BIOLOGICAL MONITORING OF BOLIN CREEK AND TRIBUTARIES, CARRBORO, NORTH CAROLINA April-June 2014

LENAT CONSULTING SERVICES
3607 CORBIN STREET
RALEIGH, NC 27612
919-787-8087
LENATBKS@MINDSPRING.COM

ATTENTION: PLEASE READ THIS SECTION FIRST

This lengthy report might at first seem incomprehensible to the average citizen, but it is fairly easy to understand with minimal effort. The long lists of scientific names (in the appendices) are intended for specialists; they provide support for the scientific validity of our conclusions about water quality.

This study uses information about freshwater macroinvertebrates – "bugs" to the non-biologist. Invertebrates are animals without a backbone; "macro" means they are large enough to be seen with the naked eye. They constitute a large proportion of the aquatic life in streams and can be used as an indicator of the health of the entire stream community. Furthermore, they are indicators of the ability of the stream to support fishing, swimming and other uses by Carrboro's citizens. The use of the macroinvertebrate community to assess stream water quality is supported by decades of scientific research. With increasing levels of pollution, we expect to see both fewer species and a shift in community structure to more tolerant groups.

To understand the summary tables, the reader must understand the terms "Taxa Richness" (especially "EPT Taxa Richness", page 2) and "NC Biotic Index" (See page 5). Streams are rated as Excellent, Good, Good-Fair or Fair, using information on the macroinvertebrate community. This report provides information on the present status of water quality in Carrboro's streams and looks for any temporal changes in water quality.

HOW TO READ THIS REPORT

This is the 8th 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 Creek, 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 2014 by sampling benthic macroinvertebrates at 4 sites. Collections also were made in April 2014 at three small tributaries of Bolin Creek and the headwaters 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. EPT taxa richness is the number of taxa within the most intolerant groups: Ephemeroptera, Plecoptera and Trichoptera.

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 permanent 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, and April-June 2012-2014. The months for sampling in 2012-2014 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 2014; Larger streams were sampled in June 2014. 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 2014. The habitat rating is based on standard Division of Water Quality procedures, and produces a value between 0 and 100.

Tributary sites sampled in April of 2014 include UT Bolin Creek at Seawell School Road (a reference site), Jolly Branch and Dry Gulch. Dry Gulch was sampled before and after stream restoration work.

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	4	16	11	6	14	6/6	9	3/4	79	4	25	35	25	15	Tr	Good habitat and flow
Bolin Cr #2	3	16	12	8	14	4/6	10	5/0	78	5.5	10	20	25	30	10	DownstreamWinmore/Claremont. Sand deposition in pools
Bolin Cr #3	4	14	12	9	14	7/6	9	5/4	87	6.5	40	30	15	15	Tr	Very rocky, Poor bank areas
Bolin Cr #4	4	16	12	6	14	6/6	10	4/3	82	6	30	35	20	15	Tr	Rocky. Downstream of some development
Tributaries																
Jolly Br	5	16	14	6	14	6/6	7	4/4	82	2	30	30	25	15	-	Some bank erosion, but largely forested. Good habitat.
UT Bolin Cr	5	15	14	8	14	7/6	10	5/5	89	1.5	40	40	10	10	-	Very small stream, high gradient.
Dry Gulch	2	16	12	10	16	6/7	10	5/3	87	1.5	30	40	20	10	Tr	Sections of the stream have ben restored.

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

The fauna of Chapel Hill streams have been frequently affected by droughts, with some streams 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 2013. 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 Upper Morgan Cr (similar to Bolin Creek), 1999-2014.
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
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	0.03	1.5	3
2012	2	3	7	3	2	0.5	0.2	0.3	8	0.8	0.5	0.8
2013	7	9	4	6	9	8	13	4	0.7	2*	1*	8*
2014	11*	10*	11*	11	15*							

*Estimated from graph of daily flows

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 2012 are median monthly values (not means).

Summer flows for 2013 were much higher than for 2004-2013; 2013-2014 fall/winter/spring flows were relatively high.

PRIOR BIOLOGICAL DATA [Largely unchanged from 2013 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.

For table below, BI = NC Biotic Index, EPT S = Taxa Richness for the EPT (most intolerant) species, EPT N = EPT Abundance, Bioclass = Bioclassification based on macroinvertebrate data. See Methods for greater detail.

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	06/13	-	19	-		Good-Fair
	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 (2012-2014) 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 2012-2014 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 2012-2014 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.

For summaries below, BI = NC Biotic Index, EPT S = Taxa Richness for the EPT (most intolerant) species, EPT N = EPT Abundance, Bioclass = Rating based on macroinvertebrate data.

Data summarized by site for Bolin Creek sites:

-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 Bolin Creek. It has consistently been assigned a Good-Fair bioclassification, with stable biotic index values of 5.6-6.0. This was the only site that supported "small-stream" species like *Eccoptura xanthenes*. EPT taxa richness was at a minimum in 2013, but rebounded in 2014.

Date	Total S	EPT S	BI	EPT N	Bioclass
6/14	53	11	5.8	78	Good-Fair
4/14	52	13	5.6*	93	Good-Fair
6/13	51	8	5.8	58	Good-Fair
6/12	52	10	6.0	57	Good-Fair
3/11	67	18	5.9*	71	Good-Fair
3/10	63	12	5.9*	58	Good-Fair
7/09	54	11	5.5	60	Good-Fair
12/08	57	12	5.9	60	Good-Fair

*Seasonally corrected.

