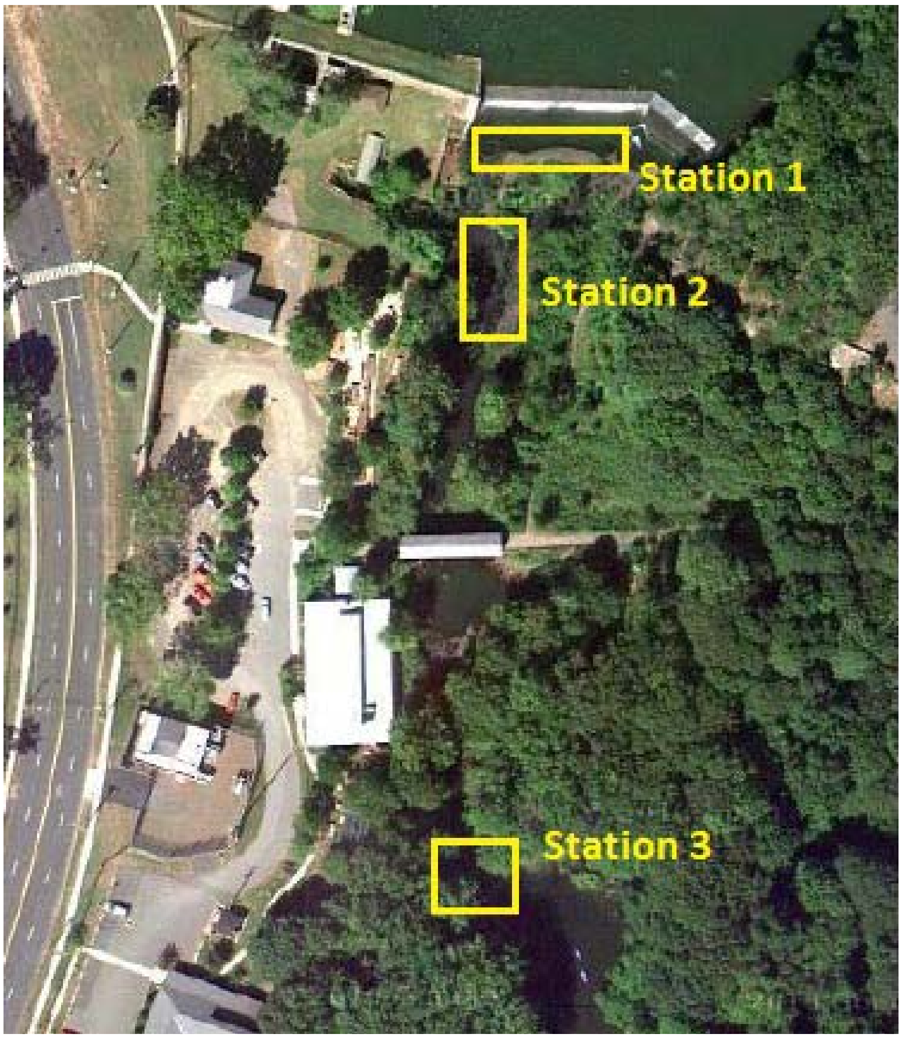


Figure 1. Mill River sampling stations

Results

The Mill River below the Lake Whitney dam contains a thriving and dynamic invertebrate community (Table 1) which has been assessed every August since 2000. A total of 81 taxa have been identified from three stations, including twenty orders representing eight classes, with insects (Class Insecta) representing the most taxa and largest numbers of individuals. The invertebrate community of Mill River, as determined from all August samples from 2000 through 2010 at Stations 1-3, includes mainly caddisflies (Order Trichoptera, seven families), true flies (Order Diptera, six families), scud (Order Amphipoda, two families), flatworms (Order Tricladida, Dugesiidae), beetles (Order Coleoptera, four families) and snails (Order Gastropoda, five families). Most families are represented by multiple taxa, although a single taxon is often dominant within the family. Midgeflies were the taxonomically richest familly with 15 taxa identified from 2006 on, with up to nine taxa per station, although only five taxa were abundant over the monitoring period (based on total individuals counted).

The seven most abundant taxa (Table 2) include a caddisfly (*Macrostemum*, Hydropsychidae), midgeflies (Chironomidae, used collectively because identification beyond family was not performed prior to 2006), a scud (*Gammarus*, Gammaridae), a flatworm (*Dugesia*, Dugesiidae), dance flies (Empididae, with *Hemerodromia* and unidentified empidids pooled), a riffle beetle (*Stenelmis*, Elmidae), and a snail (*Amnicola*, Hydrobiidae). Together, these taxa comprise 93% of all individuals collected over 11 years, and their indications for feeding groups and water quality (biotic index) will strongly affect station values for related calculations.

This assessment focuses on possible flow impacts on the invertebrate community, facilitated by comparisons of the average flow for ten weeks prior to sampling to quantifiable features of the macroinvertebrate community (Table 3, Figures 2-18). In short, there are no comparisons that suggest that flow, as measured, is a dominant influence on the macroinvertebrate community features assessed.

Short bursts of very high flows may alter habitat or wash invertebrates downstream, despite an overall lower average flow for the ten weeks prior to sampling. Yet the habitat has not changed appreciably except possibly at station 1 (where additional substrate was added during a construction related drawdown). Additionally, the average flows seem representative of relative flow conditions for the period preceding sampling; there are no cases of flooding interrupting extreme low flow conditions for the period of record. There have been observed fluctuations in the amount and type of plant cover, of the buildup or loss of fine sediments, and of wetted channel width and water depth, but the overall conditions represented by ten week average flow do not correlate strongly to any measured feature of the invertebrate community at Stations 1-3.

The strongest relationship is between flow and total individuals (and to a similar extent with some of the most abundant taxa), with high flows leading to lower abundance (Figure 2). While this is consistent with high flows yielding high velocities that wash many invertebrates downstream, it is not a very strong relationship. The highest abundance occurs at low flows, but there are many instances of lower abundance at lower flow as well. Other influences are clearly at work, and high flows may simply put a cap on the maximum abundance that can occur.

Table 1. Macroinvertebrate data for three stations in the lower Mill River, Connecticut, sampled from 2000 – 2010.

							1-Aug-00			21-Aug-01			19-Aug-02			26-Aug-03			2-Sep-04			23-Aug-05			1-Aug-06			17-Aug-07			17-Aug-08			20-Aug-09			23-Aug-10		
Class	Order	Family	Taxon	Feeding Group	Biotic Index Value	Total Indiv (all samples)	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Annelida	Hirudinea	Glossiphoniidae	Glossiphonia complanata	Parasite	8	10	5	1	2		2																													
Annelida	Hirudinea		Unidentified Hirudinea	Parasite	8	71													8			53	10																	
Annelida	Oligochaeta	Naididae	Nais communis	Collector	8	483																367	7	13	5			4			17	45	25						
Annelida	Oligochaeta	Tubificidae	Unidentified Tubificidae	Collector	10	20							20																										
Annelida	Oligochaeta		Unidentified Oligochaeta	Collector	5	31															7	20															4		
Annelida	Polychaeta	Ampherididae	Unidentified Ampherididae	Detritivore	6	4							4																										
Arachnida	Trombidiformes	Lebertiidae	Lebertia sp.	Predator	6	9												3						1			5												
Arachnoidea	Hydracarina	Arrenuridae	Unidentified Arrenuridae	Parasite	6	4								4																									
Crustacea	Amphipoda	Crangonyctidae	Crangonyx sp.	Shredder	6	197	86	19	18			2							5			67																	
Crustacea	Amphipoda	Gammaridae	Gammarus sp.	Shredder	6	9859	1212	2311	1904	36	540	212	116	92	16	434	103	287		20	27	247	137	264	241	117	316	80	117	54	108	82	242	22	23	24	128	8	340
Crustacea	Isopoda	Asellidae	Caecidotea communis	Collector	8	46										4		3	1						4	0	4		30										
Crustacea	Isopoda	Asellidae	Lirceus/Acellus sp. (communis)	Shredder	8	28	9	9	8		2																												
Hydrozoa	Hydroida	Hydridae	Hydra sp.	Predator	5	9		1			8																												
Insecta	Coleoptera	Elmidae	Stenelmis sp.	Scraper	5	1263										6	3	12		13	38	20	24	48	5	4	8	24	3	17	8	36	108			22	12	64	788
Insecta	Coleoptera	Hydrophilidae	Berosus sp.	Predator	5	61		5	7	2	2											20			1												4	4	16
Insecta	Coleoptera	Psephenidae	Unidentified Psephenidae	Predator	4	8								8																									
Insecta	Coleoptera		Unidentified Coleoptera	Predator	5	7										6		1																					
Insecta	Diptera	Ceratopognidae	Unidentified Ceratopognidae	Predator	6	2										1	1																						
Insecta	Diptera	Chironomidae	Chironominae																																				
Insecta	Diptera	Chironomidae	Chironomini																																				
Insecta	Diptera	Chironomidae	Chironomus riparius	Collector	10	16																			3									5	5	3			
Insecta	Diptera	Chironomidae	Dicrotendipes neomodestus	Collector	8	877																			36	114	22	48	17	9	31	2		10	55		75	35	423
Insecta	Diptera	Chironomidae	Glyptotendipes lobiferus	Shredder	10	224																			4	9	15	32	33			6		34	30	17	22		23
Insecta	Diptera	Chironomidae	Paratendipes albimanus	Collector	6	28																			8	11													9
Insecta	Diptera	Chironomidae	Polypedilum flavum	Shredder	6	2163																			66	69	35	24	103	7		10	72	24		79	1031	316	326
Insecta	Diptera	Chironomidae	Polypedilum braseniae	Shredder	6	46																										2					38	6	
Insecta	Diptera	Chironomidae	Polypedilum sp.	Shredder	6	46																					1								45				
Insecta	Diptera	Chironomidae	Tanytarsini																																				
Insecta	Diptera	Chironomidae	Paratanytarsus sp.	Collector	6	85																					1											70	14
Insecta	Diptera	Chironomidae	Rheotanytarsus exiguus group	Collector	6	37																				4	6		17						10				
Insecta	Diptera	Chironomidae	Orthocladiinae																																				
Insecta	Diptera	Chironomidae	Cardiocladius obscurus	Predator	5	62																						8	7	3	6			24	10	3			
Insecta	Diptera	Chironomidae	Cricotopus trifascia	Shredder	6	448																			13		44	40	47	13	28	10	17	24	45	89	57	12	10
Insecta	Diptera	Chironomidae	Cricotopus intersectus	Shredder	7	120																			5	9	18	4	13				22				49		
Insecta	Diptera	Chironomidae	Cricotopus sylvestris	Scraper	7	18																												5	5	3			4
Insecta	Diptera	Chironomidae	Eukiefferiella tirolensis	Collector	4	241																									22	10	17	5			173	6	9
Insecta	Diptera	Chironomidae	Tanypodinae																																				
Insecta	Diptera	Chironomidae	Thienemannimyia group	Predator	6	113																												68		45			
Insecta	Diptera	Chironomidae	Unidenitifed Chironomidae	Collector	7	7279	50	336	206	394	188	78	1252	280	140	285	577	712	144	143	275	747	1087	385															
Insecta	Diptera	Empididae	Hemerodromia sp.	Predator	6	283	8	98	23	42	40		48	20	4																								
Insecta	Diptera	Empididae	Unidentified Empididae	Predator	6	1025										1	67	33	1	20	24	533	227			49	42			1				9	10	8			
Insecta	Diptera	Simuliidae	Simulium sp.	Filterer	5	382	5	6		37	30					42	31		1	50	3	33			44	37					8	18		9	8	12	8		
Insecta	Diptera	Tipulidae	Unidentified Tipulidae	Shredder	4	367																287	7	1	4	17	4					9		2	15	18		4	
Insecta	Diptera		Unidentified Diptera	Collector		515										45	45	29	2	37	30	40	80	4	22	51	30	28	13	6	17	36							

Table 1. continued. Mill River macroinvertebrate data.

