# BIOLOGICAL MONITORING OF BOLIN CREEK CARRBORO, NORTH CAROLINA

# JULY 2009 SURVEY

**LENAT CONSULTING SERVICES**
**3607 CORBIN STREET**
**RALEIGH NC 27612**
**919-787-80897**
**LENATBKS@MINDSPRING.COM**

**INTRODUCTION**
Water quality in Bolin Creek was evaluated in 2009 by sampling benthic macroinvertebrates at 5 sites on July 7, 2009 Benthic macroinvertebrates, especially aquatic insects, are associated with the substrates of streams, rivers and lakes. This group of aquatic species is especially useful as an indicator of biological integrity.

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

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

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

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

This report is designed to function as a “stand-alone” document, and many of the introductory sections are repeated from earlier reports. A reader who is familiar with earlier Bolin Creek reports (2008) may wish to skip to the Results section.

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

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

**METHODS** [Repeated from earlier Bolin Creek report]
All collection methods are derived from techniques used by the NC Division of Water Quality (Lenat 1988). These methods have been in use by North Carolina since 1982, and have been thoroughly tested for accuracy and repeatability. More details can be found at their web site: http://h2o.enr.state.nc.us/esb/BAU.html. Two of DWQ's collection methods have been used for the Bolin Creek study: intensive "Standard Qualitative" collections and more rapid" Qual 4" collections. These two methods are briefly described below.

**Standard Qualitative Method - Overview**

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.

**Qual 4 Method - Overview**

The EPT method is a more rapid collection technique, limited to 4 samples: 1 kick, 1 bank sweep, 1 leaf pack and visuals. Note that the Qual 4 method is a subset of the standard qualitative method described above.

**Assigning Bioclassifications - Overview**

The ultimate result of a benthos sample is a bioclassification. Bioclassifications used by NC DWQ are Excellent, Good, Good/Fair, Fair, and Poor. For standard qualitative samples, these categories 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. Excellent, Good, and Good-Fair rating indicate that a stream is supporting designated uses; Fair and Poor rating are used to indicate that a stream is not supporting designated uses.

**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 (Lenat 1993). This index is similar to the Hilsenhoff Biotic Index (Hilsenhoff, 1987), but with tolerance values objectively 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 Piedmont streams, equal weight should be given to both the NC Biotic Index value and EPT taxa richness value in assigning bioclassifications. For these metrics, bioclassifications are assigned from the following scores:

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

"Borderline" values are assigned near half-step values (1.4. 2.6, etc.) and are defined as boundary EPT values ±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. Sampled were collected four times a year in 2000 and 2001 to evaluate normal season trends, but only once per year (August or September) from 2003-2007. These samples were collected and identified by Ecological Consultants (Chapel Hill, NC), with assistance from Pennington and Associates (Kentucky). These studies established 4 sites along the Carrboro portion of Bolin Creek, which have been repeated in December 2008 and July 2009 (Lenat Consulting Services, Inc.).

Sites are numbered from most upstream (Site 1) to most downstream (Site 4). Samples were collected (with assistance from Randy Dodd, City of Carrboro Planning) on July 8, 2009. More detailed site descriptions (with photos) are presented in Appendix 1.

Table 1. Site characteristics, Bolin Creek and Morgan Creek, July 2009.

| | Morgan | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Substrate (%) | | | | | |
| Boulder | 20 | 15 | 25 | 25 | 50 |
| Rubble | 30 | 20 | 15 | 40 | 25 |
| Gravel | 30 | 40 | 20 | 20 | 15 |
| Sand | 20 | 25 | 20 | 15 | 10 |
| Silt | - | Trace | 20 | Trace | Trace |
| Width (m) | 6 | 3 | 3 | 4.5 | 4 |

The most upstream site has a higher proportion of sand and gravel, although there is adequate boulder and rubble to support a normal macroinvertebrate community. Site 2 (below the Winmore development) was the only site with a significant amount of silt. Sites 3 and 4 are very rocky. DWQ does not assign ratings to streams less than 4.0 meters in width, and sites 1 and 2 are both les than 4 meters wide during normal summer flows.

