BIOLOGICAL MONITORING OF BOLIN CREEK AND TRIBUTARIES, CARRBORO, NORTH CAROLINA

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HOW TO READ THIS REPORT

This is the 7th report by Lenat Consulting on water quality and habitat quality in Bolin Creek and its tributaries in Carrboro, North Carolina. This report is intended to function as a "stand-alone" document, so it repeats much of the material in earlier reports, especially in the introduction, summary of flow data, methods, and summary of prior biological monitoring. Long lists of species are primarily confined to the appendices, but the reader will often find species names used in the discussion, especially in regard to *tolerant* or *intolerant* species. **In order to comprehend many of the summary tables, the reader should understand the terms "EPT taxa richness" and "biotic index", and should understand how bioclassifications are assigned to streams** (see Methods section). Once you are familiar with these terms, the fastest way to view our results is in Table 1, Table 4 and the Summary. **Individuals who have read the prior reports may wish to skip to the Results and Discussion sections (Page 9)**.

A companion report has been produced for the Town of Chapel Hill, giving information on lower Bolin Cr, Morgan Creek, Booker Creek, Little Creek and many tributary streams. Combining information from these two reports provides valuable information on the effects of urban/residential development in this part of North Carolina. Reports by LCS to the town of Chapel Hill can be obtained at:
http://www.townofchapelhill.org/index.aspx?page=412.

INTRODUCTION [Note: this section largely repeated from early reports.]
Water quality in Bolin Creek was evaluated in June 2013 by sampling benthic macroinvertebrates at 4 sites. Collections also were made in April 2013 at three small tributaries of Bolin Creek. 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 type of organism 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 earlier reports.]
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, Tanyard 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 more developed areas in Carrboro and Chapel Hill.

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 may have extremely 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).

METHODS [Note: this section largely repeated from earlier 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 DWQ biologists since 1982, and have been thoroughly tested for accuracy and repeatability. More details can be found at their web site: http://portal.ncdenr.org/web/wq/ess/bau.
Three of DWQ's collection methods have been used for the Bolin Creek study: Standard Qualitative (Full scale), Qual-4 and EPT collections. These three methods are briefly described below.

Standard Qualitative Method – Overview [Bolin Creek 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.

Qual-4 Method – Overview [Bolin Creek tributaries]

The Qual-4 method uses the same 4 samples as the EPT method, but all benthic macroinvertebrates are collected. DWQ uses this method to evaluate small streams (drainage area < 3 square miles) and assigns ratings based solely on the biotic index values. This method is intended for use, however, only in perennial streams. For this reason, the majority of bioclassifications assigned to the Carrboro tributaries are tentative ratings supplemented by best professional judgment.

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. A score from 1 to 5 is assigned to each site, with 1 for Poor EPT taxa richness and a 5 for Excellent EPT taxa richness (see below).

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), but with tolerance values derived from NC collections. Biotic indices are based on a 0-10 scale, where 0 represents the best water quality and 10 represents the worst water quality. Abundance values used in the biotic index calculation are 10 for Abundant taxa, 3 for Common taxa, and 1 for Rare taxa. The highest values (>5.1) indicate the worst water quality and receive a score of 5; the lowest values indicate Excellent water quality and receive a score of 1 (see below)

NC Division of Water Quality: Scoring for Biotic Index and EPT taxa richness values for Piedmont streams (Standard Qualitative collections)

Score	BI Values	EPT Values
5	<5.14	>33
4.6	5.14-5.18	32-33
4.4	5.19-5.23	30-31
4	5.24-5.73	26-29
3.6	5.74-5.78	24-25
3.4	5.79-5.83	22-23
3	5.84-6.43	18-21
2.6	6.44-6.48	16-17
2.4	6.49-6.53	14-15
2	6.54-7.43	10-13
1.6	7.44-7.48	8-9
1.4	7.49-7.53	6-7
1	>7.53	0-5

Derivation of Final Bioclassification for Standard Qualitative Samples
For most piedmont 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 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.

Small Stream Criteria
Small streams (<4 meters wide) are expected to have lower EPT taxa richness relative to larger streams. NC DWQ has developed criteria for small piedmont stream based solely on biotic index values:

Excellent:	<4.3
Good :	4.3-5.1
Good-Fair:	5.2-5.8
Fair:	5.9-6.9
Poor:	>6.9

These criteria were developed only for perrenial criteria, but most of the Chapel Hill small streams are intermittent.

SAMPLING SITES
The Carrboro section of Bolin Creek has been sampled yearly since 2000. Samples 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.), July 2009, March 2010 and March 2011, April-June 2012 and April-June 2013. The months for sampling in 2012 and 2013 were selected after consultation with biologists with the NC Division of Water Quality.

Sites are numbered from most upstream (Site 1) to most downstream (Site 4). Note that Site 4 was moved further downstream in 2011, so that data from this site can be used by both Carrboro and Chapel Hill. Tributary sites were sampled in April 2013; larger streams were sampled in June 2013 . More detailed site descriptions (with photos) are presented in Appendix 3.

Table 1A gives data on habitat ratings and substrate composition at all sites sampled in 2012. The habitat rating is based on standard Division of Water Quality procedures, and produces a value between 0 and 100.

Table 1A. Site characteristics, Carrboro Streams, March 2011, Orange County.