-Bolin Creek 2 (SR 1777). This site is only a short distance from Site 1, but drains the Winmore development. Winmore construction started around 2003, and development has continued since that time. Comparison of Site 1 and Site 2 was intended to evaluation the impact of this large development on Bolin Creek. Including information collected by the NC Division of Water Quality, there is information on the benthic macroinvertebrate community going back to 1993, with yearly data from 2000-2014. Comparison of Sites 1 and 2 are limited to 2008-2014.

Date	Total S	EPT S	BI	EPT N	Bioclass
6/14	54	11	5.9	78	Good-Fair
6/13	37	7	6.0	44	Fair
6/12	42	8	6.4	30	Fair
3/11	52	8	6.8^{+}	32	Fair
3/10	53	13	6.3^{+}	39	Fair
07/09	54	11	6.6	60	Fair
12/08	53	10	5.9	68	Good-Fair
8/06**	47	10	-	50	Fair
9/05**	36	7	-	13	Fair
9/04**	42	10	-	48	Fair
9/03**	35	9	-	40	Fair
7/01*	87	24	6.0	-	Good-Fair
2/01*	82	17	6.5^{+}	-	Not Rated (Drought)
9/00**	71	16	6.2	87	Good-Fair
4/00*	-	26	-	-	Good
3/98*	-	23	-		Good
4/93*	-	24	-	-	Good

*DWQ data, 1993-2000 collections were limited to EPT taxa
**Early Carrboro data, Ecological Consultants/Pennington, No Biotic Index
$^{+}$Seasonally corrected.

Taxa richness for the most intolerant species (EPT Taxa Richness) was greater than 20 only from 1993 and 2001, with Good ratings only from 1993-2000. A substantial decline in water quality was indicated between 2001 and 2003, coincident with the initial stages of the Winmore development. To more easily compare Sites 1 and 2, the following gives between-site changes for all metrics:

Change Bolin Creek 1 vs. Bolin Creek 2 for comparable dates (Very small changes listed as "0")

Date	Total S	EPT S	BI	EPT N	Bioclass
6/14	0	0	0	0	0
6/13	-14	-1	+0.2	-14	Good-Fair→Fair
6/12	-10	-2	+0.4	-27	Good-Fair→Fair
3/11	-15	-10	+0.9	-39	Good-Fair→Fair
3/10	-10	+1	+0.4	-19	Good-Fair→Fair
7/09	-5	0	+1.1	-5	Good-Fair→Fair
12/08	-4	-2	0	-8	0

This table indicates sufficient changes between Sites 1 and 2 to drop the Bioclassification from Good-Fair to Fair from 2009-2013. The Fair rating assigned to Site 2 from 2003-2006 (prior to sampling at Site 1) suggest this impact also occurred from 2003-2006, a overall period of at least ten years. The 2014 sampling showed little difference between Site 1 and Site 2 for summary metrics, although differences could still be see at the species level for taxa like *Psephenus herricki* and *Elimia.*

-Bolin Creek 3. Some recovery is evident between sites 2 and 3, with a Good-Fair rating for this site in 3 out of 7 samples since 2008. The early Carrboro collections (2000-2006) rated the stream based solely on EPT taxa richness; there does not appear to be any true long-term change in water quality for this segment of Bolin Creek. Two intolerant taxa (*Chimarra* and *Psephenus herricki*) were abundant at this site in 2014.

Date	Total S	EPT S	BI	EPT N	Bioclass
6/14	56	9	6.2	63	Fair
6/13	32	6	5.6	39	Good-Fair
6/12	33	5	5.5	34	Fair
3/11	60	10	6.7*	22	Fair
3/10	32	12	6.3*	60	Fair
7/09	46	10	6.4	64	Fair
12/08	52	12	6.2	63	Fair
8/06**	18	6	-	21	Poor?
9/05**	27	6	-	30	Poor?
9/04**	20	7	-	45	Fair
9/03**	35	9	-	46	Fair
9/00**	48	10	6.1	47	Fair

*Seasonally corrected.

**Early Carrboro data, Ecological Consultants/Pennington.

Bolin Creek 3 is often intermediate between a Fair and a Good-Fair bioclassification: Good-Fair according to the Biotic Index, but Poor according to EPT taxa richness. When deciding whether to "round-up" or "round-down", DWQ criteria employ information on EPT abundance (EPT N). Rounding up (to Good-Fair) is used only when EPT N is greater than a value of 71. EPT N for this site is often 60-64, so only a small change in the benthic community will produce the Good-Fair rating.

-Bolin Creek Site 4 (Village Drive). This site is intended to be equivalent to the Estes Drive site that has been monitored by the Town of Carrboro since 2000 and was also sampled by

the NC Division of Water Quality from 1993-2002. When all sources of data are combined, the pattern clearly shows a large decline in water quality between 1998 and 2001.

The Estes Drive/Village Drive site had usually received a Fair rating during drought years, but recovered to Good-Fair in July of 2009. The return of severe summer-drought conditions in 2010 and 2011, however, brought the bioclassification for this segment of Bolin Creek back down to Fair for all collections through 2014. The biotic index for this segment of Bolin Creek was significantly higher (6.7-6.8) in 2011 and 2012 relative to prior collections (5.8-6.4), but the 2013-2014 collections again produced a lower biotic index (5.9-6.3). This suggests some recovery, largely due to the appearance of the intolerant caddisfly, *Chimarra*. The 2014 collection produced a rating right on the borderline between a Fair and a Good-Fair rating. The abundance of the snail *Physa* in both 2011 and 2012 indicated that this segment of Bolin Creek had experienced low dissolved oxygen concentrations, but this problem was not evident in 2013-2014.