**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 September 2008 (latest available) for monthly means and daily flow data from 1999 to 2009. The USGS measures daily flow at Morgan Creek and Cane Creek; both streams are in Orange county and both are similar to Bolin Creek. Low flows (means less than 0.5 cfs) are highlighted in yellow; severe low flows (means less than 0.1 cfs) are highlighted in red.

Mean Monthy flow (cfs) in streams most similar to Bolin Creek, 1999-2008. [Monthly data not available for 2009 at the time of this report]

*Morgan Creek nr White Cross*

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

*Cane Creek nr Orange Grove*

| Year | Month: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1999 | 14 | 4 | 3 | 6 | 1.1 | 0.5 | 0.2 | 0.09 | 18 | 4 | 6 | 4 |
| 2000 | 9 | 14 | 8 | 12 | 2 | 8 | 14 | 3 | 5* | 0.9 | 0.8 | 5* |
| 2001 | 3 | 9 | 21 | 11 | 1.2 | 2* | 0.4 | 0.1 | 0.1 | 0.1 | 0.06 | 0.2 |
| 2002 | 5 | 2 | 3 | 1.1 | 0.1 | 0.03 | 0.04 | 0.04 | 0.4* | 13 | 9 | 20 |
| 2003 | 6 | 20 | 34 | 37 | 17 | 8 | 5 | 4 | 1.3* | 0.7 | 0.7 | 6 |
| 2004 | 2 | 8 | 5 | 4 | 0.9 | 0.4 | 1.9 | 10 | 9* | 1.8 | 4 | 4 |
| 2005 | 7 | 6 | 15 | 6 | 2 | 0.8 | 0.3 | 0.3* | 0.000 | 0.03 | 0.5 | 8 |
| 2006 | 3 | 2 | 1.2 | 2 | 1.0 | 7 | 4 | 0.1 | 0.2 | 1.2 | 19 | 6 |
| 2007 | 11 | 8 | 12 | 12 | 0.9 | 0.2 | 0.03 | 0.00 | 0.00* | 0.005 | 0.000 | 0.08 |
| 2008 | 0.3 | 1.2 | 7 | 9 | 3 | 0.2 | 0.5 | 0.3 | 3.8 | | | |

*Month for prior Bolin Creek samples


QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

**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 | Fair (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. A one-year recovery was also seen after the drought conditions in 2008.

Town of Carrboro Data, 2000-2007, Ecological Consultants, Standard Qualitiative Samples. (DWQ method).
Bioclassifications were assigned yearly from 2000-2007, but severe droughts (see flow data) made it inappropriate to assign ratings in 2002, 2006, and 2007. Biotic index numbers are only available from 2000-2001. Between June 2001 and September 2004, the rating is based solely on EPT taxa.

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

**RESULTS AND DISCUSSION** (Tables 2-3, Appendix 2)
Early samples from Bolin Creek (prior to 2000) indicated Good water quality in the upper section, declining slightly to Good-Fair further downstream. Surveys in 2000, however, produced a Fair rating for sites at Waterside Drive (#3) and Estes Drive (#4). It appears that nonpoint source runoff had a significant negative effect on water quality in Bolin Creek between 1998 and 2000. Note that changes in habitat were not responsible for any these changes and that there were no drought problems in 2000.

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

-Aug-Dec 2001 (6 months, with lowest flow in Nov)
-June-Sept 2002 (4 months with streams drying up much of this time)
-June 2004
-July-Oct 2005 (4 months with streams going dry in September)
-Aug-Sept 2006
-June-Dec 2007 (7-8 months, with streams going dry for 4-6 months).

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. Most of the invertebrate samples had been collected in September, which would have been a normal seasonal minimum. The repeated Fair and Poor rating assigned to much of Bolin Creek during this period have been used to show that Bolin Creek does not support designated used, but the 2008 and 2009 samples (see below) suggested that a different answer may be obtained as the stream recovers from drought impacts.

December 2008 collections (largely repeated from prior report)
Sampling in 2008 was conducted in the month of December, in contrast to the August-September collections in most other years. December, however, can also be a low point for taxa richness: summer species have emerged, but many spring species not yet hatched.