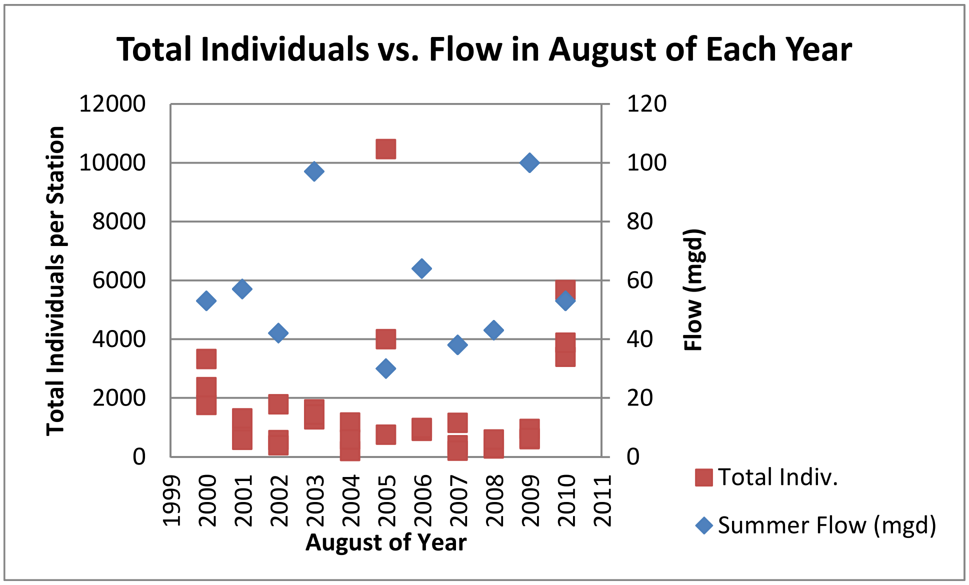
							1-Aug-00			21-Aug-01			19-Aug-02			26-Aug-03			2-Sep-04			23-Aug-05			1-Aug-06			17-Aug-07			17-Aug-08			20-Aug-09			23-Aug-10		
Class	Order	Family	Taxon	Feeding Group	Biotic Index Value	Total Indiv (all samples)	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Insecta	Ephemeroptera	Baetidae	Baetis sp.	Collector	6	15																															5	6		4	
Insecta	Ephemeroptera	Caenidae	Brachycercus sp.	Collector	3	214																		1								9							204
Insecta	Ephemeroptera	Caenidae	Caenis sp.	Collector	6	5	1	2	2																														
Insecta	Ephemeroptera	Heptageniidae	Stenonema sp.	Scraper	3	5												1																		4			
Insecta	Ephemeroptera	Oligoneuridae	Isonychia sp.	Collector	2	1		1																															
Insecta	Hemiptera	Gerridae	Rheumatobates sp.	Predator	5	3																								3									
Insecta	Hemiptera	Gerridae	Unidentified Gerridae	Predator	5	1												1																					
Insecta	Hemiptera	Mesoveliidae	Mesovelia sp.	Predator	5	3												3																					
Insecta	Hemiptera	Veliidae	Microvelia sp.	Predator	5	1																								1									
Insecta	Hemiptera		Unidentified Hemiptera	Predator	5	2										2																							
Insecta	Neuroptera	Sisyridae	Sisyira sp.	Predator	5	1	1																																
Insecta	Odonata	Coenagrionidae	Ischnura/Enallagma sp.	Predator	8.5	69		1						68																									
Insecta	Odonata	Coenagrionidae	Argia sp.	Predator	6	8																											8						
Insecta	Plecoptera	Perlidae	Perlidae sp.	Predator	1	52																									17	18	17						
Insecta	Trichoptera	Brachycentridae	Brachycentrus sp.	Filterer	1	70					1	1	64		4																								
Insecta	Trichoptera	Hydropsychidae	Macrostemum sp.	Filterer	3	23550	1	8	8	264	303	1				743	434	311	3	307	152	7707	2376	24	416	468	401	76	740	87		9		318	660	286	3888	2200	1360
Insecta	Trichoptera	Hydropsychidae	Hydropsyche sp.	Filterer	4	287				2			228	40															17										
Insecta	Trichoptera	Hydropsychidae	Parapsyche sp.	Filterer	0	10	9		1																														
Insecta	Trichoptera	Hydroptilidae	Agraylea sp.	Collector	8	115										1	1	21				20	10	1		1	22							11	15	8	4		
Insecta	Trichoptera	Hydroptilidae	Oxyethira sp.	Predator	3	9		3		6																													
Insecta	Trichoptera	Leptoceridae	Ceraclea sp.	Collector	3	121	12	36	35	8	12	11						3																				4	
Insecta	Trichoptera	Leptoceridae	Mystacides sp.	Collector	4	13			1			12																											
Insecta	Trichoptera	Leptoceridae	Triaenodes sp.	Shredder	6	1			1																														
Insecta	Trichoptera	Limnephilidae	Rossiana sp.	Scraper	5	12					10	2																											
Insecta	Trichoptera	Limnephilidae	Unidentified Limnephilidae	Shredder	5	10						10																											
Insecta	Trichoptera	Philopotamidae	Chimarra sp.	Filterer	4	17											13	1																	3				
Insecta	Trichoptera	Uenoidae	Neophylax sp.	Shredder	3	85																									17		42	2					24
Insecta	Trichoptera		Trichoptera pupae	Inactive	NA	32																															32		
Mollusca	Bivalvia	Sphaeriidae	Pisidium sp.	Filterer	6	28																																	28
Mollusca	Bivalvia	Sphaeriidae	Unidentified Sphaeriidae	Filterer	6	23		1	4		2		4		12																								
Mollusca	Gastropoda	Ancylidae	Ferrissia rivularis	Scraper	6	11		3	5			3																											
Mollusca	Gastropoda	Hydrobiidae	Amnicola limosa	Scraper	5	682				36	62	201	44	40	200			9			3	33					10	8		3			17						16
Mollusca	Gastropoda	Physidae	Physa sp.	Scraper	8	135	11	25	4		43			8		19				7								8								2	4	4	
Mollusca	Gastropoda	Planorbidae	Gyraulus parvus	Scraper	8	359	22	147	117	4	26	19	4	8	12																								
Mollusca	Gastropoda	Planorbidae	Helisoma sp.	Scraper	6	36										4			2				10														12	8	
Mollusca	Gastropoda	Planorbidae	Gyraulus deflectus	Scraper	8	7		3																				4											
Mollusca	Gastropoda	Planorbidae	Gyraulus circumstriatus	Scraper	8	24			6	2																													16
Mollusca	Gastropoda	Valvatidae	Valvata tricarinata	Scraper	8	1					1																												
Mollusca	Gastropoda		Unidentified Gastropoda	Scraper	7	8																									8								
Nemertea	Nemertea		Unidentified Nemertea	Predator	8	46										4	1		3			33													5				
Turbellaria	Tricladida	Dugesiidae	Dugesia sp.	Predator	4	2739	325	309	16	50	33	28				9			22	567	32	233	20	7		1								22	3	2	128	660	272
			Total Individuals			55296	1757	3325	2368	883	1305	580	1784	568	388	1606	1276	1430	192	1164	590	10460	3995	749	877	960	982	388	1157	204	288	300	587	596	950	632	5668	3404	3884
			Total Taxa			81	15	21	19	13	18	13	10	10	7	16	11	16	11	9	10	17	12	11	10	11	11	9	7	9	9	10	8	9	11	12	12	11	11

Table 2. Data for the seven most abundant taxa identified from lower Mill River samples, 2000 – 2010.

Order	Family	Taxon	Feeding Group	Biotic Index Value	Total Indiv. for all samples	8/1/00	8/21/01	8/19/02	8/26/03	9/2/04	8/23/05	8/1/06	8/17/07	8/17/08	8/20/09	8/23/10
Trichoptera	Hydropsychidae	Macrostemum sp.	Filterer	3	23550	17	568	0	1488	462	10107	1284	903	9	1264	7448
Diptera	Chironomidae	Chironomidae	Collector	7	11802	592	660	1672	1574	562	2219	492	424	254	645	2708
Amphipoda	Gammaridae	Gammarus sp.	Shredder	6	9859	5427	788	224	824	47	648	674	251	432	69	476
Tricladida	Dugesiidae	Dugesia sp.	Predator	4	2739	650	111	0	9	621	260	1	0	0	27	1060
Diptera	Empididae	Empididae	Predator	6	1308	129	82	72	101	45	760	91	1	0	27	0
Coleoptera	Elmidae	Stenelmis sp.	Scraper	5	1263	0	0	0	21	51	92	17	44	152	22	864
Gastropoda	Hydrobiidae	Amnicola limosa	Scraper	5	682	0	299	284	9	3	33	10	11	17	0	16

Table 3. Average flows and macroinvertebrate community features for use in comparisons.

Year	Summer Flow (mgd)	Station	Total Indiv.	Total Taxa	Even-ness	Biotic Index	% Filterer	% Shredder	% Collector	% Scraper	% Predator	% Other	Macrostemum	Chironomidae	Gammarus	Dugesia	Stenelmis	Empididae	Amnicola
2000	53	1	1757	15	0.39	5.7	0.9	74.4	3.6	1.9	19.0	0.3	17	592	5427	650	0	129	0
		2	3325	21	0.38	6.0	0.5	70.3	11.3	5.4	12.5	0.0							
		3	2368	19	0.29	6.1	0.5	81.5	10.3	5.6	1.9	0.1							
2001	57	1	883	13	0.61	5.3	34.3	4.1	45.5	4.8	11.3	0.0	568	660	788	111	0	82	299
		2	1305	18	0.61	5.4	25.7	41.5	15.3	10.9	6.4	0.2							
		3	580	13	0.61	5.6	0.3	38.6	17.4	38.8	4.8	0.0							
2002	42	1	1784	10	0.47	6.3	16.6	6.5	71.3	2.7	2.7	0.2	0	1672	224	0	0	72	284
		2	568	10	0.70	6.6	7.0	16.2	49.3	9.9	16.9	0.7							
		3	388	7	0.59	5.9	4.1	4.1	36.1	54.6	1.0	0.0							
2003	97	1	1606	16	0.51	4.6	48.9	27.0	20.9	1.8	1.4	0.0	1488	1574	824	9	21	101	9
		2	1276	11	0.57	5.2	37.5	8.1	48.8	0.2	5.4	0.0							
		3	1430	16	0.50	5.7	21.8	20.1	53.7	1.5	2.9	0.0							
2004	No Data	1	192	11	0.42	6.5	2.0	2.8	76.6	1.2	13.6	3.9	462	562	47	621	51	45	3
		2	1164	9	0.65	4.1	30.7	1.7	15.5	1.7	50.4	0.0							
		3	590	10	0.68	5.2	26.4	4.5	52.8	6.9	9.4	0.0							
2005	30	1	10460	17	0.40	3.8	74.0	5.7	11.4	0.5	7.8	0.5	10107	2219	648	260	92	760	33
		2	3995	12	0.46	4.4	59.5	3.6	29.6	0.9	6.2	0.3							
		3	749	11	0.49	6.3	3.2	35.4	53.9	6.4	1.1	0.0							
2006	64	1	877	10	0.57	4.5	52.5	38.0	8.8	0.6	0.1	0.0	1284	492	674	1	17	91	10
		2	960	11	0.65	4.4	52.5	22.9	19.0	0.4	5.2	0.0							
		3	982	11	0.60	4.7	40.8	44.0	8.6	1.9	4.7	0.0							
2007	38	1	388	9	0.86	5.5	19.6	46.4	20.6	11.3	2.1	0.0	903	424	251	0	44	1	11
		2	1157	7	0.54	4.2	65.4	27.1	6.6	0.3	0.6	0.0							
		3	204	9	0.68	4.5	42.7	36.4	7.0	9.8	4.2	0.0							
2008	43	1	288	9	0.84	5.3	2.8	53.2	30.4	5.6	8.1	0.0	9	254	432	0	152	0	17
		2	300	10	0.84	4.9	9.0	39.2	33.8	12.0	6.0	0.0							
		3	587	8	0.77	5.5	0.0	67.3	7.1	21.3	4.3	0.0							
2009	100	1	596	9	0.64	4.6	54.9	18.4	5.1	0.8	20.8	0.0	1264	645	69	27	22	27	0
		2	950	11	0.47	4.2	70.5	16.6	9.5	0.5	2.9	0.0							
		3	632	12	0.66	4.7	47.2	35.9	2.8	5.0	9.2	0.0							
2010	53	1	5668	12	0.39	3.9	68.7	23.4	4.5	0.5	2.3	0.6	7448	2708	476	1060	864	0	16
		2	3404	11	0.41	3.7	64.6	10.2	3.5	2.2	19.5	0.0							
		3	3884	11	0.67	4.7	35.7	18.6	17.0	21.2	7.4	0.0							
Mean	58		1676	12	0.57	5.1	30.9	28.6	24.5	7.5	8.2	0.2	2141	1073	896	249	115	119	62