Date	Total S	EPT S	BI	EPT N	Bioclass
6/14	57	10	6.3	64	Fair
6/13	33	6	5.9	53	Fair
6/12	52	8	6.8	48	Fair
3/11	58	8	6.7	21	Fair
3/10	42	9	5.8	35	Fair
7/09	58	10	6.2	73	Good-Fair
12/08	44	12	5.9	63	Fair
8/06**	21	6	-	19	Poor?
9/04**	25	8	-	46	Fair
9/03**	25	8	-	48	Fair
3/02*	40	7	7.0	-	Fair (follows Drought)
7/01*	52	9	6.6	-	Fair
2/01*	54	6	7.0	-	Poor?
9/00**	45	4	-	26	Poor
2/98*	59	26	5.1	-	Good
4/93*	-	24	-	-	Good-Fair

*DWQ data, 1993 collections were limited to EPT taxa
**Early Carrboro data, Ecological Consultants/Pennington.
Bioclass based only on EPT Taxa richness

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 absent or rare at Bolin Creek sites in 2013 and 2014.

Chimarra had shown a significant decline in 2011 and 2012, being abundant only at the upstream site on Bolin Creek. In 2013 and 2014, however, this taxon was abundant at all sites. The latter pattern suggested that the better flow conditions 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. This between-site difference was reduced in 2014.

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. Under the higher flow conditions of 2014, Physa was not common or abundant at any of the Bolin Creek sites.

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 2014

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

UT Tanyard Branch below Baldwin Park. 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.

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.

Sampled in 2014

-UT Bolin at Seawell School Road. Sampled in 2009, 2011 and 2012 and 2014. 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*).

-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 in most years (for example heptagenid mayflies and hydropsychid caddisflies) clearly indicated stream flow has often been intermittent. The abundance of *Ironoquia* in 2011, 2013 and 2014 also suggested intermittent flow. Abundant EPT species in most years included two stoneflies *(Perlesta, Amphinemura*) and one caddisfly (*Rhyacophila fenestra*), indicating no significant water quality problems. The stoneflies were less abundant in 2014, but this may be due to colder water temperatures and delayed development of these species. This site was tentatively given a Good-Fair rating in all years, but appeared to have the best water quality in 2013-2014. Higher stream flows in the last two years may have contributed to the modest improvement.

	2011	2012	2013	2014
Total Taxa Richness	33	24	39	37
EPT Taxa Richness	8	6	11	10
NC Biotic Index	6.2	6.1	5.5	5.4
Rating	G-F	G-F	G-F	G-F

-Dry Gulch. Dry Gulch drains a largely residential area, with a “Low Impact Development” (LID) adjacent to the sampling location. There have been some restoration activities in this area, including stream bank stabilization. The abundance of *Ironoquia puntatissima* in 2014 indicated that this is a temporary stream, but the abundance of the intolerant caddisfly

Chimarra suggested some improvement in water quality. Few invertebrates were found in the stream above the development, but macroinvertebrates became abundant about 30 meters further downstream. This may indicate further groundwater inputs to the stream. Between 2009 and 2014, we observed an increase in EPT taxa richness and a change to more intolerant species. The overall classification changed from Poor in 2009 to Fair in 2014. Greater flow rates in 2014 may also have contributed to this change.

	3/2009	4/2014
Total Taxa Richness	20	29
EPT Taxa Richness	3	5
NC Biotic Index	7.1	6.7
Small Stream Rating	Poor	Fair

SUMMARY

Biological sampling on Bolin Creek has consistently indicated Good-Fair 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) was assigned only a Fair rating for 2010-2013, although there is some evidence of a gradual recovery for this part of the stream in 2012 and 2013. Both sites were assigned a Good-Fair rating in 2014, indicating further improvement. Areas further downstream are usually rated as Fair, although Site 3 reached a Good-Fair rating in 2013. Both Sites 3 and 4 are intermediate between a Fair and a Good-Fair rating, and would be assigned Good-Fair ratings based solely on Biotic Index values. A very small improvement might bring both sites up to a level that indicates they as "sustaining designated uses"

No sites had indications of organic loading problems, but some sites on Bolin Creek have shown symptoms of low dissolved oxygen in 2011 and 2013. This problem was not observed in 2014, possibly due to higher flow rates.

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 2014. UT Bolin Creek at Seawell School Road is a minute stream that is fed mainly by groundwater. It continues to have a Good rating, with many rare and intolerant aquatic species. Jolly Branch has intermittent flow, but received a Good-Fair rating, supporting a diverse and intolerant fauna. Dry Gulch is a small stream that was sampled after some restoration work. It showed improvement from a Poor to a Fair rating.

Site 2 and Site 4 on Bolin Creek have been sampled for many years, giving an unusual opportunity to examine long-term trends in water quality. Site 2 showed a shift from Good to Good-Fair between 2000 and 2001. A Further decline from Good-Fair to Fair was seen between 2001 and 2003, coincident with the start of a large construction project. Declines further upstream are also indicated by data from Site 1, which has received a Good-Fair rating since monitoring of this site started in 2008. Repeated droughts may also have influenced these between-year changes.

Site 4 (near the Carrboro/Chapel Hill boundary showed a significant decline from 1998 to 2000, earlier than the changes observed further upstream. It would be useful to compare the changes in the biological community to changes in land use.