	Habitat Scoring (0-100)										Substrate (%)					
Stream	CM	IH	BS	PV	RH	BSV	LP	RVZW	Total	Width	B	R	Gr	Sa	Si	Comments
Bolin Cr #1	5	18	12	10	16	6/6	10	4/4	91	4.5	20	30	30	20	Tr	
Bolin Cr #2	3	16	10	8	14	6/3	7	5/2	74	4.5	20	25	20	25	10	DownstreamWinmore/Claremont. Sand deposition in pools
Bolin Cr #3	5	16	8	10	16	6/6	10	5/4	86	5	50	30	10	10	-	Very rocky, Poor bank areas
Bolin Cr #4	4	20	12	6	14	7/7	7	3/3	83	5.5	35	25	20	20	Tr	Rocky. Downstream of developed areas in Carrboro.
Tributaries																
Jolly Br	5	16	11	6	7	5/5	7	5/5	70	1	15	40	20	15	10	Severe bank erosion, but largely forested. Good habitat.
UT Tanyard	3	15	8	10	14	5/3	7	3/3	71	1	15	50	25	15	Tr	High density residential/urban. High Conductivity
UT Bolin Cr	No data									1						Very small stream, sampled prior to mitigation work.

Habitat Components: CM = Channel Modification (0-5), IH = Instream Habitat (0-20), BS = Bottom Substrate (1-15), PV = Pool Variety (0-10), RH = Riffle Habitats (0-16), BSV = Bank Stability and Vegetation (0-7 for both left and right banks), LP = Light Penetration (0-10), RVZM = Riparian Vegetative Zone Width (0-5 for both left and right banks).
Substrate: Boulder (B), Rubble (R), Gravel (Gr), Sand (Sa), Silt (Si), Tr = Trace (<10%). Stream width is in meters.

FLOW DATA [Similar to prior report, but updated to include the latest 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 2012. The USGS measures daily flow at Morgan Creek at NC 54 and Cane Creek; both streams are in Orange County and both are similar in geology to the Bolin Creek catchment. The Cane Creek site, however, may be affected by the upstream Cane Creek Reservoir, so this year's report only shows the Morgan Creek flow information.

Mean Monthly flow (cfs) in streams most similar to Bolin Creek, 1999-2009.
Morgan Creek nr White Cross (Drainage area 8.3 square miles)

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	0.05	7.7	18.7
2010		13	21	7	3	4	0.6	0.1	0.02	0.6	0.3	0.6	0.8
2011		0.7	1.4	3	4	1.1	0.1	0.6	0.004	0.01	0.05	0.2	3
2012		2	3	7	3	2	0.5	0.2	0.3	8	0.8	0.5	0.8
2013		2	5	4	3								

Flow data from further downstream on Morgan Creek at Chapel Hill (41 square miles) did not indicate any months with average flows less than 7 cfs (1999-2012).
Low flows (less than 0.5 cfs) are highlighted in yellow; severe low flows (less than 0.1 cfs) are highlighted in red. Values past September 2011 are median monthly values (not means).

Good flow information for 2013 is not yet available, but the benthic collections for this year were preceded by better than average flow, especially relative to the repeated summer droughts seen from 2005-2011. Flows were about normal for the April tributary samples, but Bolin Creek experienced very high flows prior to the June collections, with some local flooding.

PRIOR BIOLOGICAL DATA [Largely unchanged from 2011 report]
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). There have been few recent collections due to problems with low summer flows.

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 Qualitative 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 1-4, Appendices 1-3)
Morgan Creek, NC 54
Combining the DWQ collections (which go back to 1985) with collections for Carrboro gives a good long-term look at changes in water quality for the upper segment of Morgan Creek. Much of the variation in EPT taxa richness observed at this site is due to drought effects and sampling in different months (with higher values for spring collections). However, there does appear to be a decline in water quality, with Excellent ratings found only for years prior to 2000 and more Good-Fair ratings in recent years.

Bolin Creek (Tables 1-3, Appendix 1)
Early DWQ 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 (see "Prior Biological Data" section of this report). Note that changes in habitat were not responsible for any of these changes.

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

-Sept-Dec 2001 (4 months, with lowest flow in Oct-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 2006
-July-Dec 2007 (6 months, with streams going dry for 4-6 months)
-June and September 2008 – no streams went completely dry. A period of possible recovery.
-July-Oct 2009 (4 months with severe drought for 2-3 months)
-June-August 2010 (severe drought in August)
-August-November 2011

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 ratings assigned to much of Bolin Creek during 2000-2004 have been used to suggest that Bolin Creek does not support designated uses. A more complicated pattern, however, has been observed in later collections, with some parts of Bolin Creek receiving a Good-Fair bioclassification. DWQ protocols use an Excellent, Good or Good-Fair rating to show that a site supports designated uses; a Fair rating indicates partial support and a Poor rating indicates nonsupport.

Routine sampling was switched from summer months to winter/spring months in 2008 to avoid these periods of extreme low flow. The most recent collections (2012-2013) were made in both April (tributaries) and in June (Bolin Creek), following DWQ recommendations. Much of Bolin Creek is functioning as an intermittent stream during the drought years and this system is difficult to evaluate using DWQ criteria for perennial streams.

Comparisons of the June 2012 and 2013 surveys with earlier collections must take into account some normal seasonal changes, in particular when comparing the March samples of 2010 and 2011 with the June samples of 2012-2013. Some species that have "disappeared" may be lost through emergence in spring, rather than through a change in water quality (see Table 3). The EPT taxa richness values for Bolin Creek in 2012-2013 were unusually low, but these low values are sometimes offset by the presence of highly intolerant species (for example, see Tables 2 and 3). This pattern suggests that summer low-flows are still limiting the diversity of Bolin Creek macroinvertebrates.

Data summarized by site:

-Bolin Creek 1. The most upstream site drains a lightly developed catchment, but we would expect drought effects to be most severe for this segment of the stream. It has consistently been assigned a Good-Fair bioclassification, with stable biotic index values of 5.7-6.0. This was the only site that supported "small-stream" species like *Eccoptura xanthenes*.

