BIOLOGICAL MONITORING OF BOLIN CREEK CARRBORO, NORTH CAROLINA

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INTRODUCTION [Note: this section largely repeated from early reports.]
Water quality in Bolin Creek was evaluated in March 2010 by sampling benthic macroinvertebrates at 5 sites. Benthic macroinvertebrates, especially aquatic insects, are associated with the substrates of streams, rivers and lakes. This group of aquatic species is especially useful as an indicator of biological integrity.

There are several reasons for using biological surveys in monitoring water quality. Conventional water quality surveys do not integrate fluctuations in water quality between sampling periods. Therefore, short-term critical events may often be missed. The biota, especially benthic macroinvertebrates, reflect both long and short-term conditions. Since many species in a macroinvertebrate community have life cycles of a year or more, the effects of a short-term pollutant will generally not be overcome until the following generation appears.

Macroinvertebrates are useful biological monitors because they are found in all aquatic environments, they are less mobile than many other groups of organisms, and they are small enough to be easily collectable. Moreover, chemical and physical analysis for a complex mixture of pollutants is generally not feasible. The aquatic biota, however, show responses to a wide array of potential pollutants, including those with synergistic or antagonistic effects. Additionally, the use of benthic macroinvertebrates has been shown to be a cost-effective monitoring tool (Lenat 1988). The sedentary nature of the benthos ensures that exposure to a pollutant or stress reliably denotes local conditions, and allows for comparison of sites that are in close proximity (Engel and Voshell 2002).

Analysis of stream life is one way to detect water quality problems (Rosenberg et al 1986). Different kinds of stress will often produce different benthic macroinvertebrate communities. For example, the species associated with organic loading (and low dissolved oxygen) are well known. More recent studies have begun to identify the biological impacts of sedimentation and toxic stress. Identification at, or near, the species level is desirable for many groups of organisms (Resh and Unzicker 1975), and recent work by Lenat and Resh (2001) has shown the benefits of precise taxonomy for both pollution monitoring and conservation biology.

Organisms cannot always be identified at the species level, thus counts of the number of kinds of stream organisms often include identifications at higher levels (genus, family, etc.). Each different critter in these situations is called a “taxon” and the plural form of this word is “taxa”. Thus “taxa richness” is a count of the number of different types of organisms.

BOLIN CREEK CATCHMENT [Note: this section largely repeated from early reports.]
The Carrboro portion of Bolin Creek lies in the Carolina Slate Belt, resulting in the narrow valleys and rocky substrates associated with this geologic zone. Slate belt streams tend suffer extreme low flows during droughts, as the clay soils have poor groundwater storage (see USGS flow data below). An OWASA (Orange Water and Sewer Authority) sewer easement follows Bolin Creeks for much of its length. Bolin Creek is classified as C NSW (nutrient sensitive waters) upstream of East Franklin Street (US 15-501 Business).

The headwaters of Bolin Creek are located northwest of the intersection of Homestead Road (SR 1777) and Old NC 86 (SR 1109), north of Carrboro. Bolin Creek is joined by the following named tributaries, in order from upstream to downstream: Jones Creek, Jolly Branch, Tanbark Branch, and Battle Branch. Bolin Creek is dammed several times in its headwaters, most notably to form Lake Hogan, a 12-acre impoundment located just downstream of Old NC 86. Bolin Creek begins in a fairly undeveloped area and drains progressively more urban and developed areas in Carrboro and Chapel Hill as it flows towards its confluence with Booker Creek.

METHODS [Note: this section largely repeated from early reports.]
All collection methods are derived from techniques used by the NC Division of Water Quality (Lenat 1988). These methods have been in use by North Carolina since 1982, and have been thoroughly tested for accuracy and repeatability. More details can be found at their web site: http://h2o.enr.state.nc.us/esb/BAU.html. Two of DWQ's collection methods have been used for the Bolin Creek study: intensive "Standard Qualitative" collections and more rapid" EPT" collections. These two methods are briefly described below.

Standard Qualitative Method – Overview [Bolin Creeks sites 1-4]

The standard qualitative technique includes 10 separate samples and is designed to sample all habitats and all sizes of invertebrates. This collection technique consists of two kick net samples (kicks), three sweep-net samples (sweeps), one leaf-pack sample, two fine-mesh rock and/or log wash samples, one sand sample, and visual collections. Invertebrates are separated from the rest of the sample in the field ("picked") using forceps and white plastic trays, and preserved in glass vials containing 95% ethanol.

Organisms are picked roughly in proportion to their abundance, but no attempt is made to remove all organisms. If an organism can be reliably identified as a single taxon in the field, then no more than 10 individuals need to be collected. Some organisms are not picked, even if found in the samples, because abundance is difficult to quantify or because they are most often found on the water surface or on the banks and are not truly benthic.

Organisms are classified as Abundant if 10 or more specimens are collected, Common if 3-9 specimens are collected, and Rare if 1-2 specimens are collected.

EPT Method – Overview – [Morgan Creek reference site]

The EPT method is a more rapid collection technique, limited to 4 samples: 1 kick, 1 bank sweep, 1 leaf pack and visuals. Furthermore, collections are limited to the most intolerant "EPT" groups: Ephemeroptera, Plecoptera and Trichoptera. Note that the EPT method is a subset of the standard qualitative method described above.

Assigning Bioclassifications - Overview

The ultimate result of a benthos sample is a bioclassification. Bioclassifications used by NC DWQ are Excellent, Good, Good/Fair, Fair or Poor for standard qualitative samples; they are based on both EPT taxa richness and the biotic index values. A score (1-5) is assigned for both EPT taxa richness and the NC biotic index. The final site classification is based on the average of these two scores. In some situations, adjustments must be made for stream size or the season, but such adjustments were not required for this study.

EPT Criteria

The simplest method of data analysis is the tabulation of species richness and species richness is the most direct measure of biological diversity. The association of good water quality with high species (or taxa) richness has been thoroughly documented. Increasing levels of pollution gradually eliminate the more sensitive species, leading to lower and lower species richness.