Sampling in December 2008 produced very similar results for all 4 sites on Bolin Creek: EPT taxa richness of 10-12 species and a NC Biotic index of 5.9-6.2. This produced a Fair rating using only the EPT taxa richness and a Good-Fair rating using tolerance data. In light of the negative effect of severe drought on taxa richness, all sites were "rounded up" to a tentative Good-Fair rating. *These ratings implied that Bolin Creek supported designated uses in 2008 and has at least partially recovered from the impacts seen in 2000, 2001, 2003, and 2004.*

| | | Sites | | | |
|---|---|---|---|---|---|
| | Morgan Cr | 1 | 2 | 3 | 4 |
| Total Taxa Richness | - | 57 | 53 | 52 | 44 |
| EPT Taxa Richness | 18 (21*) | 12 | 10 | 12 | 12 |
| NC Biotic Index | - | 5.9 | 5.9 | 6.2 | 5.9 |
| Rating | Good? | Good-Fair | Good-Fair | Good-Fair | Good-Fair |

*Value predicted for more comprehensive standard 10-sample collection, see below

A 4-sample EPT collection was taken at Morgan Creek to provide additional reference data. Note that EPT tax richness predicted for a 10-sample collection was almost twice that of the Bolin Creek samples[1]. Furthermore, the EPT biotic index value (3.9) was much lower than those observed at Bolin Creek sites (4.3-5.4), indicating a more intolerant community. Species which were very abundant at Morgan Creek, but absent from Bolin Creek, included both *Isonychia* and *Leucrocuta*. Both of these mayflies have been collected from Bolin Creek, but appear to have been eliminated by the combination of drought and water quality problems.

A commonly observed pattern at Bolin Creek sites is low taxa richness (suggesting stress) and the abundance of intolerant species (suggesting good water quality). This pattern was especially evident in December of 2008. Key intolerant species include the caddisfly *Chimarra* plus the stoneflies *Eccoptura xanthenes* and *Acroneuria abnormis*. *Eccoptura* favors small headwater streams, while *Acroneuria* is more commonly found in large streams; both are similar long-lived species that reflect water quality conditions over a period of six months to one year.

*Chimarra* was common or abundant mainly at the upstream control site in 2000-2001. It became abundant at all sites in 2004 and 2008, suggesting improving water quality at downstream sites 3 and 3. *Acroneuria* has consistently been common or abundant at the downstream sites on Bolin Creek. The abundance of this highly intolerant species at site 2 in 2008 clearly indicated good water quality.

July 2009 collections

EPT taxa richness was uniformly low at all sites (10-11), but there were significant changes in community composition between sites. This low EPT taxa richness may reflect a slow recovery from prior droughts. Species associated with the bank area were more abundant than in samples from 2003-2007, including *Caenis* (a mayfly), *Triaenodes ignitus* (a caddisfly), *Hyallela azteca* (an amphipod), plus many dragonflies and damselflies. During droughts, the stream water may not be in contact with bank areas, greatly reducing the abundance and diversity of species associated with root mats, undercut banks, etc.

Site 1. The most upstream site had the most intolerant community; this was the only site where an intolerant caddisfly, *Neophylax oligius* , was abundant. Site 1 received the same Good-Fair bioclassification that was assigned in December 2008.

Site 2. This site is located downstream of the Winmore development. Relative to Site 1, there was a significant increase in the biotic index (5.6→6.6), indicating a shift to a more tolerant community. Two intolerant species declined from Abundant to Common (*Chimarra* sp and *Psephenus herricki*), while there were increases in more tolerant groups (fingernail clams, Chironomidae). The bioclassification for Site 2 declined from Good-Fair in December 2008 to

[1] The 10-sample EPT value can be estimated from the 4-sample value by multiplying by a correction factor of 1.15.

Fair in July 2009, but the invertebrate community was similar to that obtained from the last summer sample in August 2006.

Site 3. Site 3 showed a similar a trend similar to that observed at Site 2 – A good-Fair rating in December 2008, declining slightly to Fair in July 2009. Both ratings, however, are a significant increase over the Poor ratings seen in summer samples from 2003, 2005, and 2006. Relative to Site 2, Intolerant species increased in abundance.

Site 4. Although this is very similar to Site 3, a slight improvement in the biotic index was sufficient to produce a Good-Fair rating. This site was also rated as Good-Fair in December 2008 – a large improvement over the Poor ratings assigned in 2005 and 2006.

