BIOLOGICAL MONITORING OF BOLIN CREEK CARRBORO, NORTH CAROLINA

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HOW TO READ THIS REPORT
This is the 4th 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 the 2009 and 2010 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.

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 12 tributary streams.

INTRODUCTION [Note: this section largely repeated from early reports.]
Water quality in Bolin Creek was evaluated in March 2011 by sampling benthic macroinvertebrates at 4 sites. Collections were also made at two small unnamed 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 early 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, Tanbark Branch, and Battle Branch. Bolin Creek is dammed several times in its headwaters, most notably to form Lake Hogan, a 12-acre impoundment located just downstream of Old NC 86. Bolin Creek begins in a fairly undeveloped area and drains progressively more urban and developed areas in Carrboro and Chapel Hill as it flows towards its confluence with Booker Creek.

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

METHODS [Note: this section largely repeated from early reports.]
All collection methods are derived from techniques used by the NC Division of Water Quality (Lenat 1988). These methods have been in use by North Carolina since 1982, and have been thoroughly tested for accuracy and repeatability. More details can be found at their web site: http://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 Creeks sites 1-4]
The standard qualitative technique includes 10 separate samples and is designed to sample all habitats and all sizes of invertebrates. This collection technique consists of two kick net samples (kicks), three sweep-net samples (sweeps), one leaf-pack sample, two fine-mesh rock and/or log wash samples, one sand sample, and visual collections. Invertebrates are separated from the rest of the sample in the field ("picked") using forceps and white plastic trays, and preserved in glass vials containing 95% ethanol.

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

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

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

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.

Assigning Bioclassifications - Overview

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

EPT Criteria

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

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

Biotic Index Criteria

To supplement EPT taxa richness criteria, the North Carolina Biotic Index (NCBI) was derived as another (independent) method of bioclassification to support water quality assessments (Lenat 1993). This index is similar to the Hilsenhoff Biotic Index (Hilsenhoff, 1987) with tolerance values derived from the NC database. Biotic indices are based on a 0-10 scale, where 0 represents the best water quality and 10 represents the worst. Abundance values used in the biotic index calculation are 10 for Abundant taxa, 3 for Common taxa, and 1 for Rare taxa.

Derivation of Final Bioclassification for Standard Qualitative Samples

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

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

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

SAMPLING SITES

The Carrboro section of Bolin Creek has been sampled yearly since 2000. 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.

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. Samples were collected (with assistance from Randy Dodd, City of Carrboro Planning) on March 16-17 and March 22, 2011. 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 March 2011. The habitat rating is based on standard Division of Water Quality procedures, and produces a value between 0 and 100. Most Carrboro sites had good habitat scores, but Bolin Creek Site #2 and Site #4 had problems with excessive algal growths. Spring months may produce abundant algal growths in most streams, due to rising temperatures and absence of shading before leaf-out. If coupled wit high nutrient values, this spring growth of algae can grow over the entire stream bottom. Increased sediment levels were seen only at Site 2, downstream of the Winmore development.

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	8	6	14	6/7	10	5/5	84	4.5	25	30	25	20	Tr	Lots of algae at edges of pools
Bolin Cr #2	5	16	8	4	7	6/2	7	5/1	61	4	15	20	20	35	15	DownstreamWinmore/Claremont. Sand deposition in pools, Excessive filamentous algae.
Bolin Cr #3	5	18	8	9	14	7/7	10	5/5	88	4.5	25	30	25	20	Tr	Lots of algae at edges of pools
Bolin Cr #4	4	18	8	6	7	6/3	7	3/1	63	7	30	30	15	25	Tr	Rocky, but with excessive filamentous algae.
Morgan Cr	5	18	10	6	16	7/7	10	5/5	89	7.5	35	25	25	15	Tr	Lots of algae.
Unnamed Tribs																
Hornehollow	5	16	13	8	16	5/5	7	3/3	81	1.5	10	40	30	20	Tr	Sparse fauna, but with intolerant species.
Seawell School	5	19	12	6	16	7/7	10	5/5	92	1	40	40	10	10	-	Small, dry in upstream segment. Forested.
Jolly Br	5	16	11	4	16	2/2	10	5/5	76	1	15	40	25	15	5	Severe bank erosion, but largely forested. Good habitat.

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 Bolin Creek has been frequently affected by droughts, with sections of the stream becoming entirely dry during severe droughts. Changes due to water quality problems cannot be discerned without taking into consideration this natural stress. The data below is taken from the USGS web site, using data from 1999 to the September 2010. The USGS measures daily flow at Morgan Creek and Cane Creek; both streams are in Orange county and both are similar in geology to the Bolin Creek catchment. These streams are of similar size relative to Bolin Creek, but note that the Bolin Creek catchment is slightly smaller than either Morgan Creek or Cane Creek catchments. Low flows (less than 0.5 cfs) are highlighted in yellow; severe low flows (less than 0.1 cfs) are highlighted in red.

