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

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HOW TO READ THIS REPORT

This is the 6th 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**.

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

INTRODUCTION [Note: this section largely repeated from early reports.]

Water quality in Bolin Creek was evaluated in June 2012 by sampling benthic macroinvertebrates at 4 sites. Collections also were made in April 2012 at six 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 developed areas in Carrboro and Chapel Hill as it flows towards its confluence with Booker Creek.

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 North Carolina 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: intensive "Standard Qualitative" collections and more rapid" EPT" and Qual-4 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) with tolerance values derived from the NC database. Biotic indices are based on a 0-10 scale, where 0 represents the best water quality and 10 represents the worst 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

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

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

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

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 - <4.4
Good - 4.4-5.4
Good-Fair – 5.5-6.0
Fair - 6.1-7.0
Poor - >7.0

These criteria were developed only for permanent criteria; 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. The months for sampling in 2012 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 2012; Larger streams were sampled in June 2012. More detailed site descriptions (with photos) are presented in Appendix 3.

Table 1 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 1. 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	15	8	14	6/7	10	5/5	93	4.5	20	30	30	20	Tr	
Bolin Cr #2	5	18	12	6	7	7/2	7	5/1	70	4.5	20	25	20	25	10	DownstreamWinmore/Claremont. Sand deposition in pools
Bolin Cr #3	5	20	15	6	14	6/6	9	5/4	90	5	50	30	10	10	-	Very rocky, poor banks. Raining
Bolin Cr #4	5.	18	8	6	7	6/3	7	3/1	63	5.5	35	25	20	20	Tr	Rocky. Downstream of developed areas in Carrboro.
Morgan Cr	7.5	18	10	6	16	7/7	10	5/5	89	7.5	35	35	20	10	-	
Tributaries																
Seawell UT	4	20	15	4	14	7/6	10	5/5	90	1	40	40	10	10	-	Small, dry in upstream segment. Forested.
Horne Hollow	5	18	12	6	14	6/6	7	4/3	81	1	10	30	40	20	Tr	Sparse fauna, but with intolerant species.
Jolly Br	5	10	14	10	10	5/5	7	5/5	76	1	15	40	20	15	10	Severe bank erosion, but largely forested. Good habitat.
Jones Cr	4	16	12	8	15	5/5	10	5/5	85	2	10	30	30	20	10	Entrenched, silt layer
Camden UT	5	20	13	10	16	6/6	8	4/3	91	0.7	-	10	60	30	Tr	Residential, small
UT Tanyard	4	15	11	10	14	5/6	7	4/4	79	1	15	50	25	15	Tr	High density residential/urban. High Conductivity

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	2	20	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).

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):

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)

Bolin Creek (Tables 1-3, Appendix 1)

Early samples from Bolin Creek (prior to 2000) indicated Good water quality in the upper section, declining slightly to Good-Fair further downstream. Surveys in 2000, however, produced a Fair rating for sites at Waterside Drive (#3) and Estes Drive (#4). It appears that nonpoint source runoff had a significant negative effect on water quality in Bolin Creek between 1998 and 2000. Note that changes in habitat were not responsible for any 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
Note that 2003-2004 would be expected to be a period of recovery.
-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. Another 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 rating assigned to much of Bolin Creek during this period have been used to show that Bolin Creek does not support designated used, but note that some intolerant species were still abundant at some Bolin sites through 2012.

Routine sampling was switched from summer months to winter/spring months to avoid these periods of extreme low flow. The 2012 collections were made in both April (tributaries) and in June (Bolin Creek). Much of Bolin Creek is functioning as an intermittent stream and may be difficult to evaluate using DWQ criteria for perennial streams. Taxa typical of temporary stream or smaller streams are increasing at Bolin Creek, especially the caddisflies *Rhyacophila fenestra* and *Ironoquia punctatissima*. Conversely some components of a normal stream fauna (esp. hydropschid and philopotamid caddisflies) are declining in abundance at both Morgan Creek and upper Bolin Creek. The latter species are filter-feeders and they are highly dependent on the presence of flowing water. This pattern suggests that the continuing droughts are having an impact on the composition of the invertebrate fauna in Carrboro streams.