The relationship of total taxa richness to water quality is nonlinear, as this metric may increase with mild enrichment. Taxa richness for the most intolerant groups (Ephemeroptera + Plecoptera + Trichoptera, EPT S) is more reliable, but must be adjusted for ecoregion. Piedmont criteria were used for the Bolin Creek study.

Biotic Index Criteria

To supplement EPT taxa richness criteria, the North Carolina Biotic Index (NCBI) was derived as another (independent) method of bioclassification to support water quality assessments (Lenat 1993). This index is similar to the Hilsenhoff Biotic Index (Hilsenhoff, 1987) with tolerance values derived from the NC database. Biotic indices are based on a 0-10 scale, where 0 represents the best water quality and 10 represents the worst. Abundance values used

in the biotic index calculation are 10 for Abundant taxa, 3 for Common taxa, and 1 for Rare taxa.

Derivation of Final Bioclassification for Standard Qualitative Samples
For most mountain, piedmont and coastal plain (Coastal A) streams, equal weight should be given to both the NC Biotic Index value and EPT taxa richness value in assigning bioclassifications. For these metrics, bioclassifications are assigned from the following scores:

Excellent: 5 Good: 4 Good-Fair: 3 Fair: 2 Poor: 1

"Borderline" values are assigned near half-step values (1.4. 2.6, etc.) and are defined as boundary EPT values $\pm$1 (except coastal plain), and boundary biotic index values $\pm$0.05. The two ratings are then averaged together, and rounded up or down to produce the final classification. When the EPT and BI score differ by exactly one unit, the EPT abundance value is used to decide on rounding up or rounding down.

SAMPLING SITES

The Carrboro section of Bolin Creek has been sampled yearly since 2000. Sampled were collected four times a year in 2000 and 2001 to evaluate normal season trends, but only once per year (August or September) from 2003-2007. These samples were collected and identified by Ecological Consultants (Chapel Hill, NC), with assistance from Pennington and Associates (Kentucky). These studies established 4 sites along the Carrboro portion of Bolin Creek, which have been repeated in December 2008 (Lenat Consulting Services, Inc.).

Sites are numbered from most upstream (Site 1) to most downstream (Site 4). Samples were collected (with assistance from Randy Dodd, City of Carrboro Planning) on December 2-3, 2008. More detailed site descriptions (with photos) are presented in Appendix 1.

Table 1. Site characteristics, Bolin Creek and Morgan Creek, March 2010.

	1	2	3	4
Substrate (%)				
Boulder	15	20	50	55
Rubble	30	30	25	30
Gravel	30	20	15	25
Sand	25	25	10	Trace
Silt	-	5	-	Trace
Width (m)	5	6	8	8

FLOW DATA

The fauna of Bolin Creek has been frequently affected by droughts, with sections of the stream becoming entirely dry during severe droughts. Changes due to water quality problems cannot be discerned without taking into consideration this natural stress. The data below is taken from the USGS web site, using data from 1999 to the September 2009. The USGS measures daily flow at Morgan Creek and Cane Creek; both streams are in Orange county and both are similar to Bolin Creek. Low flows (less than 0.5 cfs) are highlighted in yellow; severe low flows (less than 0.1 cfs) are highlighted in red.

Mean Monthy flow (cfs) in streams most similar to Bolin Creek, 1999-2008.

Morgan Creek nr White Cross

Year	Month: 1	2	3	4	5	6	7	8	9	10	11	12
1999	13	4	5	10	0.9	0.5	0.4	0.09	40	8	7	4
2000	11	15	7	11	3	4	12	4	3*	1.3	1.7	2.2*
2001	2.4	6	17*	12	3	5*	1.1	0.6	0.2	0.1	0.1	0.3
2002	7	4	4	2	0.7	0.03	0.04	0.01	0.04*	6	4	15
2003	6	20	32	39	11	7	6	3	2*	2	2	5
2004	2	8	5	4	3	0.4	0.7	5	7*	2	4	3
2005	7	7	15	6	2	0.7	0.3	0.2*	0.01	0.2	0.6	7
2006	3	2	2	2	0.7	1.7	5	0.08*	0.5	1.9	16	6
2007	13	7	9	12	1.8	0.6	0.2	0.002	0.000*	0.008	0.003	0.2
2008	0.4	1.3	9	6	2	0.4	1.6	4	15	0.3	1.4	9*
2009	5	3	19	6	3	4	0.4*	0.2	0.05			

Cane Creek nr Orange Grove

Year	Month: 1	2	3	4	5	6	7	8	9	10	11	12
1999	14	4	3	6	1.1	0.5	0.2	0.09	18	4	6	4
2000	9	14	8	12	2	8	14	3	5*	0.9	0.8	5*
2001	3	9	21	11	1.2	2*	0.4	0.1	0.1	0.1	0.06	0.2
2002	5	2	3	1.1	0.1	0.03	0.04	0.04	0.4*	13	9	20
2003	6	20	34	37	17	8	5	4	1.3*	0.7	0.7	6
2004	2	8	5	4	0.9	0.4	1.9	10	9*	1.8	4	4
2005	7	6	15	6	2	0.8	0.3	0.3*	0.000	0.03	0.5	8
2006	3	2	1.2	2	1.0	7	4	0.1	0.2	1.2	19	6
2007	11	8	12	12	0.9	0.2	0.03	0.00	0.00*	0.005	0.000	0.08
2008	0.3	1.2	7	9	3	0.2	0.5	0.3	4	0.3	0.7	8*
2009	4	1.7	18	5	0.9	8	0.2*	0.08	0.03			

*Month for prior Bolin Creek samples

PRIOR BIOLOGICAL DATA

Benthic macroinvertebrates have been collected in Orange County for over 30 years. One of the first publications was a list of species found in Cane Creek, prior to the existence of the Cane Creek Reservoir (Lenat 1983). The NC Division of Water Quality has multiple collections from Morgan Creek and Bolin Creek, including standard qualitative and EPT samples. EPT samples use a shorter 4-sample method (vs. 10 samples for the standard qualitative), and are limited to the Ephemeroptera, Plecoptera, and Trichoptera.