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			

Cane Creek nr Orange Grove (Drainage area 7.5 square miles)

Year	Month: 1	2	3	4	5	6	7	8	9	10	11	12
1999	14	4	3	6	1.1	0.5	0.2	0.09	18	4	6	4
2000	9	14	8	12	2	8	14	3	5*	0.9	0.8	5*
2001	3	9	21	11	1.2	2*	0.4	0.1	0.1	0.1	0.06	0.2
2002	5	2	3	1.1	0.1	0.03	0.04	0.04	0.4*	13	9	20
2003	6	20	34	37	17	8	5	4	1.3*	0.7	0.7	6
2004	2	8	5	4	0.9	0.4	1.9	10	9*	1.8	4	4
2005	7	6	15	6	2	0.8	0.3	0.3*	0.000	0.03	0.5	8
2006	3	2	1.2	2	1.0	7	4	0.1	0.2	1.2	19	6
2007	11	8	12	12	0.9	0.2	0.03	0.00	0.00*	0.005	0.000	0.08
2008	0.3	1.2	7	9	3	0.2	0.5	0.3	4	0.3	0.7	8*
2009	4	1.7	18	5	0.9	8	0.2*	0.08	0.03	0.01	10	21-
2010	12	24	10	3	3	0.3	0.1	0.01	1.5			

*Month for prior Bolin Creek samples

Flow data from Morgan Creek at Chapel Hill (41 square miles) did not indicate any months with average flows less than 7 cfs (1999-2010).

PRIOR BIOLOGICAL DATA

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

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

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

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

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

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

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

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

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

Town of Carrboro Data, 2000-2007, Ecological Consultants, Standard 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 flow data for Cane Creek and Morgan Creek) in:

-Aug-Dec 2001 (6 months, with lowest flow in Nov)
-June-Sept 2002 (4 months with streams drying up much of this time)
-June 2004
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-Sept 2006
-June-Dec 2007 (7-8 months, with streams going dry for 4-6 months)
-July-August + September 2008 – no streams went completely dry. Another period of possible recovery.
-July-September 2009 (4 months with severe drought for 2-3 months)
-June-August 2010 (3 months with severe drought in August)

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 all Bolin sites through 2010.

Routine sampling was switched from summer months to winter/spring months (esp. March), to avoid these periods of extreme low flow. 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.

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. The March 2011 surveys also followed a period of extreme summer drought and Bolin Creek sites 2, 3 and 4 all received a Fair rating. This change can be seen in both a decline in the number of intolerant EPT species and an increase in biotic index values. While some of this decline is drought-related, note that the control site at Morgan Creek and the upstream site on Bolin Creek (#1) retained Good or Good-Fair rating. Morgan Creek has lost some components of a normal stream fauna (*Elimia*, *Maccafertium*, *Cheumatopsyche*, *Chimarra*), but still supports a community of highly intolerant aquatic species.

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, being abundant only at the upstream site on Bolin Creek. *Acroneuria* has almost disappeared from Bolin Creek, with only a single specimen collected in 2011. We will need to see a year with higher summer flows before we can evaluate the relative contributions of urban runoff and flow interruptions.

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. Site 2 was also characterized in 2011 by extremely abundant growths of bright-green filamentous algae, producing floating mats along the edges. In 2009 and 2010, there was some recovery at site 3, but this recovery was not observed in 2011.

None of the Carrboro 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.

Bolin Creek Tributaries (Table 4, Appendix 2)

Three small 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 Hornehollow Rd, and Jolly Branch near the Carrboro/Chapel Hill boundary. Collections at all these sites attempt to document areas of higher water quality in the Bolin Creek catchment.

UT Seawell School Road. This site had also been sampled in 2009. Collections from both 2009 and 2011 indicate an area of Good-Excellent water quality, with many highly intolerant species not observed in other Carrboro collections (*Wormaldia, Psilotreta, Neophylax consimilis, Rhyacophila glaberrima*). This very small stream (<1 meter wide) was dry in its upper reaches in March 2011, 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 Hornehollow 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. This UT runs through a mix of older and newer residential areas. The area immediately around the sampling site is characterized by a cleared sewer easement with little or no buffer zone. The fauna was not as diverse as the Seawell School UT, but this stream also supported a highly intolerant fauna and received an excellent bioclassification.

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.