Comparisons of the June 2012 surveys with earlier collections (2000-2010) 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. Some species that have “disappeared” may be lost through emergence, rather than through a change in water quality. The EPT taxa richness values for Bolin Creek in 2012 are unusually low, but these low values are sometimes offset by the presence of highly intolerant species. This pattern suggests that summer low-flows are still limiting the diversity of Bolin Creek macroinvertebrates.

The December 2008 survey produced Good-Fair ratings at all Bolin Creek sites and a Good rating at Morgan Creek (Table 1). This survey followed a period of higher flow, potentially allowing some recovery from drought effects. The March 2010 survey, however, followed a period of extreme low flows, with sites 2 and 4 declining to a Fair rating. A similar pattern was observed in 2012.

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*). *Chimarra* showed the most significant decline in 2011 and 2012, being abundant only at the upstream site on Bolin Creek. Note, however, that *Chimarra* in 2012 was abundant at a site further downstream in Chapel Hill. *Acroneuria* had almost disappeared from Bolin Creek, with only a single specimen collected in 2011. In 2012, however, this intolerant species was abundant at Bolin Creek station 3, suggesting that further recovery is possible.

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. In 2009 and 2010, there was some recovery at site 3, and some recovery was also observed in 2012. Station 4, however, (at the Carrboro/Chapel Hill boundary) has shown a steady decline in water quality.

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 thee 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.

Bolin Creek Tributaries (Table 4, Appendix 2)
Six tributaries of Bolin were sampled in March 2011: an unnamed tributary (UT) in a forested area south of Seawell School Rd, an unnamed tributary at Horne Hollow Rd, an unnamed tributary above the Winmore development, an unnamed tributary of Tanyard Branch near Baldwin Park , Jolly Branch near the Carrboro/Chapel Hill boundary and Jones Creek at Turtleback Crossing.

UT Seawell School Road. This site had also been sampled in 2009 and 2011. 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*). This very small stream (<1 meter wide) is sometimes dry in its upper reaches, but was able to maintain flow in the lower sections through groundwater inputs. This stream appears to always maintain some flowing water segments, even under drought conditions.

UT Horne Hollow Rd. This small stream (1-2 meters wide) was thought by town personnel to maintain perennial flow, even during periods when Bolin Creek went dry. It runs through a mix of older and newer residential areas, usually with a good riparian buffer zone. The area immediately around the sampling site, however, has a cleared sewer easement with little or no buffer zone. The fauna was not as diverse as the Seawell UT, but this stream also supported a highly intolerant fauna and received an Excellent bioclassification in both 2011 and 2012.

Jolly Branch. This stream is near the Chapel Hill and Carrboro boundary, and will be included in reports to both towns. The stream is entirely forested at the collection site, but has some older residential areas further upstream. This stream had signs of intermittent flow, lacking filter-feeding caddisflies, *Maccaffertium*, and *Elimia*. This is similar to the pattern observed in upper Morgan Creek. These flow interruptions limit the diversity of the aquatic fauna, but the abundance of intolerant species (*Amphinemura*, *Rhyacophila fenestra*) suggested a Good-Fair rating.

Jones Cr. The April 2012 survey was the first collection for Jones Creek at Turtleback Crossing. Although this is a fairly large stream (3-4 meters wide), the macroinvertebrate fauna suggested intermittent flow. 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, Limnodrilus*). This site is tentatively assigned a Fair rating.

UT Bolin Creek at Camden Rd. This site was sampled for the first time in 2012. It is a very small stream with gravel and sand substrate. The fauna (*Ironoquia* abundant) clearly indicated that this stream goes dry in summer months. This site is tentatively assigned a Good-Fair rating.

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. This 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 21 in 2012; EPT taxa richness increased from 2 to 4 over the same period. The mayfly *Baetis flavistriga* was especially abundant in this stream segment. Although this small stream has good habitat after the mitigation project, conductivity remains very high (500+ uhmo/cm in 2012).