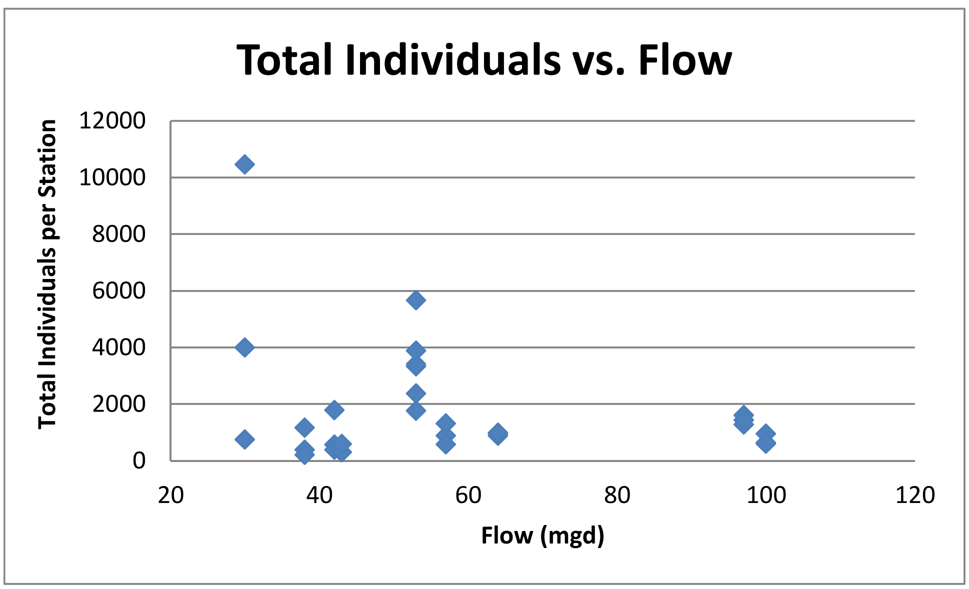
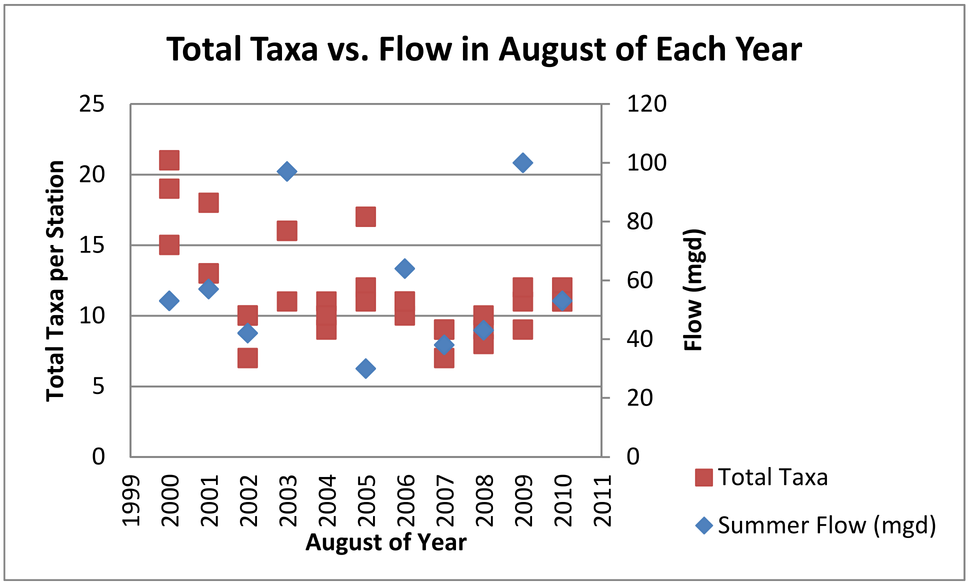


Figure 2. Total individual macroinvertebrates per station at various flow levels over time.



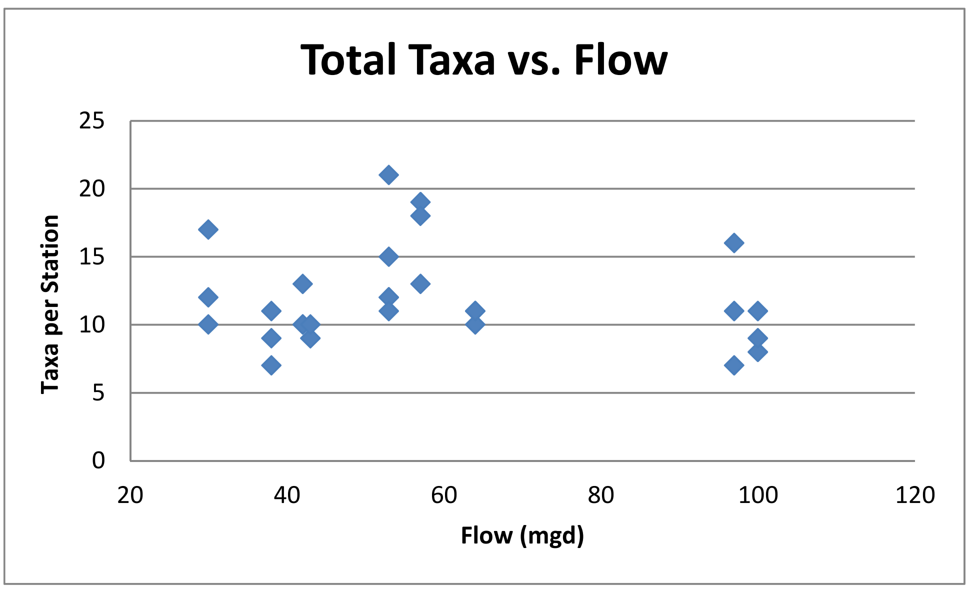
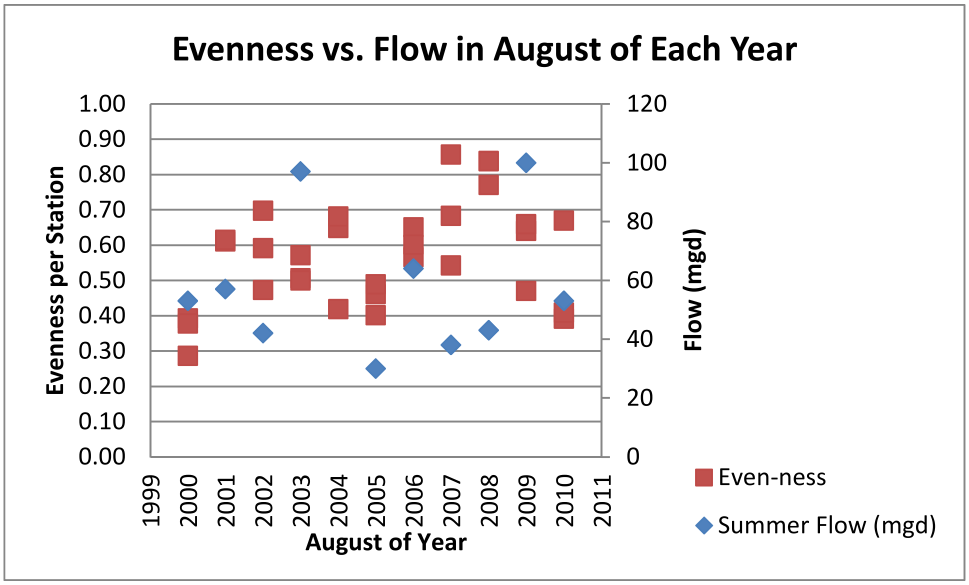


Figure 3. Total macroinvertebrate taxa per station at various flow levels over time



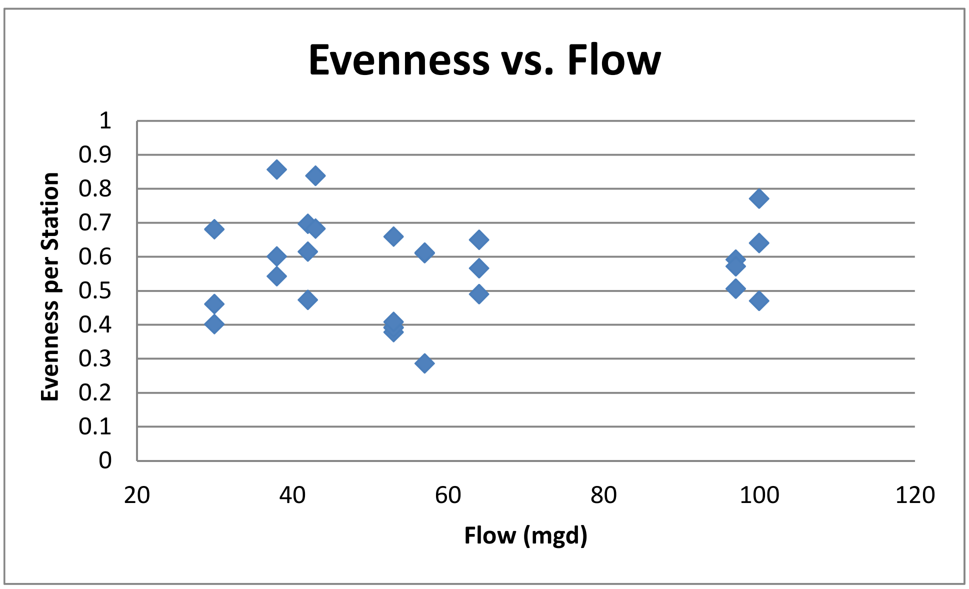
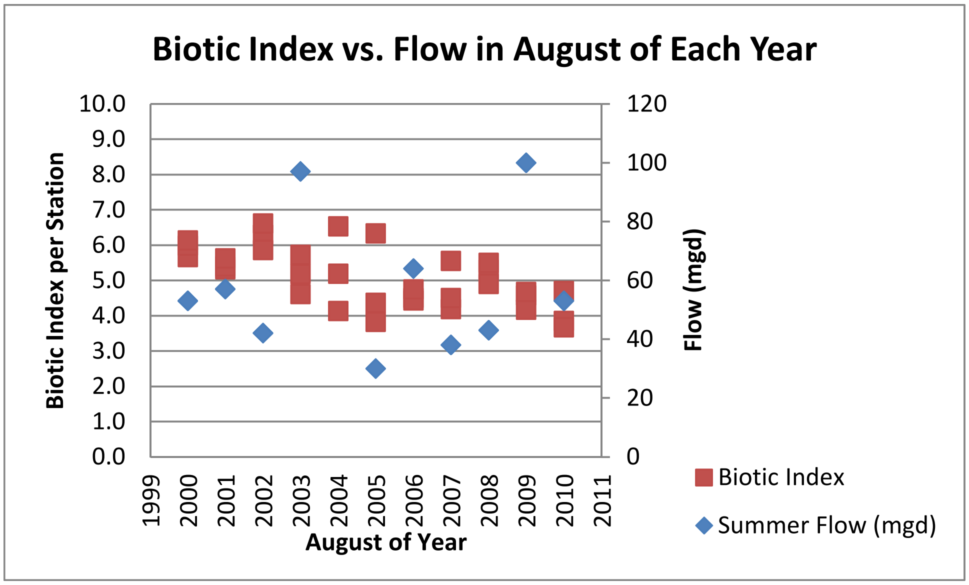


Figure 4. Evenness of macroinvertebrates per station at various flow levels over time.