-Bolin Creek 2. This site is only a short distance from Site 1, but drains the Winmore development. Since 2010, the increase in biotic index values (showing a shift to more tolerant species) has been sufficient to drop the bioclassification to Fair at site 2. The difference between sites 1 and 2 was greatest in 2011, with some evidence of improvement in 2012 and 2013.

-Bolin Creek 3. Some recovery is evident between sites 2 and 3, with a Good-Fair rating for this site in 4 out of 5 samples since 2008.

-Bolin Creek 4. This site has been rated as Fair for all years except 2008. This drop in bioclassification (compared to site 3) is likely due to increasing amounts of urban runoff.

Table 2 shows the changes in abundance for 2 key indicator groups of intolerant taxa: a philopotamid caddisfly (*Chimarra*), and two perlid stoneflies (*Acroneuria abnormis/Eccoptura xanthenes*). *Acroneuria* had almost disappeared from Bolin Creek in 2009-2011, with only a single specimen collected in 2011. Although this intolerant species was abundant at Bolin Creek station 3 in 2012, it was completely absent from Bolin Creek sites in 2013.

Chimarra had shown a significant decline in 2011 and 2012, being abundant only at the upstream site on Bolin Creek. In 2013, however, this taxon was abundant at all sites. The latter pattern suggested that the better flow condition in 2013 allowed more recovery to occur in Bolin Creek.

A more extensive list of intolerant species is presented in Table 3, producing a score (the "Sum" line) that is useful in comparing Bolin Creek sites. This score shows a consistent decline below the Winmore development (Site 1 vs. site 2), associated with runoff and sediment deposition. Some recovery is usually seen further downstream, except for 2012.

None of the Carrboro Bolin Creek sites had a community that would indicate organic loading. Some sites, however, had fauna (especially the snail *Physa*) that suggested low dissolved oxygen concentrations. *Physa* was abundant at Bolin Creek sites 2 and 4 in 2011; both of these sites had very high levels of filamentous algae. Such high levels of algae can cause supersaturation during the day, but low dissolved oxygen levels at night. This pattern was observed in 2012 only at Bolin Creek 4 and abundant growth of filamentous algae was not observed for any Bolin Creek site. In 2013, *Physa* was abundant at sites 1 and 2, suggesting some dissolved oxygen problems in the headwater area.

Bolin Creek Tributaries (Table 4, Appendix 2)
Although much of Bolin Creek shows some water quality problems, some tributary sites still maintain Good or Excellent bioclassifications. Only three tributaries were sampled in 2013, but summary information is given below for all sites.

Not sampled in 2013

UT Seawell School Road. Sampled in 2009, 2011 and 2012. Collections from all years indicated an area of Good-Excellent water quality, with many highly intolerant species not observed in other Carrboro collections (*Wormaldia, Psilotreta, Neophylax ornatus, Rhyacophila glaberrima*).

UT Horne Hollow Rd. Sampled in 2011 and 2012 with an Excellent bioclassification.

Jones Creek at Turtle back Crossing. Sampled in 2012 and tentatively assigned a Fair rating. There are some intolerant species in this segment of Jones Creek (2 stoneflies), but other taxa suggest both low dissolved oxygen (*Physa*) and organic loading (*Ilyodrilus templetoni, Limnodrilus sp.*).

UT Bolin Creek at Camden Rd. Sampled for the first time in 2012 and tentatively assigned a Good-Fair rating

Sampled in 2013

Jolly Branch. Jolly Branch is located near the Carrboro/Chapel Hill boundary; it has been included in the reports to both towns. The lack of some expected species (for example most heptagenid mayflies and hydropsychid caddisflies) clearly indicated stream flow has been intermittent in recent years. The abundance of *Ironoquia* in 2011 and 2013 also suggested intermittent flow. Abundant EPT species in both years included two intolerant stoneflies *(Perlesta, Amphinemura*) and one intolerant caddisfly (*Rhyacophila fenestra*), indicating no significant water quality problems. This site was tentatively given a Good-Fair rating in all years, but appeared to have the best water quality in 2013. Higher stream flows in 2013 may have contributed to this change.

	2011	2012	2013
Total Taxa Richness	33	24	39
EPT Taxa Richness	8	6	11
NC Biotic Index	6.2	6.1	5.5
Rating	G-F	G-F	G-F

UT Tanyard Branch below Baldwin Park. This stream drains both residential and commercial areas, with most of the catchment in Carrboro. This site was not sampled during the regular tributary collections in the spring of 2011, but a special collection had been made in March 2009. The latter collection was to establish baseline conditions, prior to mitigation efforts near the park. Although both collections produced a Poor rating, total taxa richness increased from only 12 in 2009 to 16-21 in the last two collections. EPT taxa richness increased from 2 in 2009 to 4 in 2012. The mayfly *Baetis flavistriga* was especially abundant in this stream segment in 2012, but had not yet hatched in 2013. This change does not reflect a decline in water quality, rather it shows a between-year difference in stream temperatures. Although this small stream has good habitat after the mitigation project,

conductivity remains very high (465-500+ uhmo/cm). This suggests that contaminated groundwater may continue to limit the diversity of the stream fauna.

	2009	2012	2013
Total Taxa Richness	12	21	16
EPT Taxa Richness	2	4	3
NC Biotic Index	7.5	7.8	7.4
Rating	Poor	Poor	Poor

UT Bolin Creek. This very small stream was sampled prior to a mitigation project. The very limited fauna clearly indicates Poor water quality. The abundance of the air-breathing snail, *Physa*, suggested some problems with low dissolved oxygen.