SUMMARY
Biological sampling on Bolin Creek has consistently indicated Good-Fair water quality in upper Bolin Creek, in spite of some development and persistent summer droughts. Areas further downstream have fluctuated between a Good-Fair and a Fair rating, with a Fair rating at all 3 downstream sites in 2011 (see Table 1). It is clear that summer low-flow conditions (sometimes the absence of water in the channel) contribute to problems in Bolin Creek. Samples collected in 2008, following a period of higher summer flow, allowed some recovery, while samples in 2010 and 2011 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 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 two sites on Bolin Creek showed symptoms of low dissolved oxygen. These sites also had very high levels of filamentous algae in March 2011, so the low dissolved oxygen may be the result of nighttime respiration by this algae. High levels of attached algae are often observed in streams as temperatures rise in spring, but excessive growths are likely associated with nutrient inputs.

Although much of Bolin Creek has water-quality problems, tributary sites may support more intolerant aquatic communities. Excellent water quality was demonstrated in unnamed tributaries at Seawell School Road and Hornehollow Road, Good water quality in Morgan Creek at NC 54, Good-Fair water quality was observed in Jolly Branch.

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					03/11				
Site:	2	3	4	2	3	4	M	1	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	9	7	3	5	4
Plecoptera	2	2	1	3	3	5	6	2	3	3	3	6	3	2	1	1	6	5	1	2	1
Trichoptera	6	6	2	5	4	4	5	5	3	4	4	3	5	5	6	5	3	6	4	3	3
Coleoptera	10	6	6	3	5	3		7	6	6	2		7	4	4	4		5	7	2	2
Odonata	6	6	3	4	5	1		7	4	5	2		6	5	6	4		4	2	3	2
Megaloptera	1	1	-	-	1	-		1	1	-	-		-	-	-	-		1	-	-	-
Diptera: Misc.	6	5	4	6	5	4		4	4	3	2		4	2	2	3		4	4	8	6
Diptera: Chironomidae	19	12	13	28	23	25		11	15	14	15		20	18	22	15		23	18	20	22
Oligochaeta	3	2	4	1	3	4		3	1	4	3		3	2	-	2		3	2	6	8
Crustacea	3	2	1	3	3	2		6	4	4	4		4	4	3	4		3	3	4	4
Mollusca	3	4	6	3	6	3		5	6	2	4		5	4	2	2		6	7	6	4
Other	3	1	2	2	2	2		1	2	2	-		2	1	3	-		-	1	1	2
Total Taxa Richness	70	47	43	68	66	53	-	57	53	52	44	-	63	53	32	42	-	67	52	60	58
EPT Taxa Richness	16	10	4	18	13	9	21*	12	10	12	12	24*	12	13	12	9	21*	18	8	10	8
EPT Biotic index	-	-	-	-	-	-	3.9	5.0	4.5	4.3	5.4	4.5	6.0	5.8	5.5	5.0	4.3	4.9	6.0	5.1	5.6
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	-	5.7	6.6	6.5	6.7
EPT Score	2.6	2	1	3	2	1.6	3	2	2	2	2	3.6	2	2	2	1.6	3	3	1.6	2	1.6
EPT Abundance							88	60	68	63	63	112	58	39	60	35	66	71	32	22	21
BI Score	3	3	3	3	2.4	3	-	3	3	3	3	-	4	3	3	3.4	-	3.4	2	2.4	2
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	-	3.2	1.8	2.2	1.8
Rating	G-F	G-F**	F**	G-F	F	F	G?	G-F	G-F	G-F	G-F	G	G-F	F	G-F	F	G?	G-F	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).

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	-	-	-	

Table 3. Selected intolerant species at Bolin Creek sites and Morgan Creek, July 2009 vs. March 2010. Note that seasonal changes produce a slightly different set of species for each date.

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

*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.

Site:	UT Bolin Seawell	UT Bolin Seawell	UT Bolin Hornehollow	Jolly Br
Date:	3/09	3/11	3/11	3/11
Ephemeroptera	4	6	2	3
Plecoptera	4	4	3	2
Trichoptera	8	5	5	3
Coleoptera	3	5	4	2
Odonata	1	1	1	2
Megaloptera	-	-	-	-
Diptera; Misc.	4	6	2	5
Diptera: Chironomidae	12	4	8	10
Oligochaeta	3	2	2	4
Crustacea	3	3	2	3
Mollusca	2	2	1	1
Other	3	-	-	-
Flow[1]	P	P	P	I
Total Taxa Richness	47	38	30	35
EPT Taxa Richness	16	15	10	8
NC Biotic Index	4.8	4.2	3.9	6.2
BI Rating (normal streams)[2]	Ex	Ex	Ex	G-F
BI Rating (Small streams)[2]	Good	Ex	Ex	Fair

Ex = Excellent, G-F = Good-Fair.

[1]P = Perennial stream, I = Intermittent stream
[2]Assumes perennial streams, therefore small-stream rating may not apply to Jolly Branch.