Morgan Creek. Morgan Creek had both higher EPT taxa richness and a lower Biotic Index than any of the Bolin Creek sites. The lower Biotic Index reflects the abundance of many intolerant species found at this site. Like Bolin Creek, however, Morgan Creek also suffers from the effects of going dry during summer droughts. This site received a Good-Fair rating in July 2009, but had been given a Good rating in December 2008. DWQ samples have also produced Good or Good-Fair rating fro this site in recent years.

These between site changes are easier to seen if we look at a few of the more intolerant species, especially those that are abundant at one or more of the 5 sites. Species selected are:

Ephemeroptera (Mayflies)

*Isonychia* sp. Tolerance Value = 3.5. A large brown mayflies that filter-feeds by using hairs oin it's legs. It favors high current environments, either rocks or leafpacks.

*Leucrocuta aphrodite.* Tolerance Value = 2.4. A flattened mayfly found on the bottom of rocks, often in slower water.

Plecoptera (Stoneflies)

*Acroneuria abnormis.* Tolerance Value = 3.7. A large and predacious stonefly, usually in leafpacks or large boulder/rubble habitat.

Trichoptera (Caddiflies)

*Chimarra* sp. Tolerance Value = 2.8. Live specimens are bright orange. This is a filter-feeding caddisfly that constructs a net with a very small mesh-size. It usually occurs in areas of fast current.

Coleoptera (Beetles)

*Psephenus herricki.* Tolerance Value = 2.4. The common name is the "water penny". This round beetle larvae is found under rocks, often in pool areas.

Gastropoda (Snails)

*Elimia* sp, Tolerance Value = 2.5. This is a long-lived and fairly immobile species that cannot escape the effects of pollution. It is usually found on top of rocks in areas of low water, often near the banks.

| | Sites | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | Morgan Cr |
| Isonychia spp | - | - | - | - | A |
| Leucrocuta aphrodite | - | - | - | - | A |
| Acroneuria abnormis | - | - | R | R | C |
| Chimarra sp | A | C | A | A | A |
| Acroneuria abnormis | - | - | R | R | C |
| Neophylax oligius | A | R | - | - | - |
| Psephenus herricki | A | - | A | A | A |
| Elimia sp | A | A | C | A | - |
| Sum* | 40 | 14 | 25 | 32 | 46 |

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

*Isonychia* and *Leucrocuta* are found only in Morgan Creek, although both had occurred in Bolin Creek in prior collections. *Neophylax oligius* was mainly found in Bolin Creek, upstream of the developed area. *Chimarra* and *Psephenus* were abundant at most sites in 2009, but showed a distinct minimum at Site 2, downstream of Winmore.

*Acroneuria abnormis* has been a useful indicator of water quality in past samples, but was not abundant at any sites in July. This may reflect a normal seasonal minimum, as this species was common or abundant in December 2008 at Morgan Creek and Bolin Creek sites 3-4. The absence of this species from the headwaters of Bolin Creek is likely due to low flows in this part of the stream.

*Elimia* is a large snail, often seen on the top of rocks in Slate Belt streams. Because it does not colonize by either drift or an adult aerial stage, this species can be slow to recover from the effects of pollution. It became abundant at 3 out of the 4 Bolin Creek sites in 2009, supporting the idea of a gradual recovery.

The overall distribution of these taxa (as shown by the "sum" above), suggests the best water quality in Morgan Creek and Bolin Site 1. There was a decline in water quality at Site 2, with a gradual downstream recovery. The Winmore residential area (just upstream of Site 2) is still in active development, and we might expect conditions to improve as the land stabilizes.

Winter/spring sampling vs. Summer sampling

The NC Division of Water Quality has traditionally used summer samples (June-September) to assign water quality ratings. More recently, however, they have switched to winter and spring samples for those streams that are *expected to stop flowing (or even dry up) in the summers*. This mainly includes coastal plain swamp stream, but has also been extended to some stream in the Slate Belt and Triassic ecoregions. Given the frequency of low-flow events in Bolin Creek over the last decade, winter samples may produce more reliable results than summer samples. For this reason, all of Bolin Creek down to Estes Drive should be considered as having a Good-Fair rating, and supporting designated uses. Further sampling will be useful in examining this hypothesis.