SUMMARY

Biological sampling on Bolin Creek has consistently indicated Good-Fair or Good water quality in upper Bolin Creek, in spite of some development and persistent summer droughts. This segment of Bolin Creek supports many highly intolerant species. Areas further downstream have fluctuated between a Good-Fair and a Fair rating, with a Fair rating at 2-3 downstream sites in 2011 and 2012 (see Table 1). The most severe water quality problems occur at the most downstream site, draining a more developed part of Carrboro.

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 drought. Data is needed from a year with higher summer flow before we can determine if Bolin Creek can support its designated uses.

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.

No sites had indications of organic loading problems, but the most downstream site on Bolin Creek showed symptoms of low dissolved oxygen in 2012. Excessive growth of filamentous algae may have contributed to this problem in 2011, but such growths were not seen in June 2012.

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.

Excellent water quality was demonstrated in unnamed tributaries at Seawell School Road and Hornehollow Road; Good-Fair water quality was observed in Jolly Branch and UT Bolin Creek at Camden Rd. Jones Creel received a Fair rating, while UT Tanyard Branch (draining downtown Carrboro) received a Poor rating. The very high conductivity values recorded for this site at base flow (>500 umhos/cm) suggest contaminated groundwater.

Table 1. Taxa richness*** by group and summary parameters, Bolin Creek and Morgan Creek, Orange County, September and December 2000 vs. December 2008 and March 2010. Color shading used to illustrate numbers that indicate best water quality (blue), worst water quality (red) and intermediate water quality (yellow).

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

Date:	03/11					06/12				
Site:	M	1	2	3	4	M	1	2	3	4
Ephemeroptera	9	7	3	5	4	7	3	3	3	3
Plecoptera	6	5	1	2	1	2	2	-	1	1
Trichoptera	3	6	4	3	3	2	5	5	1	4
Coleoptera		5	7	2	2		6	2	4	5
Odonata		4	2	3	2		6	2	3	3
Megaloptera		1	-	-	-		1	-	-	1
Diptera: Misc.		4	4	8	6		3	2	2	2
Diptera: Chironomidae		23	18	20	22		10	18	9	19
Oligochaeta		3	2	6	8		2	1	3	2
Crustacea		3	3	4	4		5	4	4	3
Mollusca		6	7	6	4		7	5	2	6
Other		-	1	1	2		2	-	1	3
Total Taxa Richness	-	67	52	60	58	-	52	42	33	52
EPT Taxa Richness	21*	18	8	10	8	13*	10	8	5	8
EPT Biotic index	4.3	4.9	6.0	5.1	5.6	4.4	5.0	6.2	5.0	6.4
EPT Abundance	66	71	32	22	21	44	57	30	34	48
NC Biotic Index	-	5.7	6.6	6.5	6.7	-	6.0	6.4	5.5	6.8
EPT Score	3	3	1.6	2	1.6	2	2	1.6	1	1.6
BI Score	-	3.4	2	2.4	2	-	3	3	4	2
Site Score	-	3.2	1.8	2.2	1.8	-	2.5	2.3	2.5	1.8
Rating	G?	G-F	F	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	

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				
	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
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					
Chimarra sp	A	C	A	A	A	C	R	A	A	-	A	C	-	R	-	A	R	-	C	-
Neophylax oligius	A	R	-	-	-	-	-	-	-	-	-	-	-	-	R[2]	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
Elimia sp	A	A	C	A	-	A	C	C	C	-	A	A	-	C	-	A	A	R	-	-
Sum*	40	14	24	31	43	29	6	27	20	57	37	14	7	15	40	40	11	14	6	17

*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.