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Appendix 1. Bolin Creek, Sites 1-4, September 2000 to March 2011 (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:	09/00			12/00			12/08					03/10					3/11				
Site:	2	3	4	2	3	4	M	1	2	3	4	M	1	2	3	4	M	1	2	3	4
EPHEMEROPTERA																					
Baetis flavistriga	A	C	-	C	-	-	-	R	-	-	C	-	-	-	-	-	-	-	-	-	-
Baetis pluto	-	-	-	-	R	-	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plauditus dubius gr	-	-	-	A	-	-	-	-	-	-	-	A	-	-	-	-	A	-	-	-	-
Centroptilum triangulifer	C	-	C	R	-	-	-	C	A	R	R	-	A	R	C	-	-	A	C	R	A
Procloeon sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-
Acerpenna pygmaea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	R	-
Siphlonurus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-
Caenis spp	R	-	-	C	C	-	C	-	R	R	-	A	C	R	C	-	C	R	-	-	-
Danella simplex*	-	-	-	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ephemerella dorothea*	-	-	-	C	R	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-
Eurylophella spp	R	-	-	R	-	-	C	-	-	-	R	A	-	R	C	R	R	-	-	R	R
Ameletus lineatus	-	-	-	-	-	-	-	R	-	-	-	R	-	-	-	-	C	C	-	-	-
Isonychia spp	A	-	-	-	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptophlebia sp	C	-	-	R	R	-	-	-	-	R	-	-	-	-	-	-	C	-	-	-	-
Paraleptophlebia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-
Leucrocuta aphrodite	-	-	-	-	-	-	A	-	-	-	-	C	-	-	-	-	C	-	-	-	-
Maccaffertium modestum	A	C	-	C	R	-	C	A	A	A	A	C	A	A	A	A	R	A	A	A	-
Stenonema femoratum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-
Stenacron interpunctatum	A	-	-	C	R	-	C	A	A	C	A	A	A	A	A	C	-	A	A	-	C
PLECOPTERA																					
Acroneuria abnormis	C	C	C	-	-	A	A	-	-	A	C	A	-	-	C	-	-	R	-	-	-
Eccoptura xanthenes	-	-	-	-	-	-	R	R	C	-	-	R	R	R	-	-	-	C	-	-	-
Perlesta sp	C	C	-	C	C	-	R	-	-	-	-	A	C	-	-	-	C	C	R	C	-
Allocapnia spp (2-3)	-	-	-	A	A	A	A	A	A	A	C	-	-	-	-	-	-	-	-	-	-
Taniopteryx spp	-	-	-	A	C	A	A	-	R	C	R	-	-	-	-	-	-	-	-	-	-
Strophopteryx sp	-	-	-	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isoperla sp	-	-	-	-	-	C	R	-	-	-	-	C	-	-	-	-	A	R	-	-	-
I. burkesi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		R	-	-	-	-
Clioperla clio	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	A	-	-	-	-
Amphinemura sp	-	-	-	-	-	-	-	-	-	-	-	A	C	R	-	R	A	C	-	R	R
TRICHOPTERA																					
Cheumatopsyche spp	A	A	A	A	A	A	A	A	A	A	A	-	R	C	A	C	-	C	R	R	C
Hydropsyche betteni	A	A	A	C	A	A	R	A	C	C	A	-	R	C	C	C	-	R	R	-	R
Diplectrona modesta	-	-	-	R	-	-	R	-	-	-	R	-	-	-	C	-	-	C	-	-	-
Chimarra sp	A	R	-	A	-	-	A	A	A	A	A	-	C	R	A	A	-	A	C	-	R
Polycentropus sp	-	-	-	-	-	C	-	C	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhyacophila fenestra	-	-	-	-	-	-	-	-	-	-	-	A	C	-	R	C	C	-	C	-	-
Ceraclea ancylus	R	R	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Triaenodes ignitus	-	-	-	-	-	R	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-
Neophylax oligius	R	A	-	C	R	-	-	R	-	-	-	-	-	-	-	-	R	-	-	-	-
Psilotreta sp (pupa)	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-
Pycnopsyche sp	R	C	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ironoquia punctatissima	-	-	-	-	-	-	-	-	-	-	-	C	A	C	C	R	C	C	C	R	-
Ptilostomis sp	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-
COLEOPTERA																					
Anchytarsus bicolor	A	C	C	-	-	-		A	R	-	-		A	R	-	-		A	C	-	-
Ancyronyx variegata	R	-	-	A	A	A		-	-	-	-		-	-	-	-		-	-	-	-
Macronychus glabratus	C	C	C	R	-	-		-	-	-	-		-	-	-	-		R	-	-	-
Dubiraphia sp	C	R	A	C	A	R		-	R	R	-		-	-	R	C		-	R	-	-
Stenelmis crenata	-	-	-	-	-	-		C	C	C	R		C	-	A	C		C	A	R	R
Microcyloepus pusillus	C	R	C	-	R	-		-	-	-	-		-	-	-	-		-	-	-	-