SUMMARY

Biological sampling on Bolin Creek has consistently indicated Good-Fair or Good water quality in upper Bolin Creek (Site 1), in spite of some development and persistent summer droughts. This segment of Bolin Creek supports many highly intolerant species. Site 2 (below the Winmore development) has been assigned only a Fair rating since 2010, although there is some evidence of a gradual recovery for this part of the stream in 2012 and 2013. Areas further downstream usually are rated as Good-Fair in the middle part of the stream (Site 3), declining to a Fair rating at the Carrboro/Chapel Hill boundary (see Table 1).

It is clear that summer low-flow conditions (sometimes the absence of water in the channel) contribute to problems in Bolin Creek. Samples collected in 2008, following a period of higher summer flow, allowed some recovery, while samples in 2010-2012 followed a period of very severe summer droughts. The 2013 collections followed a period of higher rainfall, although these extremely high flows may have caused some scour.

The development near Winmore and Claremont apparently still impacts the stream fauna through nonpoint source runoff and sediment deposition. Comparison of Bolin sites 1 and 2 (which bracket this development) showed a consistent decline in the diversity of the aquatic fauna, particularly in the abundance of more intolerant species. Construction was still active in this area in 2013.

No sites had indications of organic loading problems, but some sites on Bolin Creek have shown symptoms of low dissolved oxygen. Downstream areas were affected in 2011 and 2012, but the two upstream sites were most affected in 2013.

Although much of Bolin Creek has water-quality problems, tributary sites may support more intolerant aquatic communities. Studies in both Carrboro and Chapel Hill have shown that Good-Excellent water quality may be found in smaller streams, especially in residential areas with large lot sizes and good riparian buffer zones. Such small streams, however, may have intermittent flow and must be sampled in winter or spring.

Only three tributary sites were sampled in 2013. Jolly Branch has intermittent flow, but received a Good-Fair rating, supporting a diverse and intolerant fauna. UT Tanyard Branch drains a very developed area and has consistently been rated as Poor. Although mitigation efforts have improved stream habitat at this site, it still receives groundwater inputs with very high conductivity levels. UT Bolin Creek is a very small stream that was evaluated prior to mitigation work; it received a Poor rating.

Table 1. Taxa richness*** by group and summary parameters, Bolin Creek and Morgan Creek, Orange County, 2000-2013. Color shading used to illustrate numbers that indicate best water quality (blue), worst water quality (red) and intermediate water quality (yellow).

Date:	12/08					03/10				
Site:	M	1	2	3	4	M	1	2	3	4
Ephemeroptera	7	5	4	5	5	12	4	6	5	3
Plecoptera	6	2	3	3	3	6	3	2	1	1
Trichoptera	5	5	3	4	4	3	5	5	6	5
Coleoptera		7	6	6	2		7	4	4	4
Odonata		7	4	5	2		6	5	6	4
Megaloptera		1	1	-	-		-	-	-	-
Diptera: Misc.		4	4	3	2		4	2	2	3
Diptera: Chironomidae		11	15	14	15		20	18	22	15
Oligochaeta		3	1	4	3		3	2	-	2
Crustacea		6	4	4	4		4	4	3	4
Mollusca		5	6	2	4		5	4	2	2
Other		1	2	2	-		2	1	3	-
Total Taxa Richness	-	57	53	52	44	-	63	53	32	42
EPT Taxa Richness	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
EPT Abundance	88	60	68	63	63	112	58	39	60	35
NC Biotic Index	-	5.9	5.9	6.2	5.9	-	5.7	6.1	6.1	5.8
EPT Score	3	2	2	2	2	3.6	2	2	2	1.6
BI Score	-	3	3	3	3	-	4	3	3	3.4
Site Score	-	2.5	2.5	2.5	2.5	-	3	2.5	2.5	2.5
Rating	G?	G-F	G-F	G-F	G-F	G	G-F	F	G-F	F

Date:	03/11					06/12					06/13				
Site:	M	1	2	3	4	M	1	2	3	4	M	1	2	3	4
Ephemeroptera	9	7	3	5	4	7	3	3	3	3	10	3	3	3	3
Plecoptera	6	5	1	2	1	2	2	-	1	1	1	1	0	0	0
Trichoptera	3	6	4	3	3	2	5	5	1	4	5	4	4	3	3
Coleoptera		5	7	2	2		6	2	4	5		7	5	2	6
Odonata		4	2	3	2		6	2	3	3		3	3	1	1
Megaloptera		1	-	-	-		1	-	-	1		-	-	-	-
Diptera: Misc.		4	4	8	6		3	2	2	2		4	2	2	4
Diptera: Chironomidae		23	18	20	22		10	18	9	19		16	10	14	9
Oligochaeta		3	2	6	8		2	1	3	2		4	1	2	1
Crustacea		3	3	4	4		5	4	4	3		2	3	2	2
Mollusca		6	7	6	4		7	5	2	6		5	3	2	3
Other		-	1	1	2		2	-	1	3		2	3	1	1
Total Taxa Richness	-	67	52	60	58	-	52	42	33	52		51	37	32	33
EPT Taxa Richness	21*	18	8	10	8	13*	10	8	5	8	18*	8	7	6	6
EPT Biotic index	4.3	4.9	6.0	5.1	5.6	4.4	5.0	6.2	5.0	6.4	4.7	5.6	5.6	5.6	6.2
EPT Abundance	66	71	32	22	21	44	57	30	34	48	87	58	44	39	53
NC Biotic Index	-	5.7	6.6	6.5	6.7	-	6.0	6.4	5.5	6.8	-	5.8	6.0	5.6	5.9
EPT Score	3	3	1.6	2	1.6	2	2	1.6	1	1.6	3	1.6	1.4	1.4	1.4
BI Score	-	3.4	2	2.4	2	-	3	3	4	2	-	3.4	3	4	3
Site Score	-	3.2	1.8	2.2	1.8	-	2.5	2.3	2.5	1.8	-	2.5	2.2	2.7	2.2
Rating	G?	G-F	F	F	F	G-F?	G-F	F	G-F	F	G-F	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; “EPT” refers to the group of most intolerant species (Ephemeroptera. Plecoptera and Trichoptera).