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					03/11				
Site:	M	1	2	3	4	M	1	2	3	4	M	1	2	3	4
Ephemeroptera	7	5	4	5	5	12	4	6	5	3	9	7	3	5	4
Plecoptera	6	2	3	3	3	6	3	2	1	1	6	5	1	2	1
Trichoptera	5	5	3	4	4	3	5	5	6	5	3	6	4	3	3
Coleoptera		7	6	6	2		7	4	4	4		5	7	2	2
Odonata		7	4	5	2		6	5	6	4		4	2	3	2
Megaloptera		1	1	-	-		-	-	-	-		1	-	-	-
Diptera: Misc.		4	4	3	2		4	2	2	3		4	4	8	6
Diptera: Chironomidae		11	15	14	15		20	18	22	15		23	18	20	22
Oligochaeta		3	1	4	3		3	2	-	2		3	2	6	8
Crustacea		6	4	4	4		4	4	3	4		3	3	4	4
Mollusca		5	6	2	4		5	4	2	2		6	7	6	4
Other		1	2	2	-		2	1	3	-		-	1	1	2
Total Taxa Richness	-	57	53	52	44	-	63	53	32	42	-	67	52	60	58
EPT Taxa Richness	21*	12	10	12	12	24*	12	13	12	9	21*	18	8	10	8
EPT Abundance	88	60	68	63	63	112	58	39	60	35	6	71	32	22	21
NC Biotic Index	-	5.9	5.9	6.2	5.9	-	5.7	6.1	6.1	5.8	-	5.7	6.6	6.5	6.7
EPT Score	3	2	2	2	2	3.6	2	2	2	1.6	3	3	1.6	2	1.6
BI Score	-	3	3	3	3	-	4	3	3	3.4	-	3.4	2	2.4	2
Site Score	-	2.5	2.5	2.5	2.5	-	3	2.5	2.5	2.5	-	3.2	1.8	2.2	1.8
Rating	G?	G-F	G-F	F	F	G	G-F	F	F	F	G?	G-F	F	F	F

Date:	06/12					06/13					06/14					
Site:	M	1	2	3	4	M	1	2	3	4	M	1+	1	2	3	4
Ephemeroptera	7	3	3	3	3	11	3	3	3	3	10	4	5	6	5	4
Plecoptera	2	2	-	1	1	1	1	0	0	0	2	1	-	-	1	1
Trichoptera	2	5	5	1	4	5	4	4	3	3	5	8	6	5	3	5
Coleoptera		6	2	4	5		7	5	2	6		5	5	5	5	6
Odonata		6	2	3	3		3	3	1	1		5	5	8	5	6
Megaloptera		1	-	-	1		-	-	-	-		-	1	-	1	-
Diptera: Misc.		3	2	2	2		4	2	2	4		4	3	3	2	4
Diptera: Chironomidae		10	18	9	19		16	10	14	9		12	16	16	18	19
Oligochaeta		2	1	3	2		4	1	2	1		2	3	3	3	4
Crustacea		5	4	4	3		2	3	2	2		4	1	2	4	3
Mollusca		7	5	2	6		5	3	2	3		6	6	4	7	3
Other		2	-	1	3		2	3	1	1		1	2	2	2	2
Total Taxa Richness	-	52	42	33	52		51	37	32	33	-	52	53	54	56	57
EPT Taxa Richness	13*	10	8	5	8	19*	8	7	6	6	20*	13	11	11	9	10
EPT Abundance	44	57	30	34	48	89	58	44	39	53	106	93	78	78	63	64
NC Biotic Index	-	6.0	6.4	5.5	6.8	-	5.8	6.0	5.6	5.9	-	5.4	5.8	5.9	6.2	6.3
EPT Score	2	2	1.6	1	1.6	3	1.6	1.4	1.4	1.4	3	2	2	2	1.6	2
BI Score	-	3	3	4	2	-	3.4	3	4	3	-	4	3.4	3	3	3
Site Score	-	2.5	2.3	2.5	1.8	-	2.5	2.2	2.7	2.2	-	3	2.7	2.5	2.3	2.5
Rating	G-F?	G-F	F	F	F	G-F	G-F	F	G-F	F	G-F	G-F	G-F	G-F	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).
+A spring (April) collection to evaluation seasonality in the headwaters

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	-	-	-	-	
06/2014		A	A	A	A	-	-	R	R	

Table 3. Selected intolerant species at Bolin Creek sites 1-4 and Morgan Creek (M), 2009-2014. Note that seasonal changes produce a slightly different set of species for each date.

	07/09					03/10					03/11					06/12					06/13					06/14				
	1	2	3	4	M	1	2	3	4	M	1	2	3	4	M	1	2	3	4	M	1	2	3	4	M	1	2	3	4	M
Isonychia spp (July only)	-	-	-	-	A	-	-	-	-	-	-	-	-	-	-[1]	-	-	-	-	R	-	-	-	-	-	-	-	-	-	A
Acentrella ampla (March only)						-	-	-	-	A	-	-	-	-	A															
Leucrocuta aphrodite	-	-	-	-	A	-	-	-	-	C	-	-	-	-	C	-	-	-	-	A	-	-	-	-	A	-	-	-	-	A
Baetis pluto	-	-	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	A	R	R	A
Acroneuria abnormis	-	-	R	R	C	-	-	C	-	A	R	-	-	-	-	-	-	A	-	C	-	-	-	-	-	-	-	R	R	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	A	-	-	-	-	C	C	-	-	R	A	A	-	-	A
Chimarra sp	A	C	A	A	A	C	R	A	A	-	A	C	-	R	-	A	R	-	C	-	A	A	A	A	A	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	A	R	R	A	A
Elimia sp	A	A	C	A	-	A	C	C	C	-	A	A	-	C	-	A	A	R	-	-	A	R	-	R	-	A	C	R	R	-
Sum*	40	14	24	31	53	29	6	27	20	57	37	14	7	15	40	40	11	14	6	17	33	15	13	21	31	43	34	14	23	63

*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.

Table 4. Taxa richness and summary parameters, Bolin Creek tributaries, Carrboro, North Carolina, 2011-2014.