Date:	09/00			12/00			12/08					03/10					3/11				
Site:	2	3	4	2	3	4	M	1	2	3	4	M	1	2	3	4	M	1	2	3	4
Psephenus herricki	C	-	C	-	R	-		A	C	R	C		A	R	A	C		A	R	C	A
Ectopria nervosa	R	R	R	-	-	-		R	-	-	-		R	R	-	-		C	R	-	-
Helichus spp	C	-	-	-	R	C		R	R	-	-		C	C	-	R		-	C	-	-
Gyrinus sp	R	-	-	-	-	-		-	-	-	-		-	-	-	-		-	-	-	-
Neoporus spp	R	R	-	-	-	-		A	C	A	-		C	-	-	-		-	-	-	-
Neoporus mellitus gr	-	-	-	-	-	-		C	-	R	-		-	-	-	-		-	R	-	-
Peltodytes sp	-	-	-	-	-	-		-	-	R	-		R	-	R	-		-	-	-	-
ODONATA																					
Argia spp	R	C	R	R	R	-		A	R	C	-		R	R	R	R		-	-	-	-
Calopteryx sp	C	A	-	R	C	-		C	-	A	R		C	C	C	R		C	C	R	-
Enallagma spp	C	-	C	R	C	-		C	C	R	-		R	R	R	C		-	-	-	R
Ischnura sp	-	-	-	-	-	-		-	-	-	-		-	R	-	-		R	-	-	-
Cordulegaster sp	-	-	-	-	-	-		-	-	-	-		-	-	-	-		-	R	-	-
Gomphus sp	R	C	-	-	R	-		R	-	-	-		C	C	R	R		R	-	-	-
Stylogomphus albistylus	R	R	-	-	R	-		R	C	R	R		-	-	-	-		C	-	R	-
Neurocordulia obsoleta	-	R	-	-	-	-		-	-	-	-		-	-	-	-		-	-	-	-
Pachydiplax longipennis	-	-	-	-	-	-		-	-	-	-		-	-	-	-		-	-	-	R
Somatochlora sp	-	-	-	-	-	-		R	R	C	-		R	R	R	R		-	-	R	-
Tetragoneuria sp	-	-	-	-	-	-		-	-	-	-		-	-	R	-		-	-	-	-
Boyeria vinosa	C	C	C	C	-	C		R	-	-	-		R	-	-	-		-	-	-	-
MEGALOPTERA																					
Nigronia serricornis	C	R	-	-	C	-		-	-	-	-		-	-	-	-		-	-	-	-
Sialis sp	-	-	-	-	-	-		C	R	-	-		-	-	-	-		R	-	-	-
DIPTERA: MISC.																					
Aedes sp	R	-	-	-	-	-		-	-	-	-		-	-	-	-		-	-	-	-
Culex sp	R	-	-	-	-	-		-	-	-	-		-	-	-	-		-	-	-	-
Antocha spp	-	-	-	R	-	-		-	-	-	-		A	-	A	C		-	-	R	R
Hexatoma sp	-	-	-	-	-	-		-	-	-	-		-	-	-	-		-	-	R	-
Pseudolimnophila sp	-	-	-	-	-	-		-	-	-	-		-	-	-	-		-	R	R	-
Tipula spp	A	C	R	C	C	R		A	A	A	A		A	A	A	C		C	-	C	R
Dicranota sp	-	-	-	-	-	-		R	R	-	-		-	-	-	-		-	-	-	-
Atrichopogon sp	-	R	R	-	-	-		-	-	-	-		-	-	-	-		-	-	-	-
Palpomyia complex	-	R	-	C	A	-		R	-	R	-		C	R	-	-		C	R	R	R
Cnephia mutata	-	-	-	-	-	-		-	-	-	-		-	-	-	-		-	C	A	C
Prosimulium spp	R	-	C	+	+	+		-	-	-	-		-	-	-	R		A	-	C	C
Simulium spp	R	C	C	+	+	+		C	C	C	A		-	-	-	-		-	C	A	A
Simulium vittatum gr	C	C	-	+	+	+															
Simulium venustrun gr								-	R	-	-		-	-	-	-		C	-	-	-
Tabanus sp	R	-	-	-	-	-		-	-	-	-		-	-	-	-		-	-	-	-
Chrysops sp	-	-	-	-	-	-		-	-	-	-		R	-	-	-		-	-	-	-
DIPTERA: CHIRONOMIDAE																					
Ablabesmyia spp (2)	A	C	C	+	+	+		-	-	-	R		C	R	C	R		A	C	A	A
Conchapelopia group	C	R	-	+	-	+		A	C	A	R		C	C	C	R		A	A	C	C
Labrundinia sp	-	-	-	-	+	-		-	-	-	-		-	-	-	-		-	-	-	-
Larsia (?) sp	-	-	-	-	+	-		-	-	-	-		-	-	-	-		-	-	-	-
Nilotanypus sp	-	-	-	-	-	-		-	-	-	-		-	-	-	-		R	-	-	-
Natarsia sp	-	-	-	-	-	-		-	-	-	-		-	-	-	-		-	-	R	-
Procladius sp	-	C	C	-	+	+		-	-	-	-		C	-	-	-		C	C	R	R
Rheopelopia sp	-	-	-	+	-	+		-	-	-	-		-	-	-	-		-	-	-	-
Zavrelimyia sp	-	-	-	-	-	-		R	-	-	C		-	-	R	R		R	-	-	-
Brillia sp	-	-	-	+	-	+		-	-	-	-		-	-	-	-		R	-	-	-
Xylotopus par	-	-	-	-	-	-		-	C	-	-		-	-	-	-		-	-	-	-
Corynoneura spp	R	-	-	+	+	-		A	C	C	C		R	-	-	-		-	-	C	R
Thienemaniella spp	C	R	C	+	+	+		A	R	C	A		-	-	-	R		-	-	R	-