Table 2. 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	
07/2009		A	C	A	A	-	-	R	R	
03/2010		C	R	A	A	R	R	C	-	
03/2011		A	C	-	R	C	-	-	-	
06/2012		A	R	-	C	R	-	A	R	
06/2013		A	A	A	A	-	-	-	-	

Table 3. Selected intolerant species at Bolin Creek sites 1-4 and Morgan Creek (MC), 2009-2012. Note that seasonal changes produce a slightly different set of species for each date.

	07/09					03/10					03/11					06/12					06/13				
	1	2	3	4	MC	1	2	3	4	MC	1	2	3	4	MC	1	2	3	4	MC	1	2	3	4	MC
Isonychia spp (July only)	-	-	-	-	A	-	-	-	-	-	-	-	-	-	-[1]	-	-	-	-	R	-	-	-	-	-
Acentrella ampla (March only)						-	-	-	-	A	-	-	-	-	A										
Leucrocuta aphrodite	-	-	-	-	A	-	-	-	-	C	-	-	-	-	C	-	-	-	-	A	-	-	-	-	A
Acroneuria abnormis	-	-	R	R	C	-	-	C	-	A	R	-	-	-	-	-	-	A	-	C	-	-	-	-	-
Amphinemura sp (March only)						C	R	-	R	A	C	-	R	R	A										
Clioperla clio (March only)						-	-	-	-	R	-	-	-	-	A										
Isoperla spp (March only)						-	-	-	-	C	-	-	-	-	A										
Neophylax oligius	A	R	-	-	-	-	-	-	-	-	-	-	-	-	R[2]	A	-	-	-	-	C	C	-	-	R
Chimarra sp	A	C	A	A	A	C	R	A	A	-	A	C	-	R	-	A	R	-	C	-	A	A	A	A	A
Rhyacophila fenestra (March only)							C	-	R	C	A	C	-	C	-	C									
Psephenus herricki	A	-	A	A	A	A	R	A	C	A	A	R	C	A	C	A	-	C	C	C	A	R	C	A	A
Elimia sp	A	A	C	A	-	A	C	C	C	-	A	A	-	C	-	A	A	R	-	-	A	R	-	R	-
Sum*	40	14	24	31	43	29	6	27	20	57	37	14	7	15	40	40	11	14	6	17	33	15	13	21	31

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

[1]Isonychia was abundant in March 2011 further downstream on Morgan Creek, near the Botanical Garden in Chapel Hill.
[2]Neophylax was abundant in March 2011 in some high quality tributaries in both Carrboro and Chapel Hill.

Table 4. Taxa richness and summary parameters, Bolin Creek tributaries, Carrboro, North Carolina, March 2011.

	Jolly Br			UT Tanyard			UT Bolin
	3/11	4/12	4/13	3/09	4/12	4/13	4/13
Ephemeroptera	3	1	5	-	1	-	-
Plecoptera	2	2	2	-	-	-	-
Trichoptera	3	3	4	2	3	3	1
Coleoptera	2	2	2	-	1	-	1
Odonata	2	2	1	-	1	-	1
Diptera; Misc.	5	2	4	-	1	1	-
Diptera: Chironomidae	10	8	14	3	9	8	6
Oligochaeta	4	1	3	5	5	3	2
Crustacea	3	3	3	2	-	-	1
Mollusca	1	1	1	-	1	1	1
Flow	Intermittent			Perennial?			Intermittent
Total Taxa Richness	35	25	39	12	21	16	13
EPT Taxa Richness	8	6	11	2	4	3	1
NC Biotic Index	6.2	5.9	5.5	7.5	7.8	7.4	7.3
BI Rating (normal streams)[2]	**G-F**	**G-F**	**G-F**	Poor	Poor	Poor	Poor
BI Rating (Small streams)[2]	Fair	Fair	G-F	**Poor**	**Poor**	**Poor**	**Poor**

G-F = Good-Fair. Bold type indicates final classification.
[2]Assumes perennial streams, therefore small-stream rating may not apply to Jolly Branch

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Appendix 1. Bolin Creek, Sites 1-4, March 2010 to June 2012 (Winter/Spring data). R=Rare, C=Common, A=Abundant, +=Present (for Chironomidae, Dec. 2000). Morgan Creek collections (NC 54) limited to most intolerant (EPT) groups. Blue highlights indicate most intolerant species; yellow highlights indicate significant changes in abundance.