	Jolly Br				Dry Gulch		UT Bolin Seawell		Bolin 1
	3/11	4/12	4/13	4/14	3/09	4/14	3/09	4/14	4/14
Ephemeroptera	3	1	5	1	-	1	4	3	4
Plecoptera	2	2	2	2	-	-	4	3	1
Trichoptera	3	3	4	7	3	4	8	10	8
Coleoptera	2	2	2	2	-	1	3	4	5
Odonata	2	2	1	2	-	1	1	1	5
Diptera; Misc.	5	2	4	3	1	-	4	3	4
Diptera: Chironomidae	10	8	14	14	8	14	12	11	12
Oligochaeta	4	1	3	1	5	4	3	2	2
Crustacea	3	3	3	3	2	3	3	3	4
Mollusca	1	1	1	1	-	1	2	2	6
Other	-	-	-	1	1	-	3	2	1
Flow	Intermittent				Intermittent		Int/Per		Perennial
Total Taxa Richness	35	25	39	37	20	29	47	44	52
EPT Taxa Richness	8	6	11	10	3	5	16	16	13
NC Biotic Index	6.2	5.9	5.5	5.4	7.1	6.7	4.7	4.9	5.4
BI Rating (normal streams)[2]	**G-F**	**G-F**	**G-F**	**G-F**	Fair	Fair	Good	Good	**Good-Fair**
BI Rating (Small streams)[2]	Fair	Fair	G-F	G-F	**Poor**	**Fair**	**Good**	**Good**	Good-Fair

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

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Appendix 1. Bolin Creek, Sites 1-4, March 2010 to June 2014 (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					06/14				
Site:	M	1	2	3	4	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	A	A	A	A	A
Stenonema femoratum	-	-	-	-	-	C	-	-	-	-	C	-	R	-	-	A	-	-	-	-	R	-	-	-	-
Stenacron interpunctatum	A	A	A	A	C	-	A	A	-	C	-	A	C	R	C	A	A	A	C	A	A	A	A	A	A
Stenacron pallidum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	C	C	R	-
Leucrocuta aphrodite	C	-	-	-	-	C	-	-	-	-	A	-	-	-	-	A	-	-	-	-	A	-	-	-	-
Baetis flavistriga	-	-	-	-	-	-	-	-	-	-	-	R	-	C	A	C	A	A	C	A	R	A	C	A	A
Baetis intercalaris	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Baetis pluto	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A	C	A	R	R
Labiobaetis propinquum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-
Centroptilum triangulifer	-	A	R	C	-	-	A	C	R	A	R	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Procloeon sp	-	-	-	-	-	-	C	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Acerpenna pygmaea	-	-	-	-	-	-	C	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-
Caenis spp	A	C	R	C	-	C	R	-	-	-	-	-	-	-	-	C	-	-	-	-	-	-	-	-	-
Isonychia spp	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	A	-	-	-	-
Paraleptophlebia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-	-	-	-	-	-
Habrophlebia vibrans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-	-	-	-	-	-
Hexagenia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-
Eurylophella spp*	A	-	R	C	R	R	-	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Siphlonurus sp*	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plauditus dubius gr*	A	-	-	-	-	A	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	R	-	-
Leptophlebia sp*	-	-	-	-	-	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ephemerella dorothea*	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ameletus lineatus*	R	-	-	-	-	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PLECOPTERA																									
Acroneuria abnormis	A	-	-	C	-	-	R	-	-	-	C	-	-	A	R	-	-	-	-	-	C	-	-	R	R
Eccoptura xanthenes	R	R	R	-	-	-	C	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-
Perlesta sp	A	C	-	-	-	C	C	R	C	-	C	R	-	-	-	A	R	-	-	-	C	-	-	-	-
Isoperla sp*	C	-	-	-	-	A	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
I. burkesi*	-	-	-	-		R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clioperla clio*	R	-	-	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphinemura sp*	A	C	R	-	R	A	C	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Date:	03/10					03/11					06/12					06/13					06/14				
Site:	M	1	2	3	4	M	1	2	3	4	M	1	2	3	4	M	1	2	3	4	M	1	2	3	4
TRICHOPTERA																									
Cheumatopsyche spp	-	R	C	A	C	-	C	R	R	C	A	A	A	A	A	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	A	A	A	A	A
Diplectrona modesta	-	-	-	C	-	-	C	-	-	-	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-
Chimarra sp	-	C	R	A	A	-	A	C	-	R	-	A	R	-	C	A	A	A	A	A	A	A	A	A	A
Lype diversa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Polycentropus sp	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	C	-	-	-	-
Triaenodes ignitus	-	-	-	R	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	R
Triaenodes perna (pupa)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Nectopsyche exquisita	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-
Hydroptila sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
Oecetis sp A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-
Neophylax oligius	-	-	-	-	-	R	-	-	-	-	-	A	-	-	-	R	C	C	-	-	A	A	A	-	-
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	-	-		C	-	-	-
Macronychus glabratus		-	-	-	-		R	-	-	-		-	-	-	-		-	-	-	-		-	-	R	-
Dubiraphia sp		-	-	R	C		-	R	-	-		R	-	R	R		C	-	-	R		R	R	C	R
Stenelmis crenata		C	-	A	C		C	A	R	R		A	A	C	A		A	C	C	C		A	A	C	A
Psephenus herricki		A	R	A	C		A	R	C	A		A	-	C	C		A	R	C	A		A	R	R	A
Ectopria nervosa		R	R	-	-		C	R	-	-		-	-	-	-		-	-	-	-		-	-	-	-
Helichus spp		C	C	-	R		-	C	-	-		C	C	C	R		A	A	-	R		C	C	R	R
Coptotomus sp		-	-	-	-		-	-	-	-		-	-	-	-		-	-	-	-		-	-	-	R
Neoporus spp		C	-	-	-		-	-	-	-		-	-	-	-		C	C	-	R		-	-	-	A
Neoporus mellitus gr		-	-	-	-		-	R	-	-		R	-	-	-		A	-	-	R		-	R	-	-
Peltodytes sp		R	-	R	-		-	-	-	-		-	-	-	R		-	-	-	-		-	-	-	-