Date:	09/00			12/00			12/08					03/10					3/11				
Site:	2	3	4	2	3	4	M	1	2	3	4	M	1	2	3	4	M	1	2	3	4
Cricotopus bicinctus	-	R	C	+	+	+		-	-	C	-		-	-	-	-		A	A	A	A
Cricotopus triannulatus gr	-	-	-	+	-	+		-	-	-	-		-	-	-	-		-	-	-	-
Cricotopus cylindraceus	-	-	-	-	-	-		-	-	-	-		-	R	R	-		-	-	-	-
Diplocladius cultriger	-	-	-	-	+	-		A	A	A	A		C	C	R	-		C	A	A	R
Eukiefferiella claripennis gr	-	-	-	-	-	-		-	-	-	R		-	-	R	A		-	-	R	R
Eukiefferiella brevicalcar gr	-	-	-	-	-	-		-	-	-	-		A	C	-	-		-	-	-	-
Heterotrissocladius sp	-	-	-	+	-	-		-	-	-	-		-	-	-	-		-	-	-	-
Hydrobaenus sp	-	-	-	-	-	+		-	-	-	-		R	C	R	-		C	-	A	-
Krenosmittia sp	-	-	-	-	-	-		-	-	-	-		R	-	-	-		-	-	-	-
Nanocladius spp (2-3)	C	-	-	+	+	-		-	C	-	-		-	-	R	-		-	-	-	C
Orthocladius spp	C	-	-	+	+	+		R	R	-	-										
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	C	A	A		C	A	C	C		C	A	C	R
Psectrocladius spp	-	-	-	+	+	+		-	-	-	-		-	-	-	-		-	-	-	-
Rheocricotopus robacki	C	R	C	+	-	+		-	C	-	-		-	-	-	-		-	-	-	-
Rheocricotopus tuberculatus	-	-	-	-	-	+		-	-	-	-		-	-	-	-		-	-	-	-
Rheocricotopus DWQ sp. 6	-	-	-	-	-	-		-	-	-	-		R	-	-	-		-	-	-	-
Synorthocladius sp	-	-	-	-	-	-		-	-	-	-		-	-	-	-		R	-	-	-
Tvetenia bavarica gr													-	R	-	-		C	R	C	C
Diamesa sp	-	-	-	-	-	-		-	-	-	-		R	C	A	A		-	-	R	C
Potthastia longimanus	-	-	-	+	+	+		-	R	R	-		-	R	-	-		R	C	R	R
Prodiamesa sp	-	-	-	+	-	-		-	-	-	-		-	-	-	-		-	-	-	-
Sympotthastia sp	-	-	-	-	-	-		-	-	-	-		-	-	-	-		-	R	R	-
Chironomus sp	-	R	-	-	-	-		-	R	-	-		-	-	-	-		-	R	-	C
Cryptochironomus spp	A	-	-	+	+	-		-	-	-	-		-	R	-	-		R	R	-	-
Dicrotendipes spp	-	-	C	+	-	+		-	-	-	-		-	-	R	R		-	-	-	R
Microtendipes spp	-	-	-	-	-	+		C	-	A	A		R	R	R	C		R	-	-	C
Paracladopelma spp	R	-	-	+	+	-		-	-	-	-		-	-	-	-		-	-	-	-
Paratendipes sp	-	-	C	+	-	+		-	-	-	-		-	-	-	-		-	-	-	R
Phaenopsectra spp	-	-	-	-	+	+		-	-	-	-		-	-	-	-		-	-	-	C
Phaenopsectra flavipes gr.	-	C	-	-	-	-		-	-	R	-		-	-	-	-		C	R	C	C
Polypedilum convictum	A	-	R	-	-	-		A	C	C	C		A	A	A	A		-	-	-	C
Polypedilum aviceps	-	-	-	-	-	-		-	-	-	-		-	-	-	A		A	A	A	-
Polypedilum halterale	A	A	-	+	+	-		-	-	-	-		-	-	-	-		-	-	-	-
Polypedilum illinoense								-	-	-	R		-	-	-	-		-	-	-	A
Polypedilum fallax	-	C	R	+	-	-		-	-	-	-		-	-	-	-		R	C	-	-
Polypedilum scalaenum	R	-	R	+	-	-		-	-	-	-		-	-	-	-		-	-	-	-
Stenochironomus sp	-	-	-	+	+	+		-	-	-	-		-	-	-	-		R	-	-	-
Stictochironomus sp	-	-	-	-	+	+		-	-	-	-		-	C	R	-		C	C	-	-
Tribelos sp	R	-	-	+	-	-		-	C	C	A		-	-	C	C		C	-	C	-
Cladotanytarsus sp	R	-	-	-	-	-		-	-	-	-		-	R	-	-		-	-	-	-
Micropsectra spp	R	-	-	-	-	+		-	-	-	-		-	-	-	-		-	-	-	-
Paratanytarsus sp	-	-	-	+	+	+		-	R	C	-		-	-	R	-		-	-	-	-
Rheotanytarsus spp	C	C	C	-	+	+		C	R	C	C		C	-	-	R		-	R	-	-
Stempellina spo	R	-	R	-	+	-		-	-	-	-		-	-	-	-		-	-	-	-
Stempellinella sp	C	-	-	-	-	+		-	-	-	-		-	-	-	-		-	-	-	-
Tanytarsus spp	A	C	C	+	+	-		R	-	-	R		C	R	C	-		A	A	C	A