**SUMMARY**

Biological sampling on Bolin Creek in 2000 and 2001 indicated significant water quality problems in the middle and lower segments, with Fair or Poor ratings at downstream sites. This change was evident both from comparisons over time and comparisons with upstream control sites. A series of severe droughts from 2001-2007, however, greatly complicated the analysis of water quality problems by imposing an independent physical stress on stream biota. Sampling in December 2008 and July 2009 suggests that Bolin Creek is still slowly recovering from the effects of these droughts. It also appears to be recovering from past water quality problems, although most sites are borderline between a Fair and Good-Fair rating. Because of frequent low-flow problem in Bolin Creek during summer months, greater reliance should be placed on data from winter or spring collections.

Table 2. Taxa richness by group, Bolin Creek, Orange County, 2000-2009 See text for site locations.
Earlier collections have been adjusted for taxonomic consistency. G-F = Good-Fair, F = Fair, P = Poor.

| Date: | 09/00 | | | 09/03 | | | 09/04 | | | 09/05 | | | 08/06 | | | 07/09 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site: | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Morgan** |
| Ephemeroptera | 8 | 2 | 1 | 4 | 2 | 4 | 4 | 4 | 4 | 3 | 2 | 2 | 5 | 2 | 2 | 5 | 6 | 4 | 4 | 8 |
| Plecoptera | 2 | 2 | 1 | 2 | 1 | 1 | 1 | - | 1 | 1 | 1 | 1 | 1 | - | 1 | - | - | 1 | 1 | 2 |
| Trichoptera | 6 | 6 | 2 | 3 | 3 | 3 | 5 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 3 | 6 | 5 | 5 | 5 | 3 |
| Coleoptera | 10 | 6 | 6 | 3 | 2 | 2 | 4 | 2 | 4 | 5 | 2 | 2 | 6 | 3 | 3 | 7 | 5 | 4 | 6 | 5 |
| Odonata | 10 | 6 | 6 | 3 | 2 | 2 | 4 | 2 | 4 | 5 | 2 | 2 | 6 | 3 | 3 | 7 | 5 | 4 | 6 | 5 |
| Megaloptera | 1 | 1 | - | - | 1 | - | - | - | - | 1 | - | - | 1 | - | - | 1 | 1 | 1 | 1 | 2 |
| Diptera: Misc. | 4 | 4 | 4 | 2 | 3 | 2 | 2 | 1 | 2 | - | 2 | 2 | 1 | - | - | 1 | 2 | 3 | 3 | 5 |
| Diptera: Chironomidae | 19 | 12 | 13 | 12 | 6 | 7 | 14 | 4 | 2 | 6 | 7 | 6 | 11 | 2 | 3 | 14 | 17 | 15 | 17 | 11 |
| Oligochaeta | 3 | 2 | 4 | - | 1 | 3 | 2 | - | 1 | 1 | 4 | 3 | 4 | - | - | 4 | 2 | 2 | 4 | 1 |
| Crustacea | 3 | 2 | 1 | 2 | 2 | - | 1 | 1 | - | 1 | 1 | - | 4 | 1 | 2 | 4 | 3 | 2 | 3 | 3 |
| Mollusca | 3 | 4 | 6 | 4 | 2 | 1 | 4 | 3 | 3 | 3 | 2 | - | 4 | 3 | 4 | 3 | 4 | 5 | 3 | 3 |
| Other | 2 | 1 | 1 | - | - | - | 1 | - | 1 | - | 1 | - | - | - | - | 2 | 2 | - | 3 | - |
| EPT Taxa Richness | 16 | 10 | 4 | 9 | 6 | 8 | 10 | 7 | 8 | 7 | 6 | 6 | 10 | 6 | 6 | 11 | 11 | 10 | 10 | 13 |
| EPT Abundance | 87 | 47 | 26 | 40 | 46 | 48 | 48 | 45 | 46 | 13 | 30 | 19 | 50 | 21 | 25 | 60 | 55 | 64 | 73 | 107 |
| Total Taxa Richness | 71 | 48 | 45 | 35 | 25 | 25 | 42 | 20 | 25 | 36 | 27 | 21 | 47 | 18 | 21 | 54 | 52 | 46 | 56 | 48 |
| NC Biotic Index | 6.2 | 6.1 | 6.4 | * | * | * | * | * | * | * | * | * | * | * | * | 5.5 | 6.6 | 6.4 | 6.2 | 5.7 |
| Rating | G-F | F | P | F | P | F | F | F | F | F | P | P | F | P | P | G-F | F | F | G-F | |

*Not provided by consultant, rating based only on EPT taxa richness.
**A “Qual 4’ sample, expect lower taxa richness values, esp. for Chironomidae. Predicted EPT taxa richness for Standard Qualitative Sample would be 15.