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Site:	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
ODONATA																				
Argia spp	R	R	R	R	-	-	-	-	R	-	-	-	-	-	-	-	A	C	C	C
Calopteryx sp	C	C	C	R	C	C	R	-	-	-	-	-	-	-	-	-	R	-	R	-
Enallagma spp	R	R	R	C	-	-	-	R	R	-	-	-	-	-	-	R	R	C	R	C
Ischnura sp	-	R	-	-	R	-	-	-	-	-	-	-	-	R	-	-	-	R	-	-
Cordulegaster sp	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hagenius brevistylus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
Gomphus sp	C	C	R	R	R	-	-	-	R	-	-	-	-	-	-	-	-	R	-	R
Stylogomphus albistylus	-	-	-	-	C	-	R	-	C	C	R	-	R	R	R	-	-	R	-	R
Libellula sp	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Pachydiplax longipennis	-	-	-	-	-	-	-	R	-	-	-	R	-	-	-	-	-	-	-	-
Somatochlora sp	R	R	R	R	-	-	R	-	R	R	R	R	R	C	-	-	C	A	C	C
Tetragoneuria sp	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boyeria vinosa	R	-	-	-	-	-	-	-	R	-	R	-	R	-	-	-	-	R	-	-
Basiaeschna janata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	R	R	-
MEGALOPTERA																				
Sialis sp	-	-	-	-	R	-	-	-	C	-	-	R	-	-	-	-	R	-	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	A	C	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	A	A	A	A
Chrysops sp	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaoborus sp	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-	-	-	-
Empididae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
Dolichopodidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Anopheles sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	
Dixella indiana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	R

Date:	03/10				03/11				06/12				06/13				06/14			
Site:	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
DIPTERA: CHIRONOMIDAE																				
Ablabesmyia spp (2)	C	R	C	R	A	C	A	A	-	A	-	C	R	-	R	-	R	C	R	R
Conchapelopia group	C	C	C	R	A	A	C	C	A	A	R	R	A	R	C	C	A	C	C	R
Nilotanypus sp	-	-	-	-	R	-	-	-	-	-	-	-	C	-	R	-	C	R	R	R
Natarsia sp	-	-	-	-	-	-	R	-	R	C	C	R	R	-	-	-	R	R	-	-
Procladius sp	C	-	-	-	C	C	R	R	-	-	-	C	-	-	-	-	-	-	R	-
Zavrelimyia sp	-	-	R	R	R	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Brillia sp	-	-	-	-	R	-	-	-	-	-	-	-	-	-	R	R	-	-	-	-
Corynoneura spp	R	-	-	-	-	-	C	R	-	R	R	-	C	-	R	-	R	R	R	R
Thienemaniella spp	-	-	-	R	-	-	R	-	-	R	-	R	R	-	R	-	-	-	-	-
Cricotopus bicinctus	-	-	-	-	A	A	A	A	-	R	-	C	-	-	-	-	-	-	-	C
Cricotopus triannulatus gr	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	R
Cricotopus cylindraceus	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diplocladius cultriger*	C	C	R	-	C	A	A	R	-	-	-	-	-	-	-	-	-	-	-	-
Eukiefferiella claripennis gr	-	-	R	A	-	-	R	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	-	-	-	-	-	-	-	-	-	-	R	R
Paracricotopus sp	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parametriocnemus lundbecki	C	A	C	C	C	A	C	R	R	R	-	-	A	C	A	A	R	R	-	-
Rheocricotopus robacki	-	-	-	-	-	-	-	-	R	R	-	-	-	-	-	-	-	C	-	-
Rheocricotopus DWQ sp. 6	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synorthocladius sp	-	-	-	-	R	-	-	-	-	-	-	R	-	-	-	-	-	-	R	R
Tvetenia bavarica gr	-	R	-	-	C	R	C	C	-	-	-	-	C	-	C	-	R	-	-	-
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	-	-	C	C	R	-
Cryptotendipes sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-