The following data are taken from the Cape Fear River basin report (NC DWQ 2003):

NC DWQ data, 1985-2003. Standard Qualitative and EPT samples.

	Date	Total S	EPT S	BI	BIEPT	Bioclass
Bolin Cr at SR 1777	7/01	87	24	5.96	5.18	Good-Fair
	2/01	82	17	6.40	5.23	Not Rated
	4/00	-	26	-	5.05	Good
	3/98	-	23	-	4.22	Good
	4/93	-	24	-	4.46	Good
Bolin Cr at Village Rd	3/02	40	7	7.00	6.42	Fair (follows Drought)
	7/01	52	9	6.61	6.64	Fair
	2/01	54	6	7.00	5.82	Poor
	2/98	59	26	5.10	3.93	Good
	4/93	-	24	-	3.89	Good-Fair
Bolin Cr at E Franklin St	7/01	41	4	6.87	6.95	Poor
	3/01	53	4	7.05	5.94	Poor
	3/98	37	13	6.28	6.00	Fair
	2/98	-	4	-	6.65	Poor
	2/93	32	8	6.52	5.34	Fair
	4/86	89	28	6.08	4.34	Good-Fair
Morgan Cr at NC 54	03/09	-	26	-	4.36	Good
	03/08	-	12	-	3.55	Not Rated (Drought)
	06/04	-	18	-	4.43	Good-Fair
	10/03	-	22	-	4.22	Good
	7/03	-	20	-	4.61	Good-Fair
	5/03	-	16	-	4.95	Good-Fair
	3/03	-	12	-	3.07	Not Rated (Drought)
	1/03	-	8	-	3.42	Not Rated (Drought)
	9/02	-	2	-	4.10	Not Rated (Drought)
	4/00	-	36	-	4.21	Excellent
	2/98	80	33	4.37	3.28	Excellent
	10/96	64	22	5.03	4.12	Good
	7/93	61	22	4.92	3.48	Good
	2/93	90	36	4.48	3.23	Excellent
	4/85	109	32	5.71	4.69	Good

NC Department of Environment and Natural Resources (2003) provided the following summary of the Bolin Creek data:

> "When Bolin Creek was first sampled at East Franklin Street in 1986, the benthic community was reasonably diverse, and the stream, though showing indications of impact, was not considered impaired. Impairment was evident when the stream was next sampled in 1993 and has persisted at this downstream site. Upstream sites supported a reasonably intact benthic fauna until 2000, when impairment became evident as far upstream as Waterside Drive in Carrboro, located between Homestead Road and Estes Drive Extension. It is probably too soon to evaluate whether this decline in the benthic community is persistent, or was due to a specific perturbation from which this portion of the stream will yet recover. Currently, only the

upper portion of Bolin Creek (Homestead Road) appears to support an adequate benthic fauna.

The causes of impairment in the portion of Bolin Creek between Airport Road and Waterside Drive are less clear than in the downstream section of Bolin Creek. In-stream habitat is adequate. Some effects of toxicity and scour are likely, although these impacts appear less pronounced than in lower Bolin Creek, and likely decline significantly at the upstream end of this section."

Collections from Morgan Creek in 2002 and 2003 were intended to show recovery from the 4-month drought. These data indicated that the stream took about one year to recover from extreme low flow. It had shown a decline over time, never attaining the very high EPT taxa richness values seen in 1985, 1993, 1998, and 2000.

Town of Carrboro Data, 2000-2007, Ecological Consultants, Standard Qualitiative Samples. (DWQ method).
Bioclassifications were assigned yearly from 2000-2007, but severe droughts (see flow data) made it inappropriate to assign ratings in 2002, 2006, and 2007. Biotic index numbers are only available from 2000-2001.

	Site:	2 (1777)			3 (Waterside)			4(Estes)		
Date	Parameter:	EPT	S	BI Rating	EPT	S	BI Rating	EPT	S	BI Rating
09/2000		16		6.2 Good-Fair	9		6.1 Fair	4		6.4 Poor
12/2000		18		6.2 Good-Fair	12		6.5 Fair	9		6.0 Fair
03/2001		16		6.4 Good-Fair	10		6.7 Fair	10		6.3 Fair
06/2001		18		- Good-Fair	16		- Good-Fair?	11		- Fair
09/2003		9		- Fair	7		- Poor	8		- Fair
09/2004		11		- Fair	8		- Fair	8		- Fair

RESULTS AND DISCUSSION (Tables 2-3, Appendix 2)
Early samples from Bolin Creek (prior to 2000) indicated Good water quality in the upper section, declining slightly to Good-Fair further downstream. Surveys in 2000, however, produced a Fair rating for sites at Waterside Drive (#3) and Estes Drive (#4). It appears that nonpoint source runoff had a significant negative effect on water quality in Bolin Creek between 1998 and 2000. Note that changes in habitat were not responsible for any these changes.

After August 2001, Bolin Creek was potentially affected by a series of severe droughts, with very low flows (see flow data for Cane Creek and Morgan Creek) in:

-Aug-Dec 2001 (6 months, with lowest flow in Nov)
-June-Sept 2002 (4 months with streams drying up much of this time)
-June 2004
-July-Oct 2005 (4 months with streams going dry in September)
-Aug-Sept 2006
-June-Dec 2007 (7-8 months, with streams going dry for 4-6 months)
-July-August + September 2008 – no streams went completely dry
-July-September 2009 – severe drought in September.

These repeated shocks to the stream biota would be expected to severely affect the diversity of the stream fauna, and bioclassifications based on taxa richness counts might have underestimated water quality conditions. Many of the prior invertebrate samples had been collected in September, which would have been the normal seasonal minimum. The repeated Fair and Poor rating assigned to much of Bolin Creek during this period have been used to show that Bolin Creek does not support designated used, but the current samples suggest that a different answer may be obtained as the stream recovers from drought impacts.