Date:	09/00			12/00			12/08					03/10					3/11				
Site:	2	3	4	2	3	4	M	1	2	3	4	M	1	2	3	4	M	1	2	3	4
OLIGOCHAETA																					
Limnodrilus spp (hofmeisteri)	A	C	A	-	C	C		-	-	-	-		R	R	-	-		-	-	-	C
Ilyodrilus templetoni	-	-	A	-	-	R		-	-	-	-		-	-	-	-		-	R	R	R
Spirosperma nikolsyii	R	-	-	-	-	-		R	-	-	-		-	-	-	-		C	R	A	R
Nais spp	C	-	C	R	R	C		R	-	C	R		R	-	-	-		-	-	R	-
Dero sp	-	-	-	-	-	-		-	-	-	-		-	-	-	-		-	-	R	C
Stylaria lacustris	-	-	-	-	-	-		-	-	C	R		-	R	-	-		-	-	C	R
Haplotaxis gordioides	-	-	-	-	-	-		-	-	-	-		-	-	-	-		R	-	-	-
Lumbriculidae	-	R	C	-	R	C		-	-	R	-		R	-	-	R					
Lumbriculus variegatus																		-	-	-	C
Ecclipidrilus spp																		R	-	C	R
Megadriles								C	C	R	R		-	-	-	-		-	-	-	C
CRUSTACEA																					
Crangonyx spp	C	R	-	C	C	R		A	A	A	A		C	C	C	A		C	A	A	C
Hyallela azteca	R	-	-	C	R	-		C	A	C	-		R	C	C	C		R	-	R	A
Caecidotea sp	-	-	-	-	-	-		C	C	A	A		-	-	-	R		-	R	A	R
Cambarus (P.) sp. C Cooper								R	-	-	-		A	C	C	C		A	A	C	C
Cambarus (C.) davidi								R	-	-	-										
Procambarus acutus	C	R	R	C	R	R		C	C	R	R		C	C	-	-		-	-	-	-
MOLLUSCA																					
Elimia sp	C	R	C	-	R	R		A	C	-	R		A	C	C	C		A	A	-	C
Leptoxis sp	-	-	-	-	-	-		R	-	-	-		-	-	-	-		-	-	-	-
Campeloma decisum	-	-	-	-	-	-		-	-	-	-		-	-	-	-		R	C	-	R
Physella sp	-	-	R	R	A	C		R	R	R	R		-	R	R	-		R	A	R	A
Lymnaea (?) sp	-	R	R	-	-	-		-	-	-	-		-	-	-	-		-	-	-	-
Helisoma anceps	C	R	R	C	R	-		-	-	R	-		-	-	-	R		-	C	R	C
Menetus dilatatus	-	-	-	-	C	-		R	-	-	-		-	-	-	-		-	-	R	-
Ferrissia sp	-	-	-	-	-	-		-	-	-	C		-	-	R	-		R	-	R	-
Sphaerium spp	C	R	R	C	A	C		C	C	-	-		R	-	-	-		R	C	-	-
Pisidium spp	-	-	R	-	-	-		-	R	-	-		R	R	-	-		-	R	R	-
Corbicula fluminea	-	-	-	-	-	-		-	A	-	R		R	R	-	-		C	C	C	-
Elliptio sp	-	-	-	-	-	-		-	R	-	-		-	-	-	-		-	-	-	-
OTHER																					
Belostoma sp	R	-	-	-	-	-		-	-	-	-		-	-	-	-		-	-	-	-
Ranatra sp	R	-	-	-	-	-		-	-	-	-		-	-	-	-		-	-	-	-
Turbellaria	-	-	-	A	A	-															
Dugesia tigrina	-	R	C	-	-	-		-	R	-	-		-	-	R	-		-	-	-	R
Cura foremanii								R	R	R	-		R	-	R	-		-	-	-	-
Hydrolimax grisea								-	-	R	-		-	R	-	-		-	C	C	C