	Seawell			Horne Hollow		Jolly Br		Jones Cr		Camden	UT Tanyard	
	3/09	3/11	4/12	3/11	4/12	3/11	4/12	3/09*	4/12	4/12	3/09	4/12
Ephemeroptera	4	6	4	2	5	3	1	3	1	1	-	1
Plecoptera	4	4	3	3	2	2	2	4	2	2	-	-
Trichoptera	8	5	7	5	8	3	3	4	2	2	2	3
Coleoptera	3	5	4	4	5	2	2	2	4	3	-	1
Odonata	1	1	-	1	3	2	2	2	1	1	-	1
Diptera; Misc.	4	6	2	2	2	5	2	2	3	3	-	1
Diptera: Chironomidae	12	4	6	8	8	10	8	11	11	5	3	9
Oligochaeta	3	2	2	2	3	4	1	3	6	4	5	5
Crustacea	3	3	3	2	3	3	3	3	1	3	2	-
Mollusca	2	2	1	1	1	1	1	1	5	2	-	1
Other	3	-	-	-	-	-	-	1	2	-	-	-
Flow[1]	P	P	P/I	P	P	I	I	I	I	I	P	P
Total Taxa Richness	47	38	32	30	40	35	25	36	38	26	12	22
EPT Taxa Richness	16	15	14	10	15	8	6	11	5	5	2	4
NC Biotic Index	4.8	4.2	4.0	3.9	4.0	6.2	5.9	6.4	6.0	6.2	7.5	7.8
BI Rating (normal streams)[2]	Ex	Ex	Ex	Ex	Ex	**G-F**	**G-F**	**G-F**	G-F	**G-F**	Poor	Poor
BI Rating (Small streams)[2]	**Good**	**Ex**	**Ex**	**Ex**	**Ex**	Fair	Fair	Fair	**Fair**	Fair	**Poor**	**Poor**

Ex = Excellent, G-F = Good-Fair. Bold type indicates final classification.

[1]P = Perennial stream, I = Intermittent stream
[2]Assumes perennial streams, therefore small-stream rating may not apply to Jolly Branch, Jones Creek and UT Bolin at Camden.
*Further upstream relative to 2012 collections

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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				
Site:	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
Stenonema femoratum	-	-	-	-	-	C	-	-	-	-	C	-	R	-	-
Stenacron interpunctatum	A	A	A	A	C	-	A	A	-	C	-	A	C	R	C
Leucrocuta aphrodite	C	-	-	-	-	C	-	-	-	-	A	-	-	-	-
Baetis flavistriga	-	-	-	-	-	-	-	-	-	-	-	R	-	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	-	-	-	-	-	-	-	-
Eurylophella spp	A	-	R	C	R	R	-	-	R	R	-	-	-	-	-
Isonychia spp	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Paraleptophlebia sp	-	-	-	-	-	-	-	-	R	-	R	-	-	-	-
Plauditus dubius gr*	A	-	-	-	-	A	-	-	-	-	-	-	-	-	-
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	-	-	-
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
Hydropsyche betteni	-	R	C	C	C	-	R	R	-	R	-	C	C	-	A
Diplectrona modesta	-	-	-	C	-	-	C	-	-	-	-	R	R	-	-
Chimarra sp	-	C	R	A	A	-	A	C	-	R	-	A	R	-	C
Polycentropus sp	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-
Triaenodes ignitus	-	-	-	R	-	-	-	-	-	-	-	-	R	-	-
Oecetis sp A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
Neophylax oligius	-	-	-	-	-	R	-	-	-	-	-	A	-	-	-
Psilotreta sp (pupa)	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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	-	-	-
Macronychus glabratus		-	-	-	-		R	-	-	-		-	-	-	-
Dubiraphia sp		-	-	R	C		-	R	-	-		R	-	R	R
Stenelmis crenata		C	-	A	C		C	A	R	R		A	A	C	A
Psephenus herricki		A	R	A	C		A	R	C	A		A	-	C	C
Ectopria nervosa		R	R	-	-		C	R	-	-		-	-	-	-
Helichus spp		C	C	-	R		-	C	-	-		C	C	C	R
Neoporus spp		C	-	-	-		-	-	-	-		-	-	-	-
Neoporus mellitus gr		-	-	-	-		-	R	-	-		R	-	-	-
Peltodytes sp		R	-	R	-		-	-	-	-		-	-	-	R