Trends at Bolin Creek sites for winter/spring data
Sampling in 2008 was conducted in the month of December and sampling in 2010 was conducted in the months of both March and July. This contrasts to the August-September collections in most other years. For this reason, we selected the September-December collections in 2000 as

the most comparable data to the present investigation (Table 2, Appendix 2).

Sampling in December 2008 produced very similar results for all 4 sites on Bolin Creek: EPT taxa richness of 10-12 species and a NC Biotic index of 5.9-6.2. This produced a Fair rating using only the EPT taxa richness and a Good-Fair rating using tolerance data. In light of the negative effect of severe drought on taxa richness, all sites were "rounded up" to a tentative Good-Fair rating. These ratings implied that Bolin Creek might support designated uses and had at least partially recovered from the impacts seen in 2000, 2001, 2003, and 2004. Samples from the reference site at Morgan Creek produced much higher EPT taxa richness, with a much more intolerannt community. The corrected EPT taxa richness for the reference site (21), however, was much lower than that seen in prior to the recurring droughts (>30).

Sampling in March 2010 (a little over a year later) produced similar EPT taxa richness at most Bolin Creek sites (12-13), but a lower EPT count at Bolin Creek #4 (9) (Table 2). The intolerant caddisfly, *Chimarra*, was still abundant at the two most downstream sites (Bolin #3 and #4), but intolerant stoneflies were sparse at all Bolin Creek sites (Table 3). Baetid mayflies and various stoneflies (*Acroneuria, Amphinemura*) were abundant at the Morgan Creek reference site, but mostly absent at Bolin Creek sites. Bolin Creek sites #1 and #3 retained a Good-Fair bioclassification, but Bolin Creek sites #2 (below Winmore) and #4 (most downstream) declined to Fair. Sites 2-4 are all border line between a Good-Fair bioclass and a Fair bioclass, suggesting continued monitoring will be required to establish whether they are supporting on partially supporting designated uses. Summer drought conditions (with greatly reduced flows) continued through 2009, even thought recent flows (fall and winter 2009, spring 2010) appear to be higher. Note that USGS flow data is only available at this time through September 2009. Higher flows will allow colonization by a more normal stream fauna, but also might increase the impact of nonpoint source runoff.

Taxa typical of temporary stream or smaller streams are increasing at Bolin Creek, especially the caddisflies *Rhyacophila ledra* and *Ironoquia punctatissima*. This suggests that the continuing droughts are having an impact on the composition of the invertebrate fauna.

<u>Trends at Bolin Creek sites for July 2009 vs. March 2010</u>
Comparisons between different seasons most be made cautiously, as normal seasonal changes in the benthic community may be as important as changes in water quality. For example, intolerant stoneflies are expected to be most diverse in spring samples, but these species have often emerged prior to summer collections. The use of a control site (Morgan Creek) helps to separate out seasonal changes from true changes in water quality.

Morgan Creek had a large increase in mayfly (Ephemeroptera) and stonefly (Plecoptera) richness, although caddisfy (Trichoptera) richness remains low (Table 4). No significant increase in EPT taxa richness occurred at Bolin Creek sites, which had much low abundance of baetid mayflies and stonefly species in March 2010. Although we expect high taxa richness in spring (vs. summer), there was actually a drop in total richness at Bolin Creek sites #3 and #4. EPT taxa richnes declined at sites #2 and #4. These reflect the influence of runoff from the Winmore development (Site #2) and urban runoff from downtown Carrboro (Site #4). The abundance of the most intolerant species (Table 5) was lowest at Bolin Creek #2,

SUMMARY
Biological sampling on Bolin Creek in 2000 and 2001 indicated significant water quality problems in the middle and lower segments. This change was evident both from comparisons over time and comparisons with upstream control sites. A series of severe droughts from 2001-2007, however, greatly complicated the analysis of water quality problems by imposing an independent physical stress on stream biota. Sampling in December 2008 and March 2010 suggest that Bolin Creek is still recovering from the effects of these droughts, with most sites on the border-line between a Good-Fair bioclass (Fully Supporting designated uses) and Fair (Partially Supporting designated uses). Due to the continuing effects of summer droughts, there is no clear indication of any recent trends (positive or negative) in water quality.

Table 2. Taxa richness*** by group and summary parameters, Bolin Creek and Morgan Creek, Orange County, September and December 2000 vs. December 2008 and March 2010. Color shading used to illustrate numbers that indicate best water quality (blue), worst water quality (red) and intermediate water quality (yellow).

Date:	09/00			12/00			12/08					03/10				
Site:	2	3	4	2	3	4	M	1	2	3	4	M	1	2	3	4
Ephemeroptera	8	2	1	10	6	0	7	5	4	5	5	12	4	6	5	3
Plecoptera	2	2	1	3	3	5	6	2	3	3	3	6	3	2	1	1
Trichoptera	6	6	2	5	4	4	5	5	3	4	4	3	5	5	6	5
Coleoptera	10	6	6	3	5	3		7	6	6	2		7	4	4	4
Odonata	6	6	3	4	5	1		7	4	5	2		6	5	6	4
Megaloptera	1	1	-	-	1	-		1	1	-	-		-	-	-	-
Diptera: Misc.	6	5	4	6	5	4		4	4	3	2		4	2	2	3
Diptera: Chironomidae	19	12	13	28	23	25		11	15	14	15		20	18	22	15
Oligochaeta	3	2	4	1	3	4		3	1	4	3		3	2	-	2
Crustacea	3	2	1	3	3	2		6	4	4	4		4	4	3	4
Molusca	3	4	6	3	6	3		5	6	2	4		5	4	2	2
Other	3	1	2	2	2	2		1	2	2	-		2	1	3	-
Total Taxa Richness	70	47	43	68	66	53	-	57	53	52	44	-	63	53	32	42
EPT Taxa Richness	16	10	4	18	13	9	21*	12	10	12	12	24*	12	13	12	9
EPT Biotic index	-	-	-	-	-	-	3.9	5.0	4.5	4.3	5.4	4.5	6.0	5.8	5.5	5.0
NC Biotic Index	6.2	6.1	6.4	6.2	6.5	6.0	-	5.9	5.9	6.2	5.9	-	5.7	6.1	6.1	5.8
EPT Score	2.6	2	1	3	2	1.6	3	2	2	2	2	3.6	2	2	2	1.6
EPT Abundance							88	60	68	63	63	112	58	39	60	35
BI Score	3	3	3	3	2.4	3	-	3	3	3	3	-	4	3	3	3.4
Site Score	2.8	2.5	2	3	2.2	2.3	4	2.5	2.5	2.5	2.5	3.6	3	2.5	2.5	2.5
Rating	G-F	G-F**	F**	G-F	F	F	G?	G-F	G-F	G-F	G-F	G	G-F	F	G-F	F