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

	Date:	3/09	3/11	3/11	3/11
	Site:	UT Bolin Seawell	UT Bolin Seawell	UT Bolin Hornehollow	Jolly Br
EPHEMEROPTERA					
Eurylophella verisimilis		C	A	-	
Ameletus lineatus		C	C	-	C
Maccaffertium modestum		C	C	-	-
Paraleptophlebia sp		A	A	R	
Centroptilum triangulifer		-	-	-	R
Plauditus sp		-	-	-	R
PLECOPTERA					
Perlesta sp		C	R	R	A
Eccoptura xanthenes		R	R	C	
Allocapnia spp		A	-	-	
Amphinemura sp		A	A	R	A
Clioperla clio		-	R	-	
TRICHOPTERA					
Diplectrona modesta		C	C	-	-
Cheumatopsyche spp		-	-	C	-
Chimarra sp		-	-	C	-
Wormaldia sp		A	C	-	-
Polycentropus sp		C	-	R	-
Neophylax consimilis		A	A	A	R
Neophylax oligius		-	-	A	-
Ironoquia puntatissima		C	-	-	A
Psilotreta sp		C	A	-	-
Rhyacophila fenestra		A	A	-	A
Rhyacophila glaberrima		A	C	-	-
COLEOPTERA					
Anchytarsus bicolor		R	C	C	-
Helichus spp		-	R	C	R
Psephenus herricki		R	R	C	-
Ectopria nervosa		-	R	R	-
Stenelmis crenata		-	-	-	C
Neoporus spp		C	R	-	-
ODONATA					
Calopteryx sp		-	-	-	R
Neurocordulia uhleri		R	-	-	-
Somatochlora sp		-	R	-	C
Gomphus sp		-	-	R	-
DIPTERA: MISC.					
Tipula spp		A	R	R	R
Dixa sp		-	R	R	-
Dixella indiana		-	C	-	R
Palpomyia complex		R	C	-	R
Prosimulium sp		R	R	-	-
Simulium spp		R	R	-	C
Stegopterna mutata		-	-	-	R

	Date: 3/09	3/11	3/11	3/11
	Site: UT Bolin Seawell	UT Bolin Seawell	UT Bolin Hornehollow	Jolly Br
DIPTERA: CHIRONOMIDAE				
Conchapelopia group	-	-	-	R
Clinotanypus pinguis	R	-	-	-
Zavrelimyia sp	C	R	-	R
Ablabesmyia mallochi	-	-	R	-
Paramerina sp	-	-	R	-
Corynoneura spp	R	R	-	C
Thienemaniella spp	R	-	-	-
Diplocladius cultriger	R	-	-	-
Eukiefferiella claripennis gr	R	-	-	-
Eukiefferiella brevicalcar gr	-	-	-	R
Hydrobaenus spp	-	-	-	A
Orthocladius dorenus	-	-	-	A
Orthocladius obumbratus gr	C	-	-	-
Orthocladius robacki	-	R	-	A
Parametriocnemus lundbecki	C	-	C	C
Tvetenia bavarica gr	R	-	R	-
Microtendipes spp	-	R	-	-
Paralauterborniella nigrohalteralis	-	-	R	-
Phaenopsectra flavipes gr	C	-	-	R
Tribelos sp	-	-	R	-
Polypedilum aviceps	C	-	C	-
Rheotanytarsus spp	-	-	C	-
OLIGOCHAETA				
Ilyodrilus templetoni	-	-	-	R
Nais spp	-	C	R	C
Slavinia appendiculata	R	-	-	-
Lumbriculus sp	-	-	-	R
Ecclipdrilus(?) spp	A	A	A	R
Enchytraeidae	R	-	-	-
CRUSTACEA				
Crangonyx spp	A	A	R	A
Caecidotea sp (forbesi)	A	C	-	A
Cambarus spp	C	A	C	R
MOLLUSCA				
Elimia sp	C	A	A	-
Menetus dilatatus	A	R	-	-
OTHER				
Cura foremanii	R	-	-	-
Protostoma graecens	R	-	-	-
Corixidae	C	-	-	-