Date:	03/10					03/11					06/12					06/13				
Site:	M	1	2	3	4	M	1	2	3	4	M	1	2	3	4	M	1	2	3	4
EPHEMEROPTERA																				
Maccaffertium modestum	C	A	A	A	A	R	A	A	A	-	A	A	A	A	A	A	A	A	A	C
Stenonema femoratum	-	-	-	-	-	C	-	-	-	-	C	-	R	-	-	A	-	-	-	-
Stenacron interpunctatum	A	A	A	A	C	-	A	A	-	C	-	A	C	R	C	A	A	A	C	A
Stenacron pallidum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Leucrocuta aphrodite	C	-	-	-	-	C	-	-	-	-	A	-	-	-	-	A	-	-	-	-
Baetis flavistriga	-	-	-	-	-	-	-	-	-	-	-	R	-	C	A	C	A	A	C	A
Baetis intercalaris	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-
Centroptilum triangulifer	-	A	R	C	-	-	A	C	R	A	R	-	-	-	-	-	-	-	-	-
Procloeon sp	-	-	-	-	-	-	C	-	-	-	-	-	-	-	-	-	-	-	-	-
Acerpenna pygmaea	-	-	-	-	-	-	C	-	R	-	-	-	-	-	-	-	-	-	-	-
Siphlonurus sp	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-
Caenis spp	A	C	R	C	-	C	R	-	-	-	-	-	-	-	-	C	-	-	-	-
Eurylophella spp	A	-	R	C	R	R	-	-	R	R	-	-	-	-	-	-	-	-	-	-
Isonychia spp	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-
Paraleptophlebia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-
Ephemera sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Plauditus dubius gr*	A	-	-	-	-	A	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Leptophlebia sp*	-	-	-	-	-	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ephemerella dorothea*	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ameletus lineatus*	R	-	-	-	-	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-
PLECOPTERA																				
Acroneuria abnormis	A	-	-	C	-	-	R	-	-	-	C	-	-	A	R	-	-	-	-	-
Eccoptura xanthenes	R	R	R	-	-	-	C	-	-	-	-	R	-	-	-	-	-	-	-	-
Perlesta sp	A	C	-	-	-	C	C	R	C	-	C	R	-	-	-	A	R	-	-	-
Isoperla sp*	C	-	-	-	-	A	R	-	-	-	-	-	-	-	-	-	-	-	-	-
I. burkesi*	-	-	-	-		R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clioperla clio*	R	-	-	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphinemura sp*	A	C	R	-	R	A	C	-	R	R	-	-	-	-	-	-	-	-	-	-
TRICHOPTERA																				
Cheumatopsyche spp	-	R	C	A	C	-	C	R	R	C	A	A	A	A	A	A	A	A	A	A
Hydropsyche betteni	-	R	C	C	C	-	R	R	-	R	-	C	C	-	A	R	R	R	C	A
Diplectrona modesta	-	-	-	C	-	-	C	-	-	-	-	R	R	-	-	-	-	-	-	-
Chimarra sp	-	C	R	A	A	-	A	C	-	R	-	A	R	-	C	A	A	A	A	A
Polycentropus sp	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-
Triaenodes ignitus	-	-	-	R	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-
Oecetis sp A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-
Neophylax oligius	-	-	-	-	-	R	-	-	-	-	-	A	-	-	-	R	C	C	-	-
Psilotreta sp (pupa)	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anisocentropus pyraloides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-
Ironoquia punctatissima*	C	A	C	C	R	C	C	C	R	-	-	-	-	-	-	-	-	-	-	-
Rhyacophila fenestra*	A	C	-	R	C	C	-	C	-	-	-	-	-	-	-	-	-	-	-	-
COLEOPTERA																				
Anchytarsus bicolor		A	R	-	-		A	C	-	-		A	-	-	-		R	R	-	-
Macronychus glabratus		-	-	-	-		R	-	-	-		-	-	-	-		-	-	-	-
Dubiraphia sp		-	-	R	C		-	R	-	-		R	-	R	R		C	-	-	R
Stenelmis crenata		C	-	A	C		C	A	R	R		A	A	C	A		A	C	C	C
Psephenus herricki		A	R	A	C		A	R	C	A		A	-	C	C		A	R	C	A
Ectopria nervosa		R	R	-	-		C	R	-	-		-	-	-	-		-	-	-	-
Helichus spp		C	C	-	R		-	C	-	-		C	C	C	R		A	A	-	R
Neoporus spp		C	-	-	-		-	-	-	-		-	-	-	-		C	C	-	R
Neoporus mellitus gr		-	-	-	-		-	R	-	-		R	-	-	-		A	-	-	R
Peltodytes sp		R	-	R	-		-	-	-	-		-	-	-	R		-	-	-	-