	Date:	03/10				03/11				06/12			
	Site:	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	-	-	-
Ischnura sp		-	R	-	-	R	-	-	-	-	-	-	-
Cordulegaster sp		-	-	-	-	-	R	-	-	-	-	-	-
Gomphus sp		C	C	R	R	R	-	-	-	R	-	-	-
Stylogomphus albistylus		-	-	-	-	C	-	R	-	C	C	R	-
Libellula sp		-	-	-	-	-	-	-	-	-	-	-	R
Pachydiplax longipennis		-	-	-	-	-	-	-	R	-	-	-	R
Somatochlora sp		R	R	R	R	-	-	R	-	R	R	R	R
Tetragoneuria sp		-	-	R	-	-	-	-	-	-	-	-	-
Boyeria vinosa		R	-	-	-	-	-	-	-	R	-	R	-
MEGALOPTERA													
Sialis sp		-	-	-	-	R	-	-	-	C	-	-	R
DIPTERA: MISC.													
Antocha spp		A	-	A	C	-	-	R	R	-	-	-	-
Hexatoma sp		-	-	-	-	-	-	R	-	-	-	-	-
Pseudolimnophila sp		-	-	-	-	-	R	R	-	R	-	-	-
Tipula spp		A	A	A	C	C	-	C	R	C	C	C	C
Palpomyia complex		C	R	-	-	C	R	R	R	-	-	-	-
Cnephia mutata*		-	-	-	-	-	C	A	C	-	-	-	-
Prosimulium spp*		-	-	-	R	A	-	C	C	-	-	-	-
Simulium spp		-	-	-	-	C	C	A	A	R	A	A	A
Chrysops sp		R	-	-	-	-	-	-	-	-	-	-	-
DIPTERA: CHIRONOMIDAE													
Ablabesmyia spp (2)		C	R	C	R	A	C	A	A	-	A	-	C
Conchapelopia group		C	C	C	R	A	A	C	C	A	A	R	R
Nilotanypus sp		-	-	-	-	R	-	-	-	-	-	-	-
Natarsia sp		-	-	-	-	-	-	R	-	R	C	C	R
Procladius sp		C	-	-	-	C	C	R	R	-	-	-	C
Zavrelimyia sp		-	-	R	R	R	-	-	-	-	-	-	-
Brillia sp		-	-	-	-	R	-	-	-	-	-	-	-
Corynoneura spp		R	-	-	-	-	-	C	R	-	R	R	-
Thienemaniella spp		-	-	-	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	-	-
Rheocricotopus robacki		-	-	-	-	-	-	-	-	R	R	-	-
Rheocricotopus DWQ sp. 6		R	-	-	-	-	-	-	-	-	-	-	-
Synorthocladius sp		-	-	-	-	R	-	-	-	-	-	-	R
Tvetenia bavarica gr		-	R	-	-	C	R	C	C	-	-	-	-

	Date:	03/10				03/11				06/12			
	Site:	1	2	3	4	1	2	3	4	1	2	3	4
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	-	-
Dicrotendipes spp		-	-	R	R	-	-	-	R	-	-	-	R
Microtendipes spp		R	R	R	C	R	-	-	C	C	R	A	-
Paralauterborniella nigrohalterale		-	-	-	-	-	-	-	-	-	R	-	-
Paratendipes sp		-	-	-	-	-	-	-	R	R	-	R	-
Phaenopsectra spp		-	-	-	-	-	-	-	C	-	-	-	R
Phaenopsectra flavipes gr.		-	-	-	-	C	R	C	C	-	-	-	R
Polypedilum flavum		A	A	A	A	-	-	-	C	-	A	A	A
Polypedilum aviceps		-	-	-	A	A	A	A	-	-	-	-	-
Polypedilum illinoense		-	-	-	-	-	-	-	A	C	-	-	-
Polypedilum fallax		-	-	-	-	R	C	-	-	-	-	-	-
Polypedilum scalaenum		-	-	-	-	-	-	-	-	-	-	C	C
Stenochironomus sp		-	-	-	-	R	-	-	-	R	-	-	R
Stictochironomus sp		-	C	R	-	C	C	-	-	-	-	-	-
Tribelos sp		-	-	C	C	C	-	C	-	C	C	R	C
Xenochironomus xenolabis		-	-	-	-	-	-	-	-	-	C	-	-
Cladotanytarsus sp		-	R	-	-	-	-	-	-	-	-	-	-
Paratanytarsus sp		-	-	R	-	-	-	-	-	-	-	-	R
Rheotanytarsus spp		C	-	-	R	-	R	-	-	-	C	-	-
Tanytarsus spp		C	R	C	-	A	A	C	A	-	R	-	C
OLIGOCHAETA													
Limnodrilus spp (hofmeisteri)		R	R	-	-	-	-	-	C	-	R	C	C
Ilyodrilus templetoni		-	-	-	-	-	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	-
Ecclipidrilus spp						R	-	C	R	C	-	-	-
Megadriles		-	-	-	-	-	-	-	C	-	-	-	C
CRUSTACEA													
Crangonyx spp		C	C	C	A	C	A	A	C	C	R	C	R
Hyallela azteca		R	C	C	C	R	-	R	A	C	C	R	A
Caecidotea sp		-	-	-	R	-	R	A	R	R	C	C	C
Cambarus (P.) sp. C Cooper		A	C	C	C	A	A	C	C	A	A	C	-
Procambarus acutus		C	C	-	-	-	-	-	-				