(G= Good, G-F = Good-Fair, F = Fair)

*Value predicted for more comprehensive standard 10-sample collection
**Rating upgraded from original report
***Taxa richness is a count of the number of different kinds of organisms.

Table 3. Changes in key indicator species (Highly intolerant). Times of greatest abundance are highlighted in blue. TV = Tolerance Value; lower numbers indicate most intolerant species (all species selected here are considered intolerant). R=Rare, C=Common, A=Abundant.

		Chimarra (TV = 2.8)				Eccoptura xanthenes (TV = 3.7) or Acroneuria abnormis (TV = 2.1)				
Date	Sites:	1	2	3	4	1	2	3	4	
09/2000			A	R	-		C	C	C	
12/2000			A	-	-		-	-	A	
03/2001			R	-	-		R	C	-	Follows drought
06/2001			C	R	R		R	R	C	
09/2003		R	A	A	A	C	C	C	C	
09/2004		A	A	A	A	R	R	R	-	
08/2005		A	C	R	C	R	R	C	C	
12/2008		A	A	A	A	R	C	A	C	
07/07/09		A	C	A	A	-	-	R	R	
03/2010		C	R	A	A	R	R	C	-	

Table 4. Comparisons of collections at Bolin Creek and Morgan Mill Creek, July 2009 vs. March 2010. EPT taxa richness by group and summary parameters.

	07/09					03/10				
	1	2	3	4	Morgan**	1	2	3	4	Morgan**
Ephemeroptera	5	6	4	4	8	4	6	5	3	12
Plecoptera	-	-	1	1	2	3	2	1	1	6
Trichoptera	6	5	5	5	3	5	5	5	6	3
Coleoptera	7	5	4	6	5	7	4	4	4	
Odonata	7	5	4	6	5	6	5	6	4	
Megaloptera	1	1	1	1	2	-	-	-	-	
Diptera: Misc.	1	2	3	3	5	4	2	2	3	
Diptera: Chironomidae	14	17	15	17	11	20	18	22	15	
Oligochaeta	4	2	2	4	1	3	2	-	2	
Crustacea	4	3	2	3	3	4	4	3	4	
Mollusca	3	4	5	3	3	5	4	2	2	
Other	2	2	-	3	-	2	1	3	-	
EPT Taxa Richness	11	11	10	10	13	12	13	12	9	21
EPT Abundance	60	55	64	73	107	58	39	60	35	112
Total Taxa Richness	54	52	46	56	48	63	53	32	42	-
NC Biotic Index	5.5	6.6	6.4	6.2	5.7	5.7	6.1	6.1	5.8	-
Rating**	G-F	Fair	Fair	G-F	G-F?	G-F	Fair	G-F	Fair	Good

*Qual 4 or EPT sampling, lower sampling intensity with slightly lower taxa richness.
**G-F = Good-Fair

Table 5. Intolerant species at Bolin Creek sites and Morgan Mill Creek, July 2009 vs. March 2010. Note that seasonal changes produce a slightly different set of species for each date.

	07/09					03/10				
	1	2	3	4	Morgan Cr	1	2	3	4	Morgan Cr
Isonychia spp (July only)	-	-	-	-	A	-	-	-	-	-
Acentrella ampla (March only)	-	-	-	-	-	-	-	-	-	A
Leucrocuta aphrodite	-	-	-	-	A	-	-	-	-	C
Acroneuria abnormis	-	-	R	R	C	-	-	C	-	A
Amphinemura sp (March only)	-	-	-	-	-	C	R	-	R	A
Chimarra sp	A	C	A	A	A	C	R	A	A	-
Neophylax oligius	A	R	-	-	-	-	-	-	-	-
Rhyacophila ledra gr (March only)	-	-	-	-	-	C	-	R	C	A
Psephenus herricki	A	-	A	A	A	A	R	A	C	A
Elimia sp	A	A	C	A	-	A	C	C	C	-
Sum*	40	14	24	31	43	29	6	27	20	53

*Using Rare = 1, Common = 3, and Abundant = 10.

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Appendix 1. Bolin Creek and Morgan Creek Sites, March 2008

Sites are numbered from most upstream (Site 1) to most downstream (Site 4). Samples were collected (with assistance from Randy Dodd, City of Carrboro Planning) on March 23-24, 2010. There had been constant flow throughout the fall and winter, permitting some colonization of Bolin Creek by normal stream invertebrates. Periphyton growths were quite abundant at all sites, although there appeared to be differences between the periphyton community at Site 1 relative to that observed at downstream sites.

Bolin Creek 1. Site 1 was located upstream of the Winmore development, near the power line crossing. This site drains a largely rural and residential landscape; it is intended as a control site for the higher density residential areas further downstream. This portion of the stream may go completely dry during droughts.


Bolin Creek Site 1, March 2010.

This part of Bolin Creek averaged about 5 meters wide, with a substrate mainly composed of gravel and rubble. Both the substrate composition and the width, however, were highly variable. There were no significant habitat problems in this section of Bolin Creek.

Bolin Creek 2. Site 2 is located downstream of the Winmore development at SR 1777. There is private residence on one side of the stream that lacks a buffer zone. Consequently, there is significant bank erosion on one side of the stream.