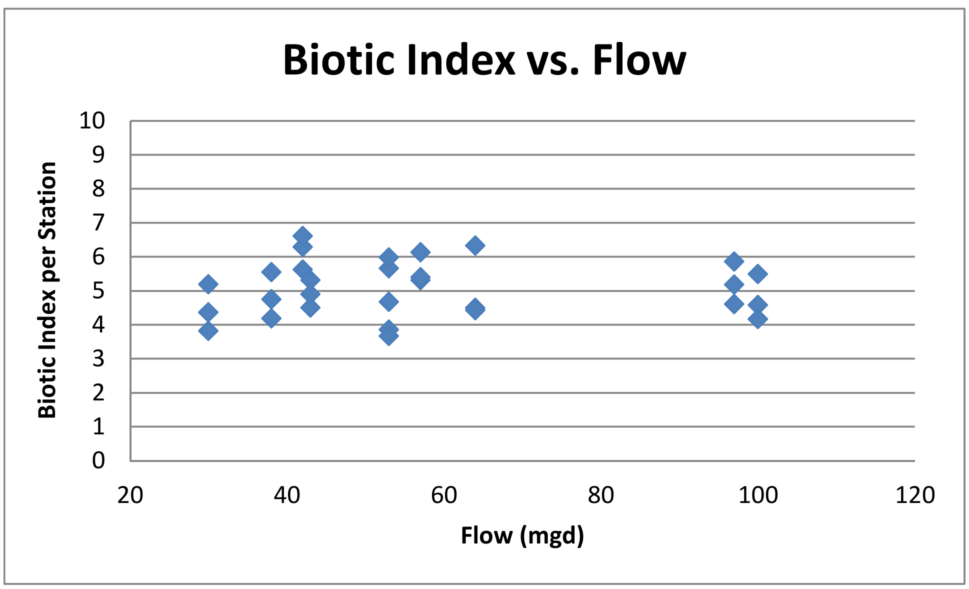
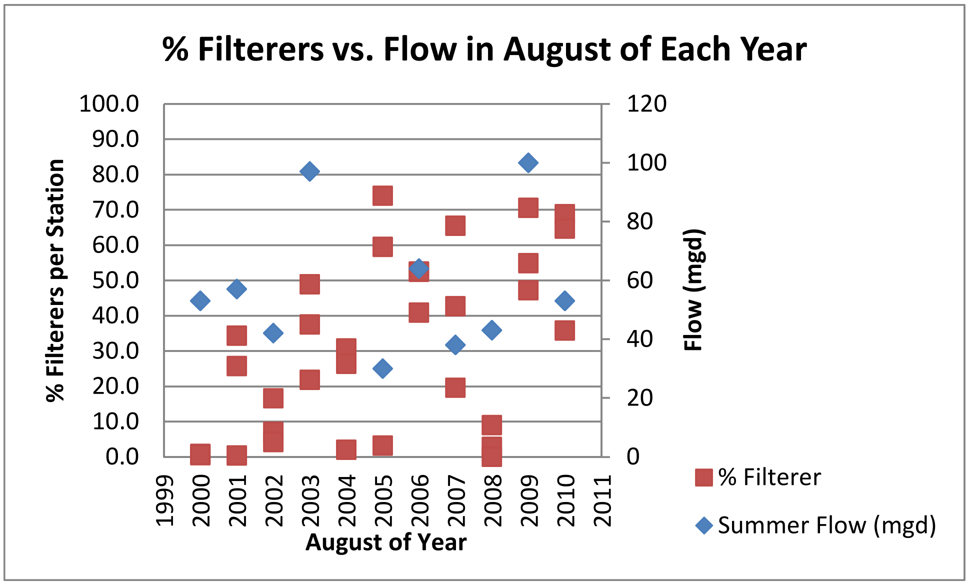


Figure 5. Biotic index for macroinvertebrates per station at various flow levels over time.



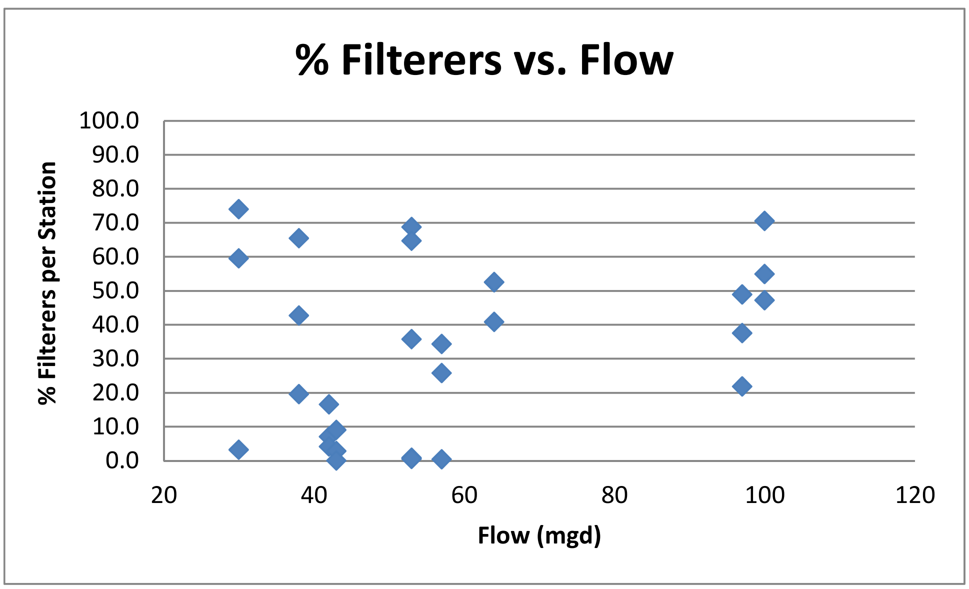
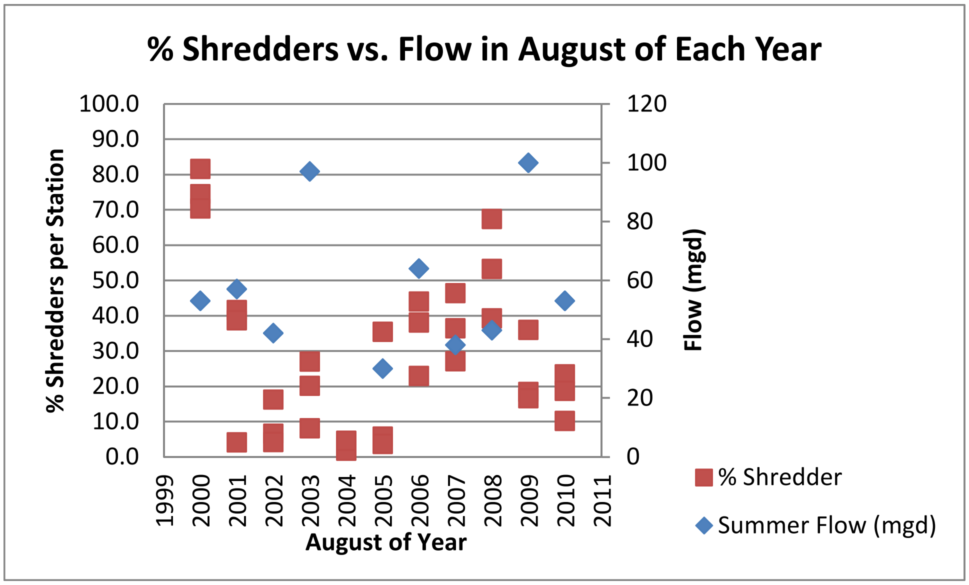


Figure 6. Percent filtering macroinvertebrates per station at various flow levels over time.



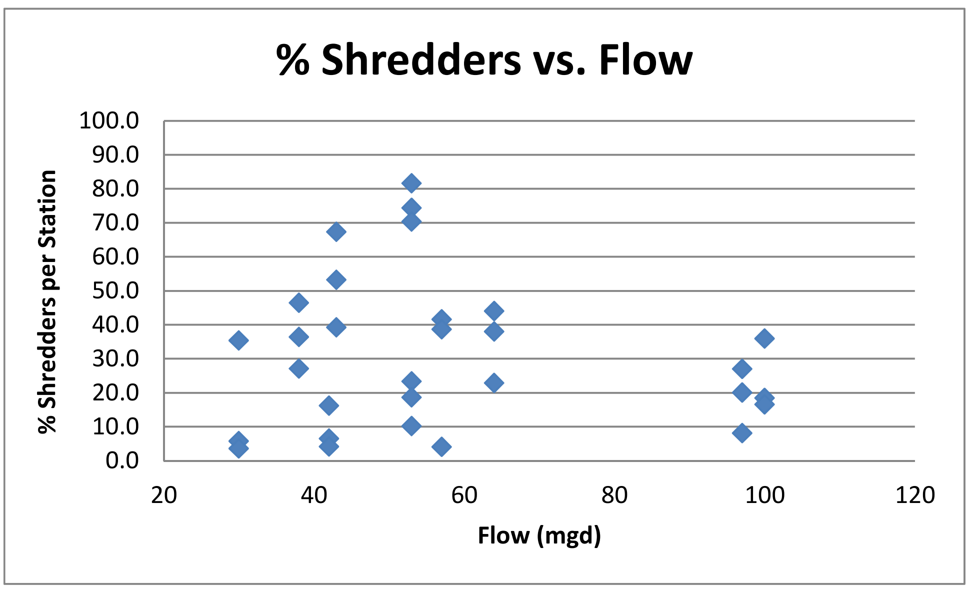
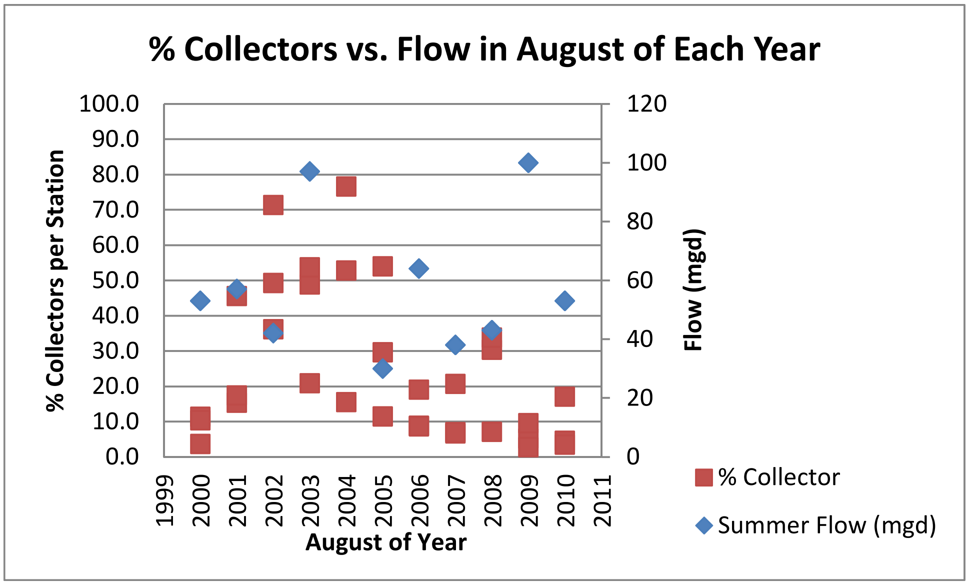


Figure 7. Percent shredding macroinvertebrates per station at various flow levels over time.