Date:	03/10				03/11				06/12				06/13				06/14			
Site:	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Dicrotendipes spp	-	-	R	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	-	R	-	C	R
Phaenopsectra spp	-	-	-	-	-	-	-	C	-	-	-	R	-	-	-	-	C	-	R	R
Phaenopsectra flavipes gr.	-	-	-	-	C	R	C	C	-	-	-	R	-	R	-	-	-	-	-	R
Polypedilum flavum	A	A	A	A	-	-	-	C	-	A	A	A	A	A	A	A	A	A	A	C
Polypedilum aviceps	-	-	-	A	A	A	A	-	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum illinoense	-	-	-	-	-	-	-	A	C	-	-	-	-	-	-	-	-	-	-	-
Polypedilum fallax	-	-	-	-	R	C	-	-	-	-	-	-	R	-	-	-	-	-	-	-
Polypedilum scalaenum	-	-	-	-	-	-	-	-	-	-	C	C	-	R	R	R	A	C	C	C
Stenochironomus sp	-	-	-	-	R	-	-	-	R	-	-	R	C	C	-	-	-	-	R	-
Stictochironomus sp	-	C	R	-	C	C	-	-	-	-	-	-	-	-	-	-	-	-	C	-
Tribelos sp	-	-	C	C	C	-	C	-	C	C	R	C	C	C	-	R	C	R	A	C
Xenochironomus xenolabis	-	-	-	-	-	-	-	-	-	C	-	-	-	-	-	-	-	-	-	-
Cladotanytarsus sp	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Paratanytarsus sp	-	-	R	-	-	-	-	-	-	-	-	R	R	-	R	R	-	R	-	-
Rheotanytarsus spp	C	-	-	R	-	R	-	-	-	C	-	-	R	-	C	R	-	R	R	C
Tanytarsus spp	C	R	C	-	A	A	C	A	-	R	-	C	R	-	-	-	R	C	C	-
OLIGOCHAETA																				
Limnodrilus spp (hofmeisteri)	R	R	-	-	-	-	-	C	-	R	C	C	-	-	-	-	R	-	C	-
Ilyodrilus templetoni	-	-	-	-	-	R	R	R	-	-	-	-	R	-	-	-	-	R	-	-
Isochaetides curvisetosus	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-
Spirosperma nikolsyii	-	-	-	-	C	R	A	R	-	-	-	-	-	-	-	-	-	-	-	-
Nais spp	R	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	R	R	R	R
Dero sp	-	-	-	-	-	-	R	C	-	-	-	-	-	-	-	-	-	-	-	-
Slavinia appendiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
Stylaria lacustris	-	R	-	-	-	-	C	R	-	-	-	-	-	-	-	-	-	-	-	-
Haplotaxis gordioides	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lumbriculidae	R	-	-	R																
Lumbriculus variegatus					-	-	-	C	-	-	C	-	R	-	R	C	-	R	C	R
Ecclipidrilus spp					R	-	C	R	C	-	-	-	C	-	-	-	R	-	-	-
Megadriles	-	-	-	-	-	-	-	C	-	-	-	C	R	R	R	-	-	-	-	-
Cambarinicolidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R

Date:	03/10				03/11				06/12				06/13				06/14			
Site:	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
CRUSTACEA																				
Crangonyx spp	C	C	C	A	C	A	A	C	C	R	C	R	-	R	-	-	-	-	R	-
Hyallela azteca	R	C	C	C	R	-	R	A	C	C	R	A	C	C	R	R	-	C	C	C
Caecidotea sp	-	-	-	R	-	R	A	R	R	C	C	C	-	-	-	R	-	-	R	R
Cambarus (P.) sp. C Cooper	A	C	C	C	A	A	C	C	A	A	C	-	A	R	C	-	A	C	C	C
Procambarus acutus	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MOLLUSCA																				
Elimia sp	A	C	C	C	A	A	-	C	A	A	R	-	A	R	-	R	A	C	R	R
Leptoxis sp	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-
Campeloma decisum	-	-	-	-	R	C	-	R	C	-	-	R	C	-	R	-	C	-	C	-
Physa sp	-	R	R	-	R	A	R	A	C	C	-	A	A	A	C	C	R	R	R	R
Lymnaea (?) sp	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Helisoma anceps	-	-	-	R	-	C	R	C	-	R	-	C	R	-	-	-	-	-	-	R
Micromenetus dilatatus	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-
Ferrissia sp	-	-	R	-	R	-	R	-	-	-	-	-	-	-	-	R	-	-	R	-
Sphaerium spp	R	-	-	-	R	C	-	-	R	C	-	-	-	C	-	-	C	A	R	-
Pisidium spp	R	R	-	-	-	R	R	-	-	-	-	R	-	-	-	-	-	-	-	-
Corbicula fluminea	R	R	-	-	C	C	C	-	A	A	C	A	A	-	-	-	A	-	C	-
Elliptio sp	-	-	-	-	-	-	-	-	C	-	-	-	-	-	-	-	R	A	R	-
OTHER																				
Turbellaria																				
Dugesia tigrina	-	-	R	-	-	-	-	R	-	-	-	R	-	-	-	-	-	-	-	-
Cura foremanii	R	-	R	-	-	-	-	-	R	-	R	-	R	C	C	A	A	A	R	C
Hydrolimax grisea	-	R	-	-	-	C	C	C	R	-	-	-	-	-	-	-	-	-	-	-
Hirudinea																				
Helobdella triserialis	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Placobdella papillifera	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	R	-
Placobdella parasitica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	R
Hemiptera: Corixidae	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Hemiptera: Notonecta sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-

Appendix 2. Benthic macroinvertebrates at tributaries of Bolin Creek and upper Bolin Creek, April 2014, Carrboro, NC.
R=Rare, C=Common, A=Abundant,

	Bolin 1	UT Bolin/Seawell	Jolly	Dry Gulch
EPHEMEROPTERA				
Maccaffertium modestum	A	A	-	-
Stenacron carolina	-	A	R	-
Stenacron interpunctatum	A	R	-	-
Paraleptophlebia sp	-	C	-	-
Leptophlebia sp				
Baetis flavistriga	A	-	-	-
Baetis intercalaris	-	-	-	R
Plauditus dubius gr	R	-	-	-
Procloeon sp				
Ameletus lineatus	-	R	-	-
Eurylophella verisimilis	-	A	-	-
PLECOPTERA				
Perlesta sp	C	C	R	-
Amphinemura sp		A	R	-
Leuctra sp	-	R	-	-
TRICHOPTERA				
Cheumatopsyche spp	A	-	R	A
Hydropsyche betteni	A	R	R	-
Diplectrona modesta	-	C	-	-
Chimarra sp	A	-	C	A
Wormaldia sp	-	C	-	-
Polycentropus sp	-	R	-	-
Neophylax ornatus	C	A	A	-
Neophylax oligius	A	-	R	-
Psilotretra sp	-	R	-	-
Ironoquia puntatissima	A	A	A	A
Rhyacophila fenestra	C	A	A	R
Rhyacophila glaberrima	-	A	-	-
Lepidostoma sp	-	R	-	-
Triaenodes ignitus	C	-	-	-
COLEOPTERA				
Helichus spp	R	R	-	R
Stenelmis crenata	R	-	C	-
ODONATA				
Argia sp	R	-	-	R
Calopteryx sp	A	-	C	-
Enallagma sp	C	-	-	-
Stylogomphus albistylus	R	-	-	-
Helocordulia uhleri	-	-	R	-
Somatochlora sp	R	R	-	-
DIPTERA: MISC.				
Tipula spp	A	A	-	-
Antocha sp	R	-	-	-
Empididae	R	-	-	-
Simulium spp	R	A	-	-
Protoplasa fitchii	-	R	-	-