Relative to Site 1, there was an increase in the amount of sand (Table 1). Habitat problems included fewer riffles, bank erosion, lack of a buffer on one side and a decrease in habitat diversity.


Bolin Creek Site 2, March 2010.

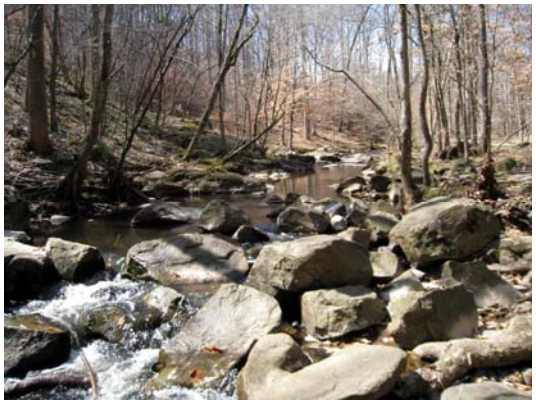
A beaver dam was observed slightly upstream of this site.

Bolin Creek 3. Site 3 is located near Waterside Drive. This section of Bolin Creek is very scenic, with a hiking and biking path along one side of the stream.


Bolin Creek Site 3, March 2010.

There are no significant habitat problems in this portion of the stream. Width increases here from 4-5 meters at Sites 1-2 to 6 meters at Site 3.

Bolin Creek 4. Site 4 is located at the Carrboro/Chapel Hill City limit, near the railroad crossing upstream of Estes Drive. Stream characteristics are almost identical to those of Site 3.


Bolin Creek Site 4, March 2010.

Morgan Creek at NC 54. Morgan Creek was chosen as a reference site, although this stream had also been affected by droughts. Prior surveys by the NC Division of Water Quality generally produced a Good or Excellent bioclassification for this site.


Morgan Creek, NC 54, March 2010.

This catchment has a largely rural character, with some minor impacts from nonpoint source runoff. Habitat quality, stream width and substrate composition are similar to Bolin Creek, but with less residential land use.

Appendix 2. Bolin Creek, Sites 1-4, September 2000 and December 2000 compared to December 2008. R=Rare, C=Common, A=Abundant, +=Present (for Chironomidae, Dec. 2000). December 2008 samples from Morgan Creek limited to most intolerant (EPT) groups. Blue highlights indicate most intolerant species; yellow highlights indicate significant changes in abundance.

Date:	09/00			12/00			12/08					03/10				
Site:	2	3	4	2	3	4	M	1	2	3	4	M	1	2	3	4
Baetis flavistriga	A	C	-	C	-	-	-	R	-	-	C	-	-	-	-	-
Baetis pluto	-	-	-	-	R	-	C	-	-	-	-	-	-	-	-	-
Plauditus dubius gr	-	-	-	A	-	-	-	-	-	-	-	A	-	-	-	-
Centroptilum triangulifer	C	-	C	R	-	-	-	C	A	R	R	-	A	R	C	-
Caenis spp	R	-	-	C	C	-	C	-	R	R	-	A	C	R	C	-
Danella simplex*	-	-	-	C	-	-	-	-	-	-	-	-	-	-	-	-
Ephemerella dorothea*	-	-	-	C	R	-	-	-	-	-	-	R	-	-	-	-
Eurylophella spp	R	-	-	R	-	-	C	-	-	-	R	A	-	R	C	R
Ameletus lineatus	-	-	-	-	-	-	-	R	-	-	-	R	-	-	-	-
Isonychia spp	A	-	-	-	-	-	A	-	-	-	-	-	-	-	-	-
Leptophlebia sp	C	-	-	R	R	-	-	-	-	R	-	-	-	-	-	-
Leucrocuta aphrodite	-	-	-	-	-	-	A	-	-	-	-	C	-	-	-	-
Stenonema modestum	A	C	-	C	R	-	C	A	A	A	A	C	A	A	A	A
Stenacron interpunctatum	A	-	-	C	R	-	C	A	A	C	A	A	A	A	A	C
PLECOPTERA																
Acroneuria abnormis	C	C	C	-	-	A	A	-	-	A	C	A	-	-	C	-
Eccoptura xanthenes	-	-	-	-	-	-	R	R	C	-	-	R	R	R	-	-
Perlesta sp	C	C	-	C	C	-	R	-	-	-	-	A	C	-	-	-
Allocapnia spp (2-3)	-	-	-	A	A	A	A	A	A	A	C	-	-	-	-	-
Taniopteryx spp	-	-	-	A	C	A	A	-	R	C	R	-	-	-	-	-
Strophopteryx sp*	-	-	-	-	-	A	-	-	-	-	-	-	-	-	-	-
Isoperla sp*	-	-	-	-	-	C	R	-	-	-	-	C	-	-	-	-
Clioperla clio	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Amphinemura sp	-	-	-	-	-	-	-	-	-	-	-	A	C	R	-	R
TRICHOPTERA																
Cheumatopsyche spp	A	A	A	A	A	A	A	A	A	A	A	-	R	C	A	C
Hydropsyche betteni	A	A	A	C	A	A	R	A	C	C	A	-	R	C	C	C
Diplectrona modesta	-	-	-	R	-	-	R	-	-	-	R	-	-	-	C	-
Chimarra sp	A	R	-	A	-	-	A	A	A	A	A	-	C	R	A	A
Polycentropus sp	-	-	-	-	-	C	-	C	-	-	-	-	-	-	-	-
Rhyacophila ledra/glaberima	-	-	-	-	-	-	-	-	-	-	-	A	C	-	R	C
Ceraclea ancylus	R	R	-	-	-	-	R	-	-	-	-	-	-	-	-	-
Triaenodes ignitus	-	-	-	-	-	R	-	-	-	-	-	-	-	-	R	-
Neophylax oligius	R	A	-	C	R	-	-	R	-	-	-	-	-	-	-	-
Psilotreta sp (pupa)	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Pycnopsyche sp	R	C	-	-	R	-	-	-	-	-	-	-	-	-	-	-
Ironoquia punctatissima	-	-	-	-	-	-	-	-	-	-	-	C	A	C	C	R
Ptilostomis sp	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-
COLEOPTERA																
Anchytarsus bicolor	A	C	C	-	-	-		A	R	-	-		A	R	-	-
Ancyronyx variegata	R	-	-	A	A	A		-	-	-	-		-	-	-	-
Macronychus glabratus	C	C	C	R	-	-		-	-	-	-		-	-	-	-
Dubiraphia sp	C	R	A	C	A	R		-	R	R	-		-	-	R	C
Stenelmis crenata	-	-	-	-	-	-		C	C	C	R		C	-	A	C
Microcyloepus pusillus	C	R	C	-	R	-		-	-	-	-		-	-	-	-
Psephenus herricki	C	-	C	-	R	-		A	C	R	C		A	R	A	C
Ectopria nervosa	R	R	R	-	-	-		R	-	-	-		R	R	-	-
Helichus spp	C	-	-	-	R	C		R	R	-	-		C	C	-	R
Gyrinus sp	R	-	-	-	-	-		-	-	-	-		-	-	-	-
Neoporus spp	R	R	-	-	-	-		A	C	A	-		C	-	-	-
Neoporus mellitus gr	-	-	-	-	-	-		C	-	R	-		-	-	-	-
Peltodytes sp	-	-	-	-	-	-		-	-	R	-		R	-	R	-