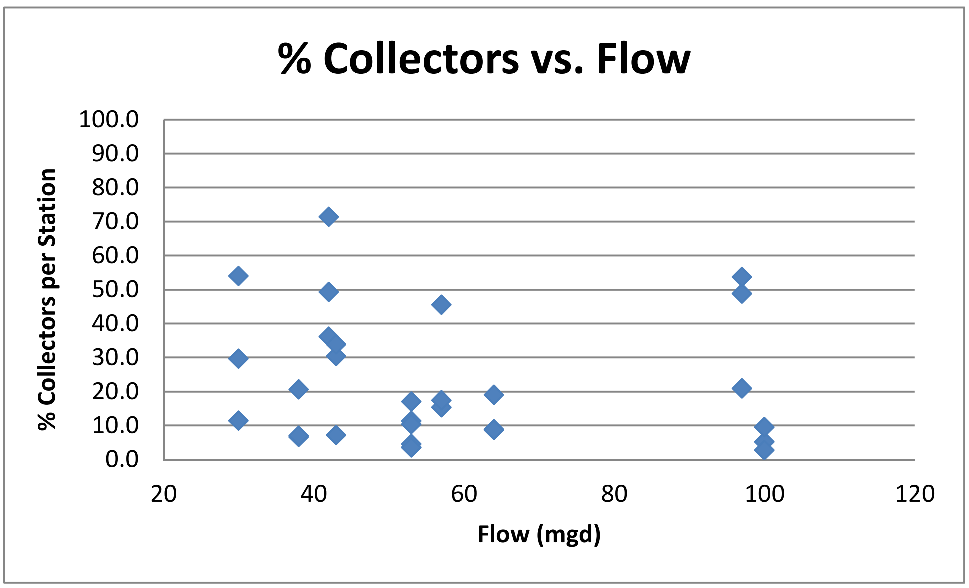
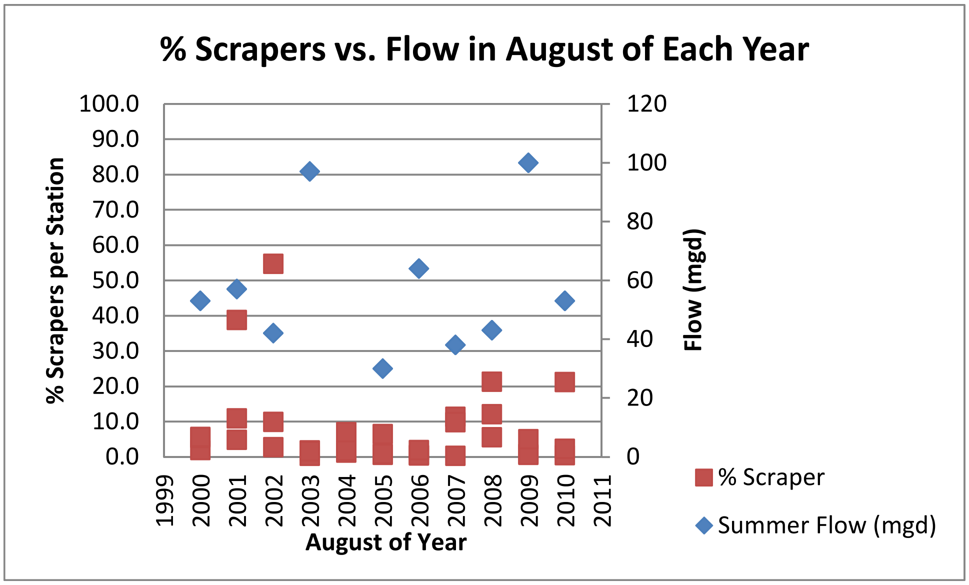


Figure 8. Percent collecting macroinvertebrates per station at various flow levels over time.



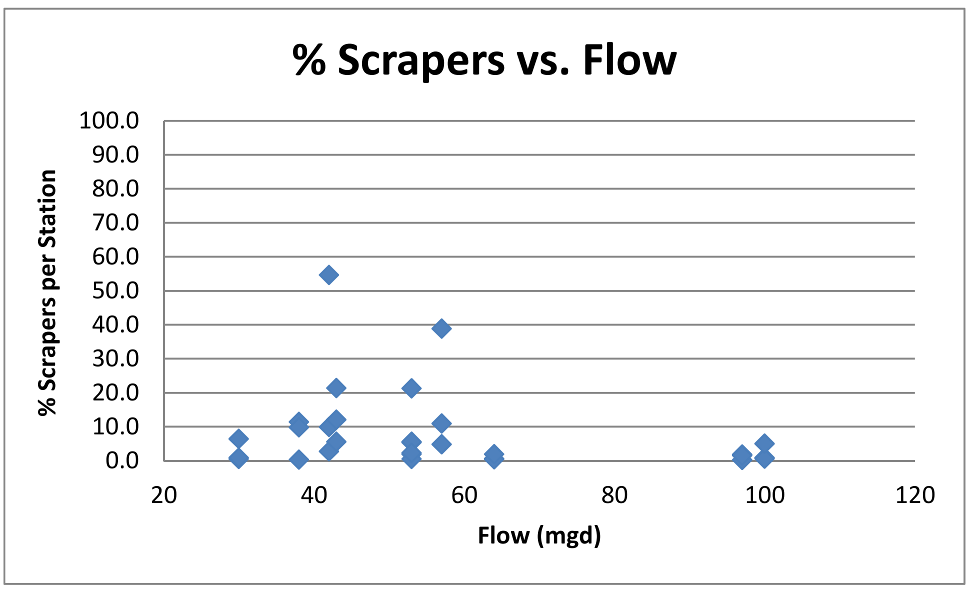
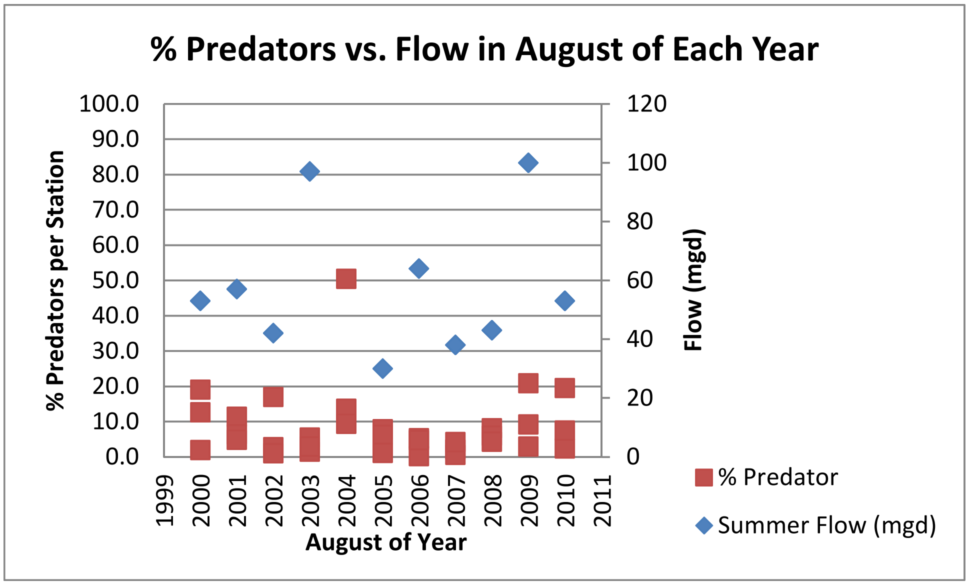


Figure 9. Percent scraping macroinvertebrates per station at various flow levels over time.



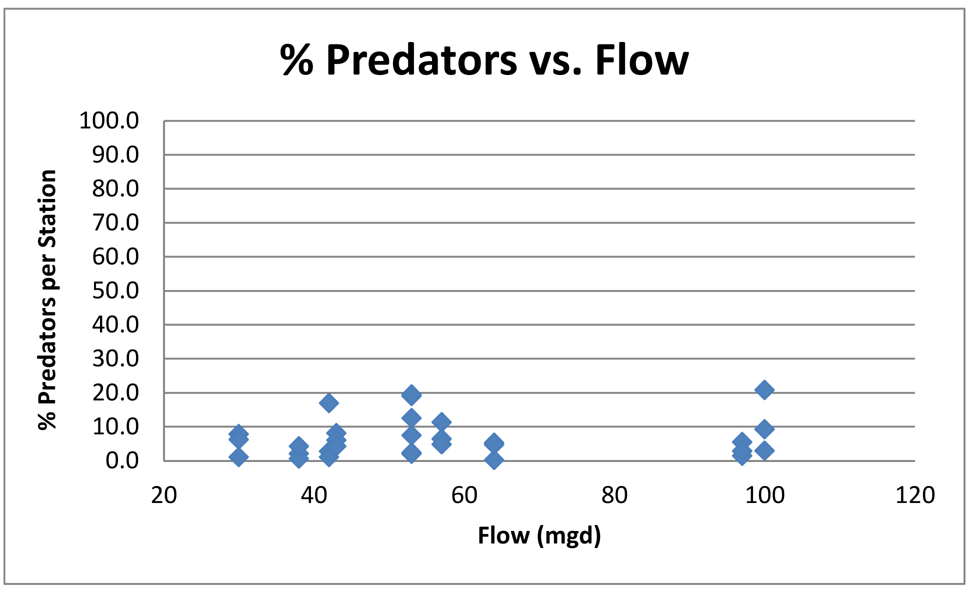
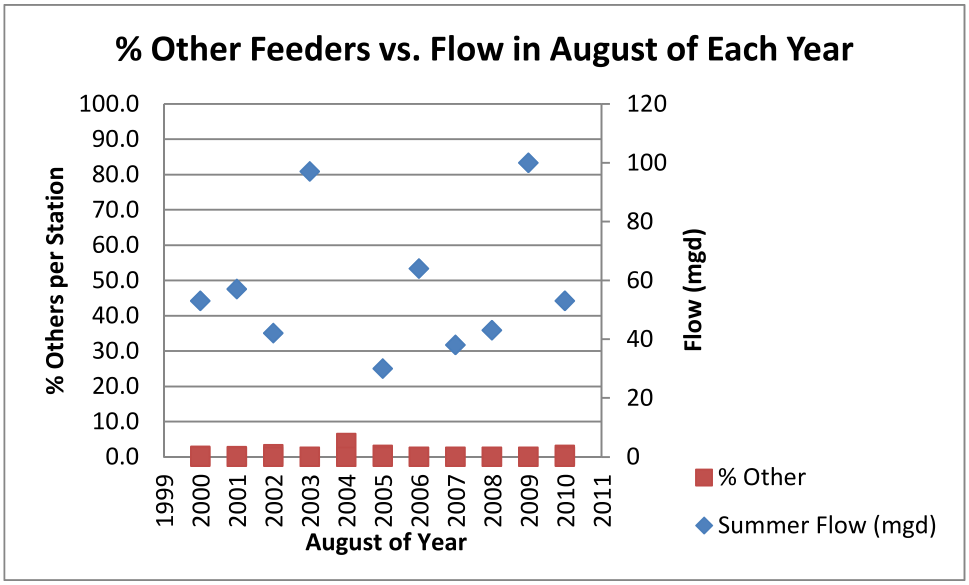


Figure 10. Percent predator macroinvertebrates per station at various flow levels over time.