	Date:	03/10				03/11				06/12			
	Site:	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	-
Leptoxis sp		-	-	-	-	-	-	-	-	R	-	-	-
Campeloma decisum		-	-	-	-	R	C	-	R	C	-	-	R
Physella sp		-	R	R	-	R	A	R	A	C	C	-	A
Lymnaea (?) sp		-	-	-	-	-	-	-	-	-	-	-	R
Helisoma anceps		-	-	-	R	-	C	R	C	-	R	-	C
Menetus dilatatus		-	-	-	-	-	-	R	-	-	-	-	-
Ferrissia sp		-	-	R	-	R	-	R	-	-	-	-	-
Sphaerium spp		R	-	-	-	R	C	-	-	R	C	-	-
Pisidium spp		R	R	-	-	-	R	R	-	-	-	-	R
Corbicula fluminea		R	R	-	-	C	C	C	-	A	A	C	A
Elliptio sp		-	-	-	-	-	-	-	-	C	-	-	-
OTHER													
Turbellaria													
Dugesia tigrina		-	-	R	-	-	-	-	R	-	-	-	R
Cura foremanii		R	-	R	-	-	-	-	-	R	-	R	-
Hydrolimax grisea		-	R	-	-	-	C	C	C	R	-	-	-
Hirudinea													
Helobdella triserialis		-	-	-	-	-	-	-	-	-	-	-	R
Hemiptera: Corixidae		-	-	-	-	-	-	-	-	-	-	-	r

Appendix 2. Benthic macroinvertebrates at tributaries of Bolin Creek, April 2012, Carrboro, NC. R=Rare, C=Common, A=Abundant, Blue highlights indicate selected intolerant species.

Site:	UT Bolin Seawell	UT Bolin Horne Hollow	Jolly Br	Jones Cr	UT Bolin Camden	UT Tanyard
EPHEMEROPTERA						
Maccaffertium modestum	-	R	-	-	-	-
Stenonema pallidum?	R	-	-	-	-	-
Stenacron interpunctatum	-	R	-	-	-	-
Paraleptophlebia sp	A	C	-	-	-	-
Leptophlebia sp	A	-	-	-	-	-
Plauditus dubius gr	-	-	C	A	C	-
Baetis flavistriga	-	-	-	-	-	A
Eurylophella verisimilis	A	C	-	-	-	-
Telagonopsis deficiens	-	R	-	-	-	-
PLECOPTERA						
Perlesta sp	C	-	A	A	C	-
Eccoptura xanthenes	-	R	-	-	-	-
Haploperla brevis	-	-	-	-		-
Leuctra sp	C	-	-	-	-	-
Amphinemura sp	A	A	A	C	C	-
TRICHOPTERA						
Cheumatopsyche spp	-	A	-	-	-	A
Hydropsyche betteni	-	-	-	-	-	R
Diplectrona modesta	-	R	-	-	-	-
Chimarra sp	-	C	-	-	-	R
Wormaldia sp	C	-	-	-	-	-
Neophylax ornatus	R	A	R	R	-	-
Neophylax oligius	-	C	-	-	-	-
Psilotreta sp	C	-	-	-	-	-
Ironoquia puntatissima	R	C	R	A	A	-
Lepidostoma sp	-	A	-	-	-	-
Anisocentropus pyraloides	C	R	-	-	-	-
Rhyacophila fenestra/ledra	R	-	A	-	R	-
Rhyacophila glaberrima	C	-	-	-	-	
COLEOPTERA						
Anchytarsus bicolor	-	A	-	-	-	-
Helichus spp	A	C	-	A	C	-
Psephenus herricki	A	C	-	-	-	-
Ectopria nervosa	R	-	-	-	-	-
Stenelmis crenata	-	R	C	R	R	-
Microcylloepus pusilus	-	R	-	-	-	-
Neoporus spp	R	-	R	A	C	-
Neoporus mellitus	-	-	-	R	-	-
Hydroporus sp	-	-	-	-	-	R
ODONATA						
Argia sp	-	-	-	-	-	R
Somatochlora sp	-	-	C	R	R	-
Gomphus sp	-	R	-	-	-	-
Stylogomphus albistylus	-	C	R	-	-	-
Boyeria vinosa	-	R	-	-	-	-
DIPTERA: MISC.						
Tipula spp	C	-	C	C	R	R
Antocha sp	-	-	C	-	-	-
Palpomyia complex	-	-	-	R	A	-
Simulium spp	C	R	C	C	R	R