Date:	09/00			12/00			12/08				03/10			
Site:	2	3	4	2	3	4	1	2	3	4	1	2	3	4
ODONATA														
Argia spp	R	C	R	R	R	-	A	R	C	-	R	R	R	R
Calopteryx sp	C	A	-	R	C	-	C	-	A	R	C	C	C	R
Enallagma spp	C	-	C	R	C	-	C	C	R	-	R	R	R	C
Ischnura sp	-	-	-	-	-	-	-	-	-	-	-	R	-	-
Gomphus sp	R	C	-	-	R	-	R	-	-	-	C	C	R	R
Stylogomphus albistylus	R	R	-	-	R	-	R	C	R	R	-	-	-	-
Neurocordulia obsoleta	-	R	-	-	-	-	-	-	-	-	-	-	-	-
Somatochlora sp	-	-	-	-	-	-	R	R	C	-	R	R	R	R
Tetragoneuria sp	-	-	-	-	-	-	-	-	-	-	-	-	R	-
Boyeria vinosa	C	C	C	C	-	C	R	-	-	-	R	-	-	-
MEGALOPTERA														
Nigronia serricornis	C	R	-	-	C	-	-	-	-	-	-	-	-	-
Sialis sp	-	-	-	-	-	-	C	R	-	-	-	-	-	-
DIPTERA: MISC.														
Aedes sp	R	-	-	-	-	-	-	-	-	-	-	-	-	-
Culex sp	R	-	-	-	-	-	-	-	-	-	-	-	-	-
Antocha spp	-	-	-	R	-	-	-	-	-	-	A	-	A	C
Tipula spp	A	C	R	C	C	R	A	A	A	A	A	A	A	C
Dicranota sp	-	-	-	-	-	-	R	R	-	-	-	-	-	-
Atrichopogon sp	-	R	R	-	-	-	-	-	-	-	-	-	-	-
Palpomyia complex	-	R	-	C	A	-	R	-	R	-	C	R	-	-
Prosimulium spp	R	-	C	+	+	+	-	-	-	-	-	-	-	R
Simulium spp	R	C	C	+	+	+	C	C	C	A	-	-	-	-
Simulium vittatum gr	C	C	-	+	+	+								
Simulium venustrun gr							-	R	-	-	-	-	-	-
Tabanus sp	R	-	-	-	-	-	-	-	-	-	-	-	-	-
Chrysops sp	-	-	-	-	-	-	-	-	-	-	R	-	-	-
DIPTERA: CHIRONOMIDAE														
Ablabesmyia spp (2)	A	C	C	+	+	+	-	-	-	R	C	R	C	R
Conchapelopia group	C	R	-	+	-	+	A	C	A	R	C	C	C	R
Labrundinia sp	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Larsia (?) sp	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Procladius sp	-	C	C	-	+	+	-	-	-	-	C	-	-	-
Rheopelopia sp	-	-	-	+	-	+	-	-	-	-	-	-	-	-
Zavrelimyia sp	-	-	-	-	-	-	R	-	-	C	-	-	R	R
Brillia sp	-	-	-	+	-	+	-	-	-	-	-	-	-	-
Xylotopus par	-	-	-	-	-	-	-	C	-	-	-	-	-	-
Corynoneura spp	R	-	-	+	+	-	A	C	C	C	R	-	-	-
Thienemaniella spp	C	R	C	+	+	+	A	R	C	A	-	-	-	R
Cricotopus bicinctus	-	R	C	+	+	+	-	-	C	-	-	-	-	-
Cricotopus triannulatus gr	-	-	-	+	-	+	-	-	-	-	-	-	-	-
Cricotopus cylindraceus	-	-	-	-	-	-	-	-	-	-	-	R	R	-
Diplocladius cultriger	-	-	-	-	+	-	A	A	A	A	C	C	R	-
Eukiefferiella claripennis gr	-	-	-	-	-	-	-	-	-	R	-	-	R	A
Eukiefferiella brevicalcar gr	-	-	-	-	-	-	-	-	-	-	A	C	-	-
Heterotrissocladius sp	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Hydrobaenus sp	-	-	-	-	-	+	-	-	-	-	R	C	R	-
Krenosmittia sp	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Nanocladius spp (2-3)	C	-	-	+	+	-	-	C	-	-	-	-	R	-
Orthocladius spp	C	-	-	+	+	+	R	R	-	-				
O. obumbratus											A	A	A	R
O. dorenus											-	-	A	A
O. robacki											R	A	C	-
O. (Eud.) dubitatus											-	-	R	-