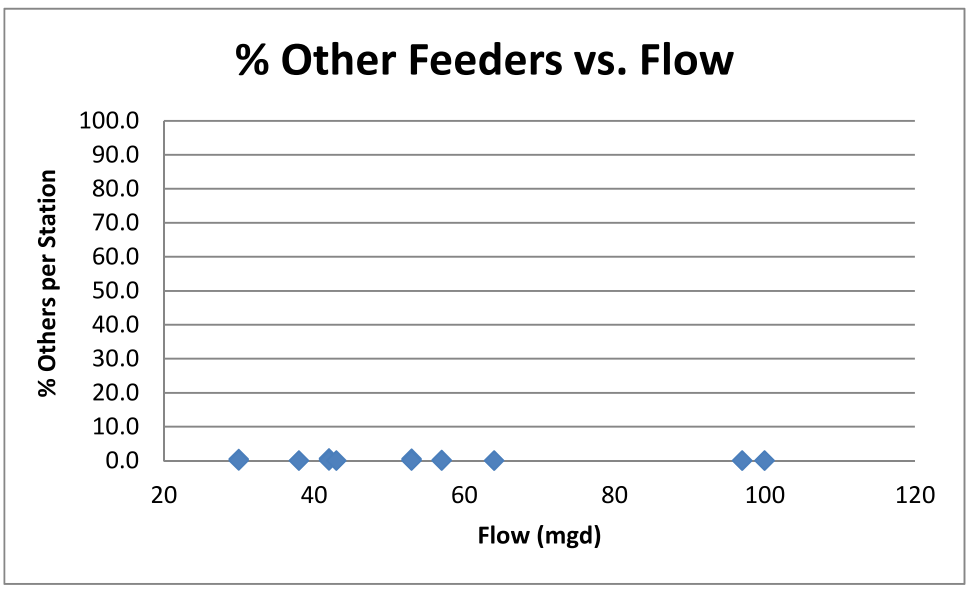
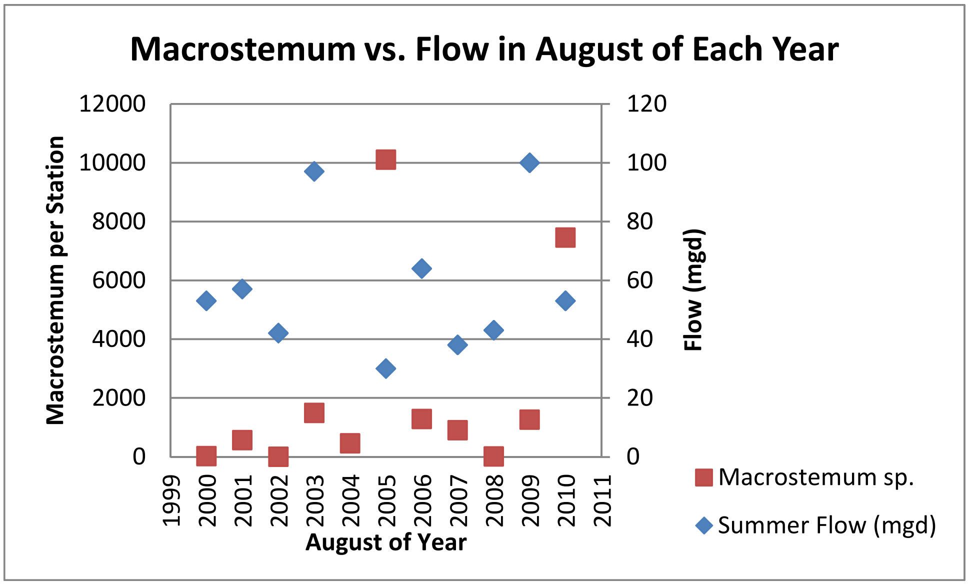


Figure 11. Percent other feeding groups of macroinvertebrates per station at various flow levels over time.



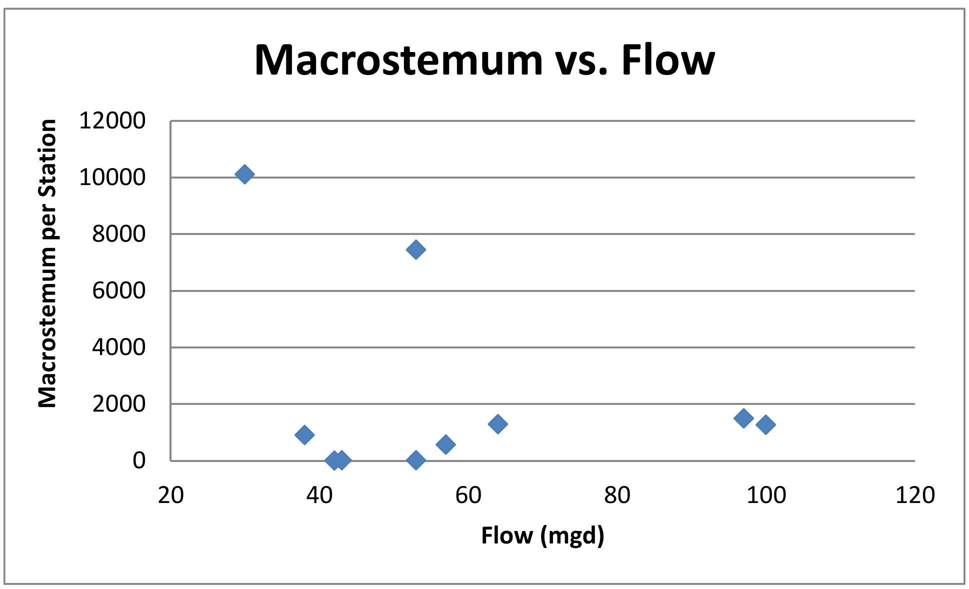
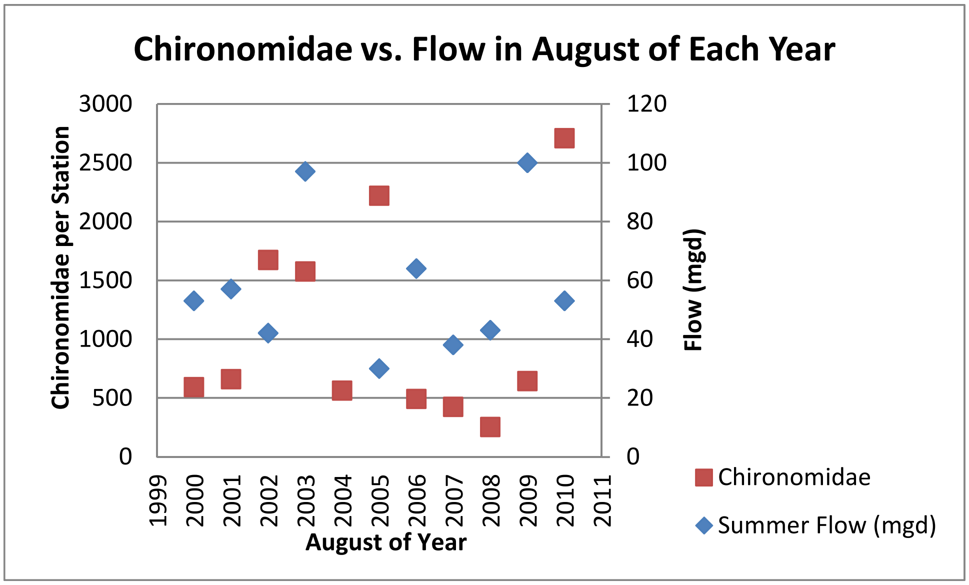


Figure 12. Number of caddisly *Macrostemum* per station at various flow levels over time.



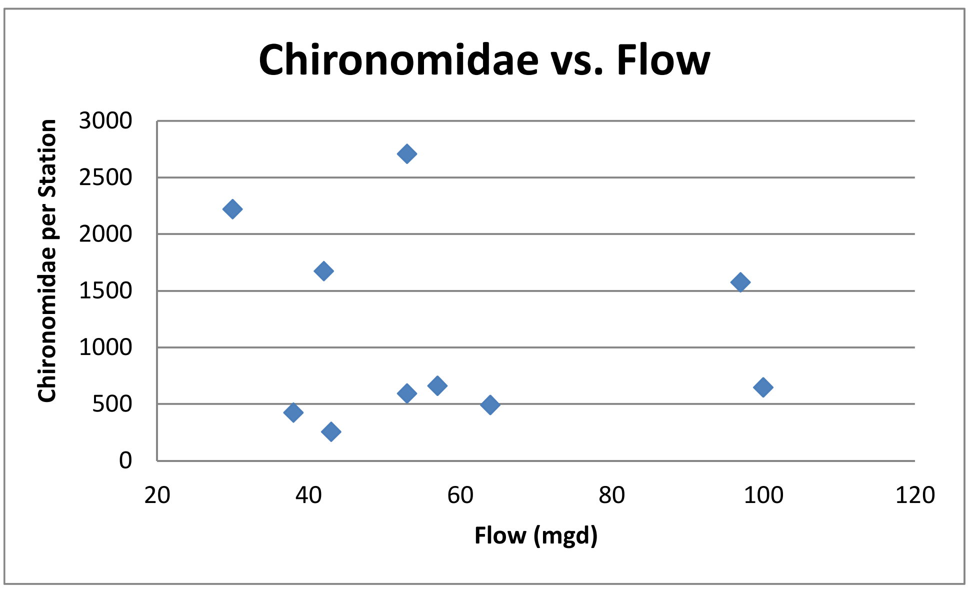
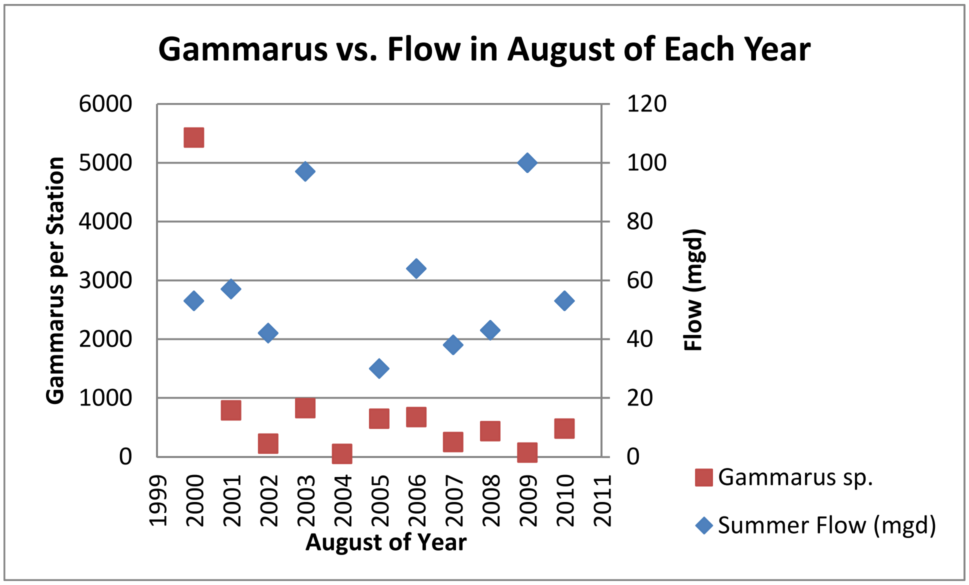


Figure 13. Number of midges (Chironomidae) per station at various flow levels over time.