Date:	03/10				03/11				06/12				06/13			
Site:	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
ODONATA																
Argia spp	R	R	R	R	-	-	-	-	R	-	-	-	-	-	-	-
Calopteryx sp	C	C	C	R	C	C	R	-	-	-	-	-	-	-	-	-
Enallagma spp	R	R	R	C	-	-	-	R	R	-	-	-	-	-	-	R
Ischnura sp	-	R	-	-	R	-	-	-	-	-	-	-	-	R	-	-
Cordulegaster sp	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-
Gomphus sp	C	C	R	R	R	-	-	-	R	-	-	-	-	-	-	-
Stylogomphus albistylus	-	-	-	-	C	-	R	-	C	C	R	-	R	R	R	-
Libellula sp	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Pachydiplax longipennis	-	-	-	-	-	-	-	R	-	-	-	R	-	-	-	-
Somatochlora sp	R	R	R	R	-	-	R	-	R	R	R	R	R	C	-	-
Tetragoneuria sp	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-
Boyeria vinosa	R	-	-	-	-	-	-	-	R	-	R	-	R	-	-	-
MEGALOPTERA																
Sialis sp	-	-	-	-	R	-	-	-	C	-	-	R	-	-	-	-
DIPTERA: MISC.																
Antocha spp	A	-	A	C	-	-	R	R	-	-	-	-	-	-	-	R
Hexatoma sp	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-
Pseudolimnophila sp	-	-	-	-	-	R	R	-	R	-	-	-	-	-	-	-
Tipula spp	A	A	A	C	C	-	C	R	C	C	C	C	R	R	C	C
Palpomyia complex	C	R	-	-	C	R	R	R	-	-	-	-	R	-	-	-
Cnephia mutata*	-	-	-	-	-	C	A	C	-	-	-	-	-	-	-	-
Prosimulium spp*	-	-	-	R	A	-	C	C	-	-	-	-	-	-	-	-
Simulium spp	-	-	-	-	C	C	A	A	R	A	A	A	A	A	A	A
Chrysops sp	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaoborus sp	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-
Dolichopodidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
DIPTERA: CHIRONOMIDAE																
Ablabesmyia spp (2)	C	R	C	R	A	C	A	A	-	A	-	C	R	-	R	-
Conchapelopia group	C	C	C	R	A	A	C	C	A	A	R	R	A	R	C	C
Nilotanypus sp	-	-	-	-	R	-	-	-	-	-	-	-	C	-	R	-
Natarsia sp	-	-	-	-	-	-	R	-	R	C	C	R	R	-	-	-
Procladius sp	C	-	-	-	C	C	R	R	-	-	-	C	-	-	-	-
Zavrelimyia sp	-	-	R	R	R	-	-	-	-	-	-	-	-	-	-	-
Brillia sp	-	-	-	-	R	-	-	-	-	-	-	-	-	-	R	R
Corynoneura spp	R	-	-	-	-	-	C	R	-	R	R	-	C	-	R	-
Thienemaniella spp	-	-	-	R	-	-	R	-	-	R	-	R	R	-	R	-
Cricotopus bicinctus	-	-	-	-	A	A	A	A	-	R	-	C	-	-	-	-
Cricotopus triannulatus gr	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Cricotopus cylindraceus	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-
Diplocladius cultriger*	C	C	R	-	C	A	A	R	-	-	-	-	-	-	-	-
Eukiefferiella claripennis gr	-	-	R	A	-	-	R	R	-	-	-	R	-	-	-	-
Eukiefferiella brevicalcar gr*	A	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydrobaenus sp*	R	C	R	-	C	-	A	-	-	-	-	-	-	-	-	-
Krenosmittia sp	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nanocladius spp (2-3)	-	-	R	-	-	-	-	C	-	-	-	-	-	-	-	-
Orthocladius spp																
O. obumbratus	A	A	A	R	-	A	C	A	-	-	-	-	-	-	-	-
O. dorenus	-	-	A	A	-	-	-	A	-	-	-	-	-	-	-	-
O. robacki*	R	A	C	-	A	-	-	-	-	-	-	-	-	-	-	-
O. (Eud.) dubitatus	-	-	R	-	-	-	-	R	-	-	-	-	-	-	-	-
Paracricotopus sp	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parametriocnemus lundbecki	C	A	C	C	C	A	C	R	R	R	-	-	A	C	A	A

Date:	03/10				03/11				06/12				06/13			
Site:	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Rheocricotopus robacki	-	-	-	-	-	-	-	-	R	R	-	-	-	-	-	-
Rheocricotopus DWQ sp. 6	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synorthocladius sp	-	-	-	-	R	-	-	-	-	-	-	R	-	-	-	-
Tvetenia bavarica gr	-	R	-	-	C	R	C	C	-	-	-	-	C	-	C	-
Diamesa sp*	R	C	A	A	-	-	R	C	-	-	-	-	-	-	-	-
Potthastia longimanus	-	R	-	-	R	C	R	R	-	-	-	-	-	-	-	-
Sympotthastia sp*	-	-	-	-	-	R	R	-	-	-	-	-	-	-	-	-
Chironomus sp	-	-	-	-	-	R	-	C	R	R	-	-	-	-	-	-
Cryptochironomus spp	-	R	-	-	R	R	-	-	-	R	-	-	-	R	-	-
Dicrotendipes spp	-	-	R	R	-	-	-	R	-	-	-	R	-	-	-	-
Microtendipes spp	R	R	R	C	R	-	-	C	C	R	A	-	A	A	A	C
Paralauterborniella nigrohalterale	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-
Paratendipes sp	-	-	-	-	-	-	-	R	R	-	R	-	-	R	R	-
Phaenopsectra spp	-	-	-	-	-	-	-	C	-	-	-	R	-	-	-	-
Phaenopsectra flavipes gr.	-	-	-	-	C	R	C	C	-	-	-	R	-	R	-	-
Polypedilum flavum	A	A	A	A	-	-	-	C	-	A	A	A	A	A	A	A
Polypedilum aviceps	-	-	-	A	A	A	A	-	-	-	-	-	-	-	-	-
Polypedilum illinoense	-	-	-	-	-	-	-	A	C	-	-	-	-	-	-	-
Polypedilum fallax	-	-	-	-	R	C	-	-	-	-	-	-	R	-	-	-
Polypedilum scalaenum	-	-	-	-	-	-	-	-	-	-	C	C	-	R	R	R
Stenochironomus sp	-	-	-	-	R	-	-	-	R	-	-	R	C	C	-	-
Stictochironomus sp	-	C	R	-	C	C	-	-	-	-	-	-	-	-	-	-
Tribelos sp	-	-	C	C	C	-	C	-	C	C	R	C	C	C	-	R
Xenochironomus xenolabis	-	-	-	-	-	-	-	-	-	C	-	-	-	-	-	-
Cladotanytarsus sp	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Paratanytarsus sp	-	-	R	-	-	-	-	-	-	-	-	R	R	-	R	R
Rheotanytarsus spp	C	-	-	R	-	R	-	-	-	C	-	-	R	-	C	R
Tanytarsus spp	C	R	C	-	A	A	C	A	-	R	-	C	R	-	-	-
OLIGOCHAETA																
Limnodrilus spp (hofmeisteri)	R	R	-	-	-	-	-	C	-	R	C	C	-	-	-	-
Ilyodrilus templetoni	-	-	-	-	-	R	R	R	-	-	-	-	R	-	-	-
Isochaetides curvisetosus	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-
Spirosperma nikolsyii	-	-	-	-	C	R	A	R	-	-	-	-	-	-	-	-
Nais spp	R	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-
Dero sp	-	-	-	-	-	-	R	C	-	-	-	-	-	-	-	-
Stylaria lacustris	-	R	-	-	-	-	C	R	-	-	-	-	-	-	-	-
Haplotaxis gordioides	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-
Lumbriculidae	R	-	-	R												
Lumbriculus variegatus					-	-	-	C	-	-	C	-	R	-	R	C
Ecclipidrilus spp					R	-	C	R	C	-	-	-	C	-	-	-
Megadriles	-	-	-	-	-	-	-	C	-	-	-	C	R	R	R	-
CRUSTACEA																
Crangonyx spp	C	C	C	A	C	A	A	C	C	R	C	R	-	R	-	-
Hyallela azteca	R	C	C	C	R	-	R	A	C	C	R	A	C	C	R	R
Caecidotea sp	-	-	-	R	-	R	A	R	R	C	C	C	-	-	-	R
Cambarus (P.) sp. C Cooper	A	C	C	C	A	A	C	C	A	A	C	-	A	R	C	-
Procambarus acutus	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Date:	03/10				03/11				06/12				06/13			
Site:	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
MOLLUSCA																
Elimia sp	A	C	C	C	A	A	-	C	A	A	R	-	A	R	-	R
Leptoxis sp	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-
Campeloma decisum	-	-	-	-	R	C	-	R	C	-	-	R	C	-	R	-
Physa sp	-	R	R	-	R	A	R	A	C	C	-	A	A	A	C	C
Lymnaea (?) sp	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Helisoma anceps	-	-	-	R	-	C	R	C	-	R	-	C	R	-	-	-
Micromenetus dilatatus	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-
Ferrissia sp	-	-	R	-	R	-	R	-	-	-	-	-	-	-	-	R
Sphaerium spp	R	-	-	-	R	C	-	-	R	C	-	-	-	C	-	-
Pisidium spp	R	R	-	-	-	R	R	-	-	-	-	R	-	-	-	-
Corbicula fluminea	R	R	-	-	C	C	C	-	A	A	C	A	A	-	-	-
Elliptio sp	-	-	-	-	-	-	-	-	C	-	-	-	-	-	-	-
OTHER																
Turbellaria																
Dugesia tigrina	-	-	R	-	-	-	-	R	-	-	-	R	-	-	-	-
Cura foremanii	R	-	R	-	-	-	-	-	R	-	R	-	R	C	C	A
Hydrolimax grisea	-	R	-	-	-	C	C	C	R	-	-	-	-	-	-	-
Hirudinea																
Helobdella triserialis	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Placobdella papillifera	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-
Hemiptera: Corixidae	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-