Date:	09/00			12/00			12/08				03/10			
Site:	2	3	4	2	3	4	1	2	3	4	1	2	3	4
CHIRONOMIDAE, Continued														
Paracricotopus sp	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Parametriocnemus lundbecki	-	-	-	+	+	+	C	C	A	A	C	A	C	C
Psectrocladius spp	-	-	-	+	+	+	-	-	-	-	-	-	-	-
Rheocricotopus robacki	C	R	C	+	-	+	-	C	-	-	-	-	-	-
Rheocricotopus tuberculatus	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Rheocricotopus DWQ sp. 6	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Tvetenia bavarica gr											-	R	-	-
Diamesa sp	-	-	-	-	-	-	-	-	-	-	R	C	A	A
Potthastia longimanus	-	-	-	+	+	+	-	R	R	-	-	R	-	-
Prodiamesa sp	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Chironomus sp	-	R	-	-	-	-	-	R	-	-	-	-	-	-
Cryptochironomus spp	A	-	-	+	+	-	-	-	-	-	-	R	-	-
Dicrotendipes spp	-	-	C	+	-	+	-	-	-	-	-	-	R	R
Microtendipes spp	-	-	-	-	-	+	C	-	A	A	R	R	R	C
Paracladopelma spp	R	-	-	+	+	-	-	-	-	-	-	-	-	-
Paratendipes sp	-	-	C	+	-	+	-	-	-	-	-	-	-	-
Phaenopsectra spp	-	-	-	-	+	+	-	-	-	-	-	-	-	-
Phaenopsectra flavipes gr.	-	C	-	-	-	-	-	-	R	-	-	-	-	-
Polypedilum convictum	A	-	R	-	-	-	A	C	C	C	A	A	A	A
Polypedilum aviceps	-	-	-	-	-	-	-	-	-	-	-	-	-	A
Polypedilum halterale	A	A	-	+	+	-	-	-	-	-	-	-	-	-
Polypedilum illinoense							-	-	-	R	-	-	-	-
Polypedilum fallax	-	C	R	+	-	-	-	-	-	-	-	-	-	-
Polypedilum scalaenum	R	-	R	+	-	-	-	-	-	-	-	-	-	-
Stenochironomus sp	-	-	-	+	+	+	-	-	-	-	-	-	-	-
Stictochironomus sp	-	-	-	-	+	+	-	-	-	-	-	C	R	-
Tribelos sp	R	-	-	+	-	-	-	C	C	A	-	-	C	C
Cladotanytarsus sp	R	-	-	-	-	-	-	-	-	-	-	R	-	-
Micropsectra spp	R	-	-	-	-	+	-	-	-	-	-	-	-	-
Paratanytarsus sp	-	-	-	+	+	+	-	R	C	-	-	-	R	-
Rheotanytarsus spp	C	C	C	-	+	+	C	R	C	C	C	-	-	R
Stempellina spo	R	-	R	-	+	-	-	-	-	-	-	-	-	-
Stempellinella sp	C	-	-	-	-	+	-	-	-	-	-	-	-	-
Tanytarsus spp	A	C	C	+	+	-	R	-	-	R	C	R	C	-
OLIGOCHAETA														
Limnodrilus spp (hofmeisteri)	A	C	A	-	C	C	-	-	-	-	R	R	-	-
Ilyodrilus templetoni	-	-	A	-	-	R	-	-	-	-	-	-	-	-
Spirosperma nikolsyii	R	-	-	-	-	-	R	-	-	-	-	-	-	-
Nais spp	C	-	C	R	R	C	R	-	C	R	R	-	-	-
Stylaria lacustris	-	-	-	-	-	-	-	-	C	R	-	R	-	-
Lumbriculidae	-	R	C	-	R	C	-	-	R	-	R	-	-	R
Megadriles							C	C	R	R	-	-	-	-
CRUSTACEA														
Crangonyx spp	C	R	-	C	C	R	A	A	A	A	C	C	C	A
Hyallela azteca	R	-	-	C	R	-	C	A	C	-	R	C	C	C
Caecidotea sp	-	-	-	-	-	-	C	C	A	A	-	-	-	R
Cambarus (P.) sp. C Cooper							R	-	-	-	A	C	C	C
Cambarus (C.) davidi							R	-	-	-				
Procambarus acutus	C	R	R	C	R	R	C	C	R	R	C	C	-	-

Date:	09/00			12/00			12/08				03/10			
Site:	2	3	4	2	3	4	1	2	3	4	1	2	3	4
MOLLUSCA														
Elimia sp	C	R	C	-	R	R	A	C	-	R	A	C	C	C
Leptoxis sp	-	-	-	-	-	-	R	-	-	-	-	-	-	-
Physella sp	-	-	R	R	A	C	R	R	R	R	-	R	R	-
Lymnaea (?) sp	-	R	R	-	-	-	-	-	-	-	-	-	-	-
Helisoma anceps	C	R	R	C	R	-	-	-	R	-	-	-	-	R
Menertus dilatatus	-	-	-	-	C	-	R	-	-	-	-	-	-	-
Sphaerium spp	C	R	R	C	A	C	C	C	-	-	R	-	-	-
Ferrissia sp	-	-	-	-	-	-	-	-	-	C	-	-	R	-
Pisidium spp	-	-	R	-	-	-	-	R	-	-	R	R	-	-
Corbicula fluminea	-	-	-	-	-	-	-	A	-	R	R	R	-	-
Elliptio sp	-	-	-	-	-	-	-	R	-	-	-	-	-	-
OTHER														
Belostoma sp	R	-	-	-	-	-	-	-	-	-	-	-	-	-
Ranatra sp	R	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbellaria	-	-	-	A	A	-								
Dugesia tigrina	-	R	C	-	-	-	-	R	-	-	-	-	R	-
Cura foremanii							R	R	R	-	R	-	R	-
Hydrolimax grisea							-	-	R	-	-	R	-	-