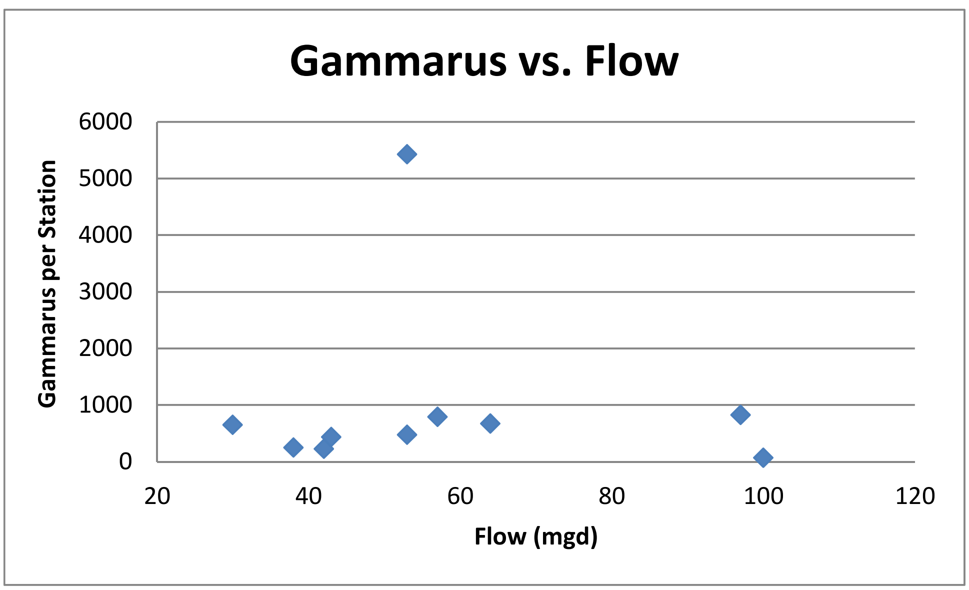
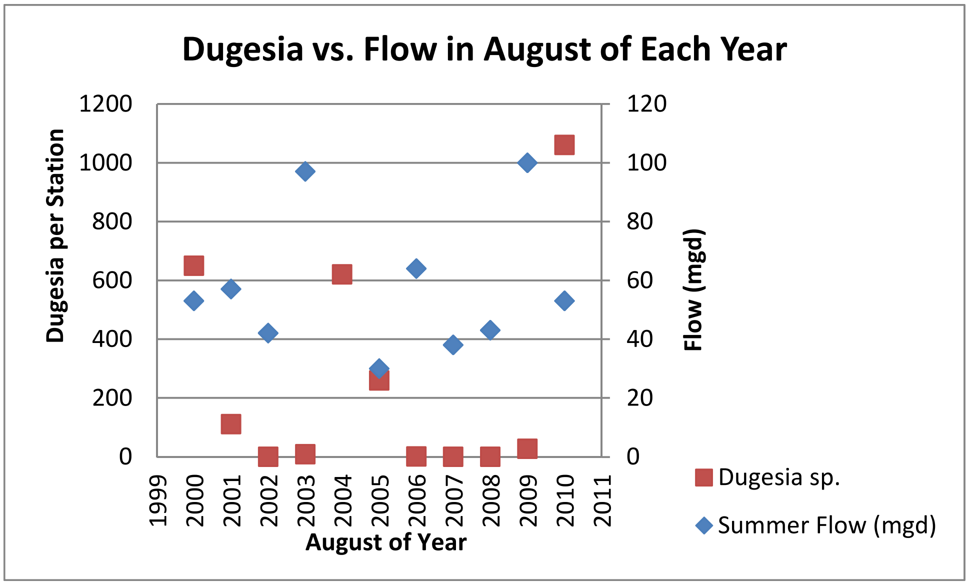


Figure 14. Number of scud *Gammarus* per station at various flow levels over time.



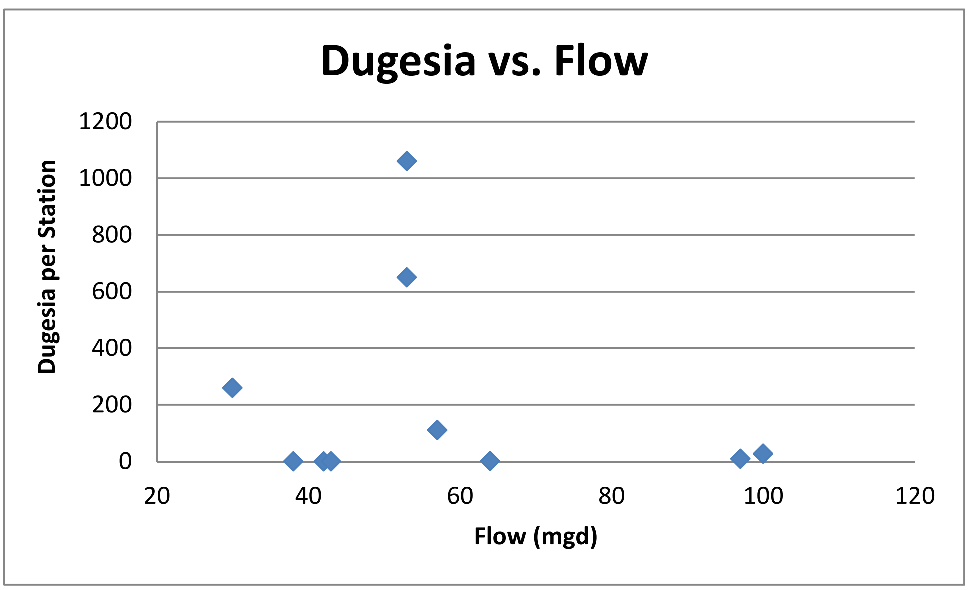
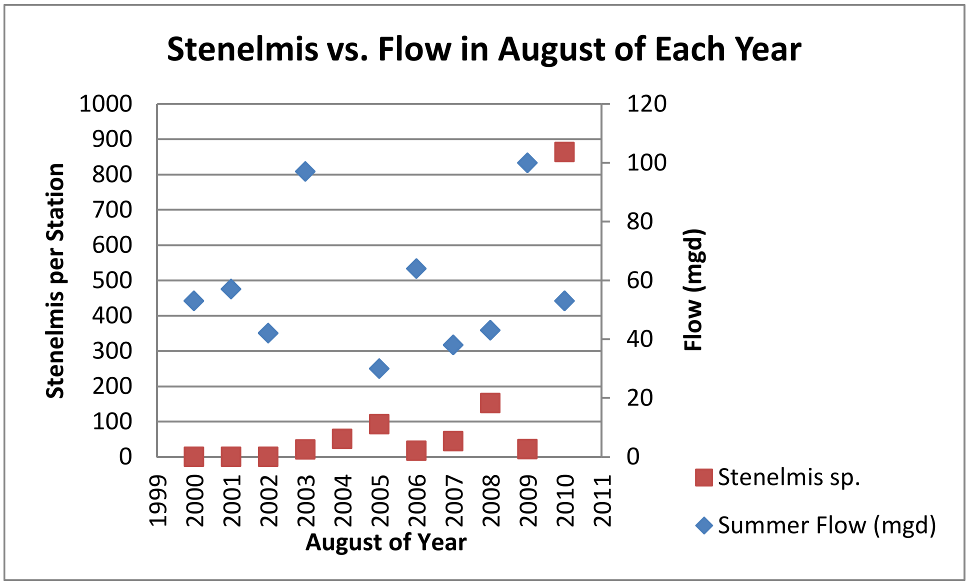


Figure 15. Number of flatworm *Dugesia* per station at various flow levels over time.



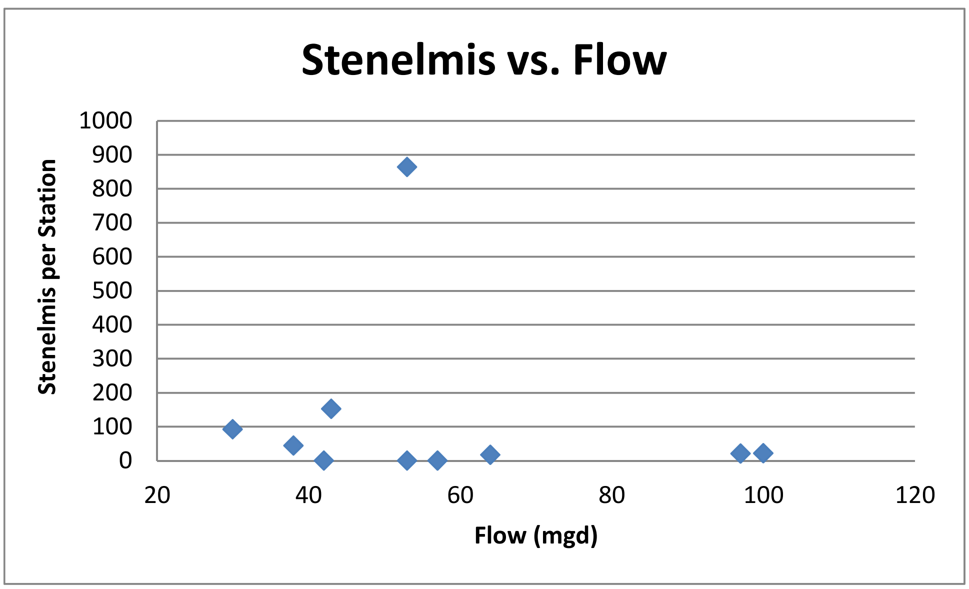
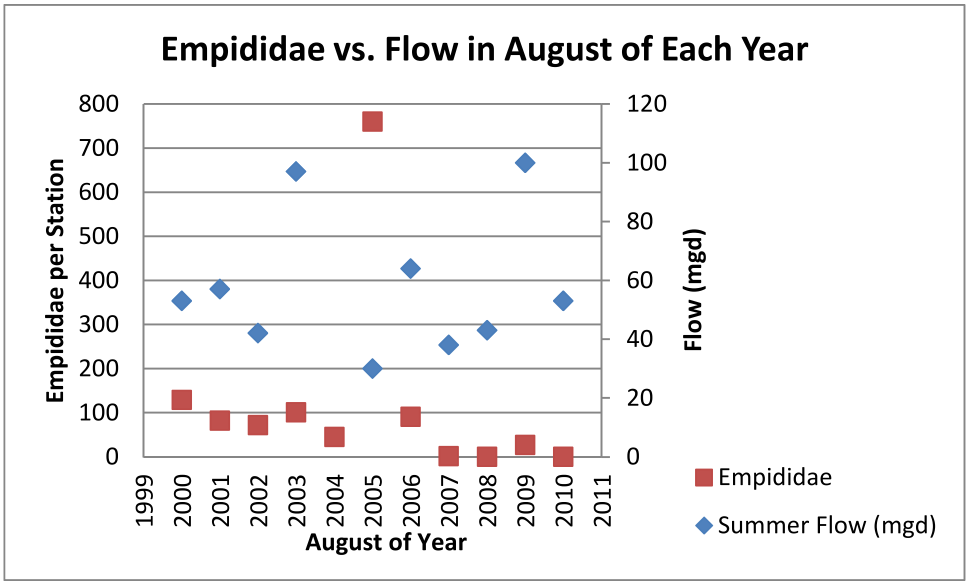


Figure 16. Number of riffle beetle *Stenelmis* per station at various flow levels over time.