Appendix 2. Benthic macroinvertebrates at tributaries of Bolin Creek, April 2013, Carrboro, NC. R=Rare, C=Common, A=Abundant,

	Jolly Br	UT Tanyard	UT Bolin
EPHEMEROPTERA			
Maccaffertium modestum	R	-	-
Paraleptophlebia sp	R	-	-
Leptophlebia sp	R	-	-
Plauditus dubius gr	R	-	-
Procloeon sp	R	-	-
PLECOPTERA			
Perlesta sp	A	-	-
Amphinemura sp	A	-	-
TRICHOPTERA			
Cheumatopsyche spp	-	A	-
Hydropsyche betteni	-	C	-
Chimarra sp	-	R	-
Neophylax ornatus	C	-	-
Ironoquia puntatissima	A	-	R
Rhyacophila fenestra	A	-	-
Rhyacophila glaberrima	R	-	-
COLEOPTERA			
Helichus spp	R	-	R
Stenelmis crenata	R	-	-
ODONATA			
Somatochlora sp	R	-	C
DIPTERA: MISC.			
Tipula spp	C	-	-
Limonia sp	-	C	-
Pseudolimnophila sp	R	-	-
Palpomyia complex	C	-	-
Simulium spp	A	-	-
DIPTERA: CHIRONOMIDAE			
Ablabesmyia mallochi	-	-	R
Conchapelopia group	C	-	R
Natarsia sp	C	-	R
Zavrelimyia sp	C	-	-
Diplocladius cultriger	-	-	C
Eukiefferiella claripennis gr	-	R	-
Cricotopus fugax	-	C	-
Cricotopus annulator gr	-	R	-
Orthocladius robacki	C	-	-
Orthocladius obumbratus	C	A	R
Orthocladius dorenus	R	A	-
O. (Eud.) dubitatus	-	A	-
Parametriocnemus lundbecki	A	-	-
Tvetenia bavarica gr	C	-	-
Diamesa sp	R	-	-
Dicrotendipes sp	-	C	-
Paratendipes sp	C	-	-
Tribelos sp	R	-	-
Polypedilum illinoense	C	-	-
Polypedilum flavum	A	-	A
Rheotanytarsus spp	-	R	-
Tanytarsus spp	R	-	-

	Jolly Br	UT Tanyard	UT Bolin
OLIGOCHAETA			
Isochaetides sp	R	-	-
Limnodrilus spp	R	R	-
Nais spp	-	R	-
Lumbriculus variegatus	-	-	A
Ecclipdrilus(?) spp	-	R	-
Megadriles	C	-	R
CRUSTACEA			
Crangonyx spp	A	-	A
Caecidotea sp (forbesi)	A	-	-
Cambarus spp	C	-	-
MOLLUSCA			
Physa spp	-	C	A
Micromenetus dilatatus	R	-	-
Pisidium sp	-	-	C
Sphaerium sp	-	-	R