Site:	UT Bolin Seawell	UT Bolin Horne Hollow	Jolly Br	Jones Cr	UT Bolin Camdden	UT Tanyard
DIPTERA: CHIRONOMIDAE						
Conchapelopia group	-	C	A	C	-	R
Clinotanypus pinguis	-	-	-	R	-	-
Zavrelimyia sp	-	R	C	-	R	R
Procladius sp	-	-	-	R	-	-
Corynoneura spp	R	-	R	-	R	R
Thienemaniella spp	-	-	-	R	-	-
Diplocladius cultriger	-	-	-	R	-	-
Eukiefferiella claripennis gr	C	-	R	-	R	C
Eukiefferiella brevicalcar gr	R	-	-	-	-	-
Cricotopus bicinctus	-	-	-	C	-	-
Cricotopus fugax	-	-	-	-	-	R
Cricotopus triannulatus gr	-	-	-	-	-	A
Cricotopus annulator gr	-	-	-	-	-	A
Cricotopus nr cylindraceus	R	-	-	-	-	-
Orthocladius robacki	R	-	-	-	-	-
Potthastia longimana	-	-	R	-	-	-
Parametriocnemus lundbecki	C	A	C	C	C	-
Psectrocladius sp	-	-	-	-	-	R
Rheocricotopus robacki	-	-	-	-	R	-
Chironomus spp	-	R	R	R	-	-
Paratendipes sp	-	C	-	-	-	-
Stictochironomus sp	-	R	-	-	-	-
Tribelos sp	-	-	-	R	-	-
Polypedilum illinoense	-	-	-	-	-	R
Polypedilum flavum	-	R	-	-	-	-
Paratanytarsus spp	-	R	-	R	-	-
Tanytarsus spp	-	-	C	R	-	-
OLIGOCHAETA						
Ilyodrilus templetoni	-	-	-	A	-	-
Limnodrilus spp	-	R	-	A	-	C
Nais spp	C	R	C	C	A	C
Dero sp	-	-	-	R	-	
Slavinia appendiculata	-	-	-	-	-	C
Stylaria lacustris	-	-	-	R	-	-
Lumbriculus variegatus	-	-	-	-	R	-
Ecclipdrilus(?) spp	A	A		A	A	
Rhynchelmis bolinenesis	-	-	-	-	R	-
Enchytraeidae	-	-	-	-	-	R
CRUSTACEA						
Crangonyx spp	C	R	A	-	A	-
Caecidotea sp (forbesi)	C	R	C	-	A	-
Cambarus spp	A	R	C	C	C	-
MOLLUSCA						
Elimia sp	A	A	-	A	-	-
Physa spp	-	-	C	A	C	A
Helisoma anceps	-	-	-	R	-	-
Micromenetus dilatatus	-	-	-	-	R	-
Pisidium sp	-	-	-	R	-	-
Sphaerium sp	-	-	-	C	-	-
OTHER						
Corixidae	-	-	-	C	-	-
Erpobdella/Mooreobdella	-	-	-	R	-	-