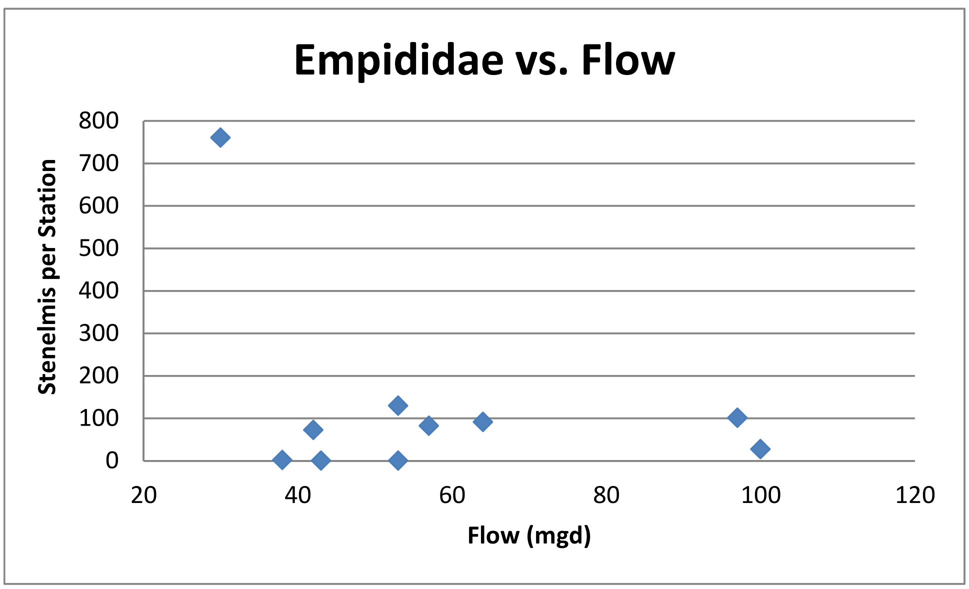
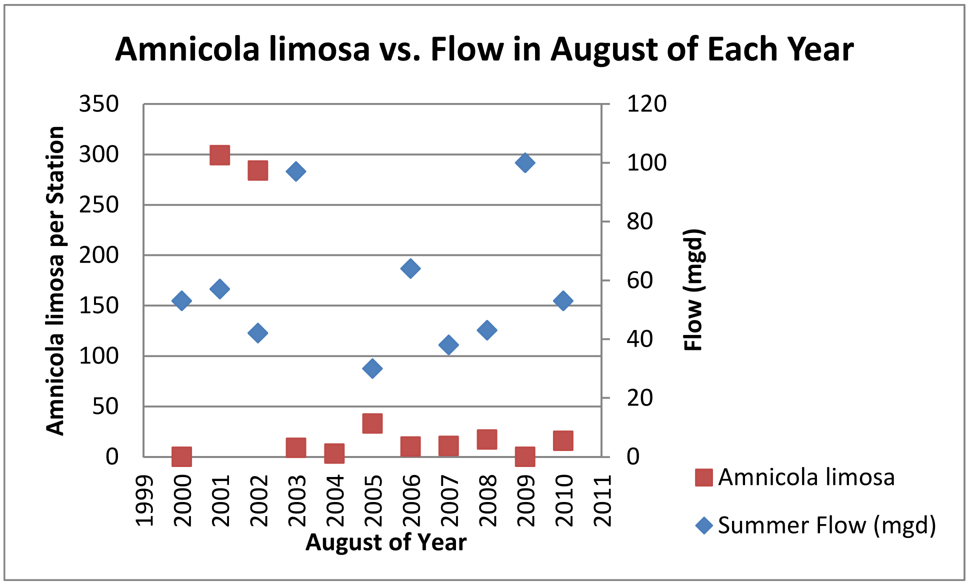


Figure 17. Number of danceflies (Empididae) per station at various flow levels over time.



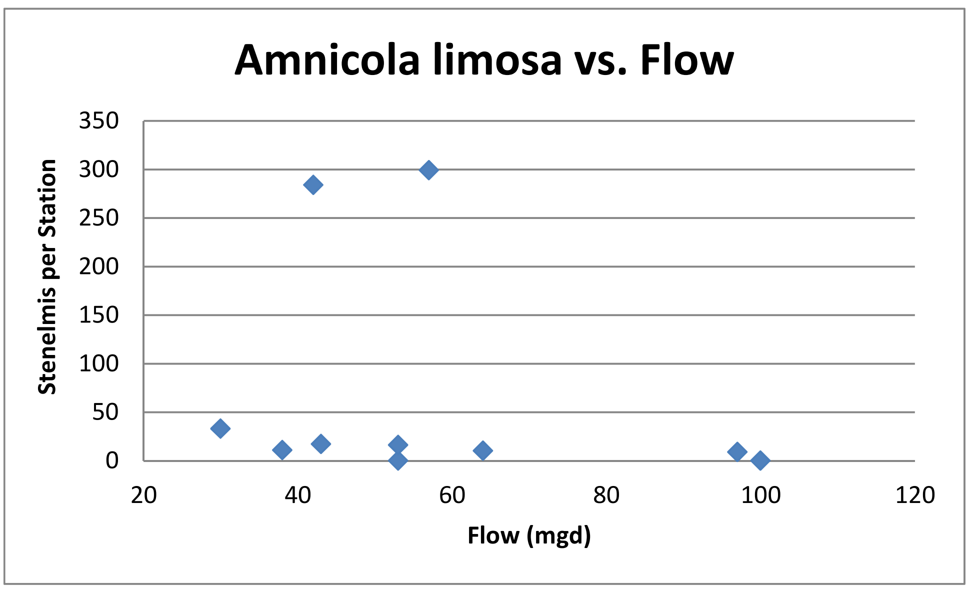


Figure 18. Number of snail *Amnicola* per station at various flow levels over time.

For the entire period of monitoring, the macroinvertebrate community is comprised mainly of filterers, shredders and collectors (82% of all individuals) among the possible feeding guilds. Scrapers, predators and other feeding types represent more minor components of the community overall, although they may be abundant in some samples. Predators and scrapers are each represented by two species each in the list of the seven most abundant taxa (Table 2), but collectively represent only 11% of all individuals collected.

Although taxa per station, evenness, and biotic index are not especially variable over time, there are major fluctuations in taxonomic and feeding groups over time that suggest instability in the system. Even the most abundant taxa for the period of monitoring are not always the most abundant taxa, with five of the seven most abundant species having at least one summer where the abundance was 0 (Table 3). Most fluctuations appear erratic, with no clear pattern over time, but the shredders appear to have declined from 2000 to 2004 then increased again through 2008 with a decline in 2009 and 2010 (Figure 7). In a near reverse of this pattern, collectors increased between 2000 and 2005, declining after that (Figure 8).

Considering the most abundant taxa, the caddisfly *Macrostemum* and midgeflies exhibit peaks in 2005 and 2010, years with below average flow (Figures 12 and 13). The scud *Gammarus* was most abundant in 2000, and has not exhibited peak abundance since, but is always present in substantial numbers (Figure 14). The flatworm Dugesia exhibited small peaks in 2000, 2004 and 2010 (Figure 15). Accurate data for flow in 2004 are not available, as the dam was largely bypassed to maintain a construction related drawdown, but summer 2004 was relatively wet, while 2000 and 2010 provided near average summers for flow. The riffle beetle *Stenelmis* peaked in abundance in 2010 (Figure 16), while danceflies (Empididae) exhibited a peak in 2005 (Figure 17). The snail *Amnicola* exhibited peak abundance in 2001 and 2002 (Figure 18).

Total invertebrate abundance in 2010 rivaled 2005 for the highest summer abundance observed in the monitoring period (Tables 1 and 2). Flows were more moderate in 2010, very close to the average for all years (Table 3), while 2005 yielded the lowest summer flow of the monitoring period. Midgeflies (Figure 13), riffle beetles (Figure 16) and flatworms (Figure 15) were more abundant than ever observed for the combined Stations 1-3 data, while caddisflies, particularly *Macrostemum* (Figure 12), were present at the second highest summer abundance measured to date.

As with most recent summers, the summer of 2010 was more like a pre-operation period, with only one day per week operation of the water withdrawal and treatment system during business hours, totaling about 6 to 9% of the legally allowed daily withdrawal. A couple of exceptions occurred, including an approximately two week period in early April and a ten day period in early July where the facility was operated daily at around 25% of the allowed daily withdrawal. Since water supply operations have been resumed at Lake Whitney, there have been no significant periods of coinciding minimum flows and maximum withdrawal.

Discussion

The influence of Lake Whitney on the lower Mill River at Stations 1-3 is apparent in the data. The production of algae and conversion of coarse particulate matter favors the filterer and collector feeding guilds, and to some extent the shredders, although shredders tend to do well anywhere that leaves enter the stream system. Scrapers would be expected to be more abundant in a stream without an impoundment just upstream, as available nutrients for periphyton growths are limited by the impoundment. Predators are typically not a dominant component, as they depend on other more plentiful invertebrates as a food supply. The observed community is therefore consistent with expectations based on the presence of an impoundment and related ecological processes, as discussed in previous annual reports and described in publications such as Hynes (1970) and Allan (1995).

Water quality in the Mill River is not ideal, given considerable upstream development and inputs of a variety of contaminants, but Lake Whitney moderates possible effects, and key water quality features such as oxygen and pH are usually well within an acceptable range for aquatic life at Stations 1-3. Species with extremely high tolerance for pollution are absent, as are species with very little tolerance, maintaining the biotic index in the moderate range for these stations on all dates.

Flow is variable from Lake Whitney, and key features such as water velocity, wetted channel width, and water depth vary daily to weekly at Stations 1-3. The dam moderates flow influence to a minor extent, reducing peak flows with some limited storage and prolonging the period of elevated flow until the lake returns to its dry weather level, but fluctuations are obvious in the flow record. The use of an average flow for ten weeks prior to sampling does not capture all variability, but does appear to represent overall summer conditions fairly well. With a range of 30 to 100 mgd for a decade of monitoring, the corresponding invertebrate data should exhibit correlation to mean flow if it is a dominant influence on a summer seasonal basis. The absence of such correlation does not mean that aquatic invertebrates do not respond to changes in flow, but it does indicate that low flows are not clearly deleterious and that other influences have a major role in shaping the community. Detecting the influence of a relatively small water withdrawal within the context of the overall variation in flows remains a challenge.

It has been suggested by outside reviewers that analysis of alternative measures of flow might prove insightful, and this may be worth pursuing. Consideration of available data and potential relationships suggests that it may be fruitful to examine macroinvertebrate measures in relation to the maximum and minimum flows with seven day duration and the standard deviation of flow to better reflect variability over the ten week pre-sampling period. It may also be useful to evaluate relationships between macroinvertebrate community features and flow features ten to twenty weeks before sampling (roughly the spring period), although analysis of flow farther in time from the sampling date does not appear useful in this system. This expansion of analysis will occur in 2011 and will include all years for which data are available. If a lack of relationships between flow features and the macroinvertebrate community continues to be demonstrated, discussion of program continuation will be warranted.

It has also been suggested by outside reviewers that transformations of macroinvertebrate abundance data might yield better correlations, Based on the recommendations of Rosenberg and Resh (1993), the total individuals and the feeding group totals are appropriate for a transformation, and using the square root of each would have the greatest probability of enhancing analytical insights. While years of data examination for this system does not suggest that the results will be appreciably different, it is a simple matter to make those transformations and they can be attempted in 2011 with all available data.

The erratic pattern of taxonomic abundance for many individual taxa suggests the potential for high flows to wash out much of the community and allow it to reset itself through immigration and reproduction, with opportunistic taxa taking advantage of available resources. High flows appear more influential than low flows at Stations 1-3 in the lower Mill River. The predator species may shape the community to some extent, and there is some potential for water quality to alter the invertebrate community through elevated contaminant loads, low oxygen, or extreme pH on a sporadic basis, but these do not appear to be major continuous influences.

The invertebrate community undoubtedly responds to changes in flow, but the influence of what are so far minor withdrawals for water supply is not apparent when superimposed on the variable background flows through Lake Whitney. The greatest concern lies with a period of extended maximum withdrawal to meet water supply needs during a period of prolonged low background flows. The SCCRWA's Management Plan is designed to minimize this combination of circumstances, which have yet to occur. Given the variability inherent in the data, it is likely to take a major shift in the macroinvertebrate community to detect any impact from extended full operation at low flows.

The ability of the benthic macroinvertebrate community to recover from disturbance is encouraging. Despite major fluctuations in abundance in response to a range of factors, a thriving and fairly diverse aquatic macroinvertebrate community exists downstream of Lake Whitney and upstream of saltwater influence. Recovery times for the assessed invertebrate community features is generally in line with timeframes suggested by Ward (1992) for post-disturbance recovery, and are typically between one and two years. This could explain the every other year periodicity of some observed fluctuations in community features, although those fluctuations may not be related to flow. If there was any impact from withdrawal during a period of low flow, it should be temporary; the community at Stations 1-3 has demonstrated its recovery ability in response to multiple stresses.

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