	Bolin 1	UT Bolin/Seawell	Jolly	Dry Gulch
DIPTERA: CHIRONOMIDAE				
Ablabesmyia mallochi	R	-	-	-
Conchapelopia group	C	C	R	R
Natarsia sp	-	-	R	R
Paramerina sp	R	-	-	-
Zavrelimyia sp	-	R	C	R
Diplocladius cultriger	-	-	-	C
Eukiefferiella claripennis gr	-	A	-	R
Corynoneura spp	-	-	-	R
Cricotopus bicinctus	A	-	-	-
Cricotopus annulator gr	-	-	R	-
Orthocladius robacki	R	C	-	R
Orthocladius obumbratus	R	A	-	R
Orthocladius dorenus	-	-	C	A
Paraphaenocladius sp	-	R	-	R
Parametriocnemus lundbecki	-	C	C	-
Rheocrocotopus unidentatus	-	-	R	-
Tvetenia bavarica gr	C	C	C	R
Diamesa sp	-	-	C	-
Chironomus sp	-	-	-	R
Dicrotendipes sp	R	-	R	-
Microtendipes sp	C	R	C	R
Tribelos sp	A	-	-	-
Polypedilum illinoense	-	-	R	-
Polypedilum aviceps	A	-	R	-
Polypedilum fallax	-	R	-	-
Polypedilum scalaenum gr	R	R	-	R
OLIGOCHAETA				
Limnodrilus spp	R	-	-	-
Ilyodrilus templetoni	-	-	-	R
Nais spp	-	A	-	A
Lumbriculus variegatus	-	A	-	C
Ecclipdrilus(?) spp	R	-	-	-
Rhynchelmis bolinensis	-	-	-	A
Megadriles	-	-	R	-
CRUSTACEA				
Crangonyx spp	R	A	R	A
Hyallela azteca	A	-	-	-
Caecidotea sp (forbesi)	-	C	-	R
Procambarus sp	R	-	-	-
Cambarus spp	C	C	C	C
MOLLUSCA				
Elimia sp	A	C	-	-
Ferrissia sp	-	-	C	-
Campeloma decisum	R	-	-	-
Physa spp	C	-	-	C
Micromenetus dilatatus	-	R	-	-
Elliptio complanata	R	-	-	-
Pisidium sp	R	-	-	-
Sphaerium sp	R	-	-	-
OTHER				
Cura foremanii	C	-	-	-
Prostoma gracens	-	R	R	-
Hydriacarina	-	R	-	-

Appendix 3. Carrboro Stream Sites, April-June 2014

Bolin Creek sites are numbered from most upstream (Site 1) to most downstream (Site 4). Samples from Bolin Creek and Morgan Creek were collected in June 2014; tributary sites were sampled in April 2014.

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, June 2014.

This part of Bolin Creek averaged about 4-5 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.

Habitat problems included fewer riffles, bank erosion, lack of a buffer on one side and a decrease in habitat diversity. Freshwater mussels (*Elliptio complanata*) were abundant in one pool.

Bolin Creek Site 2, June 2014.

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, December 2008.

There are no significant habitat problems in this portion of the stream, but there was a lack of good bank habitat.

Bolin Creek 4. Site 4 was moved slightly downstream into Chapel Hill (Village Dr) in 2011, so that data from this site could be used by both towns.

Bolin Creek Site 4, March 2011.

This portion of Bolin Creek is similar to the site on Estes Drive, having good rocky substrate. Attached filamentous algae was very abundant at the Village Drive site in March 2011, but was not a problem in later years.

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 often produced a Good or Excellent bioclassification for this site, although it has only been rated as Good-Fair in the last two years.


Morgan Creek, NC 54, June 2012.

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. Residential land use, however, has been increasing in the Morgan Creek catchment in recent years.

Jolly Branch near SR 1777 (just downstream of Bolin Creek 3). This site was accessed by walking about 100 meters downstream of SR 1777 (Homestead), crossing Bolin Creek, and going about 30 meters upstream on Jolly Branch. This small stream (1 meter wide) had good rocky habitat, but showed severe bank erosion in many places.

The surrounding area was largely forested, although there are residential areas further upstream. The aquatic life at Jolly Branch indicates that it may stop flowing (or go dry) during drought periods.


Jolly Branch, April 2012.

Dry Gulch. Dry Gulch drains a largely residential area, with a “Low Impact Development” (LID) adjacent to the sampling location. Restoration activities for this area included stream bank stabilization. Diversity in this stream may be limited by long periods with no flowing water.

Dry Gulch, June 2014.

UT Bolin Creek at Seawell School Rd. This very small UT was first sampled during a search for high quality streams in March 2009. The stream was completely dry in its upper reach, but groundwater inputs produced small areas of flowing water about 50 meters further downstream.


UT Bolin Creek, Seawell School Rd, March 2011.

This minute stream supports many rare and intolerant macroinvertebrate species. It serves as a reference site for comparisons with other small streams in the Carrboro/Chapel Hill area.