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Appendix 2. Bolin Creek, Sites 1-4, Summer samples 2000-2009. R=Rare, C=Common, A=Abundant. Blue highlights indicate most intolerant species; yellow highlights indicate significant changes in abundance.

| | Date: | 09/00 | | | 09/03 | | | 09/04 | | | 09/05 | | | 08/06 | | | 07/09 | | | | |
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| | Site: | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Morgan |
| EPHEMEROPTERA | | | | | | | | | | | | | | | | | | | | | |
| Baetis flavistriga | | A | C | - | C | C | C | C | C | C | R | C | - | R | - | - | C | C | A | A | A |
| B. intercalaris? | | - | - | - | - | - | R | R | R | R | - | - | - | - | - | - | - | - | - | - | - |
| B. pluto | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | A |
| Centroptilum minor | | C | - | C | - | - | - | R | R | R | - | - | - | - | - | - | R | - | - | - | - |
| Procloeon sp | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - |
| Acerpenna pygmaea | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - |
| Caenis spp | | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | C | R | R | A |
| Ephemerella dorothea | | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Eurylophella spp | | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Isonychia spp | | A | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | A |
| Leptophlebia sp | | C | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - |
| Leucrocuta aphrodite | | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | A |
| Stenonema modestum | | A | C | - | A | A | A | A | A | A | C | C | R | A | C | A | A | A | A | A | A |
| S. femoratum | | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - |
| Stenacron interpunctatum | | A | - | - | - | - | - | - | - | - | R | - | R | A | C | R | A | A | A | A | A |
| Hexagenia sp | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C |
| PLECOPTERA | | | | | | | | | | | | | | | | | | | | | |
| Acroneuria abnormis | | C | C | C | R | C | C | R | - | R | C | R | R | - | - | R | - | - | R | R | C |
| Perlesta sp | | C | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Eccoptura xanthenes | | - | - | - | C | - | - | - | - | - | - | - | - | C | - | - | - | - | - | - | R |
| TRICHOPTERA | | | | | | | | | | | | | | | | | | | | | |
| Cheumatopsyche spp | | A | A | A | A | A | A | A | A | A | C | C | C | A | A | A | A | A | A | A | A |
| Hydropsyche betteni | | A | A | A | R | A | A | A | A | A | R | A | A | C | R | C | C | A | A | A | A |
| Diplectrona modesta | | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Chimarra sp | | A | R | - | A | A | A | A | A | A | R | A | C | A | C | R | A | C | A | A | A |
| Polycentropus sp | | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | R | - | - | - | - |
| Lype diversa | | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - |
| Ceraclea ancylus | | R | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Triaenodes ignitus | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | C | R | A | - |
| Oecetis persimilis | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - |
| Neophylax oligius | | R | A | - | - | - | - | - | - | - | - | - | - | - | - | - | A | R | - | - | - |

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| Pycnopsyche sp | | R | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Ironoquia punctatissima | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - |
| Hydroptila sp | | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - |
| COLEOPTERA | | | | | | | | | | | | | | | | | | | | | |
| Anchytarsus bicolor | | A | C | C | - | - | - | R | - | - | - | - | - | C | - | - | R | - | - | - | - |
| Ancyronyx variegata | | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | R | R | - | - |
| Macronychus glabratus | | C | C | C | - | - | - | R | - | - | R | - | - | - | - | - | - | - | - | - | - |
| Dubiraphia sp | | C | R | A | - | - | - | - | - | - | R | - | - | - | - | - | - | C | C | A | - |
| Stenelmis crenata | | - | - | - | C | R | C | A | A | A | A | A | A | A | A | C | C | C | A | A | A |
| Microcyloepus pusillus | | C | R | C | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - |
| Oulimnius sp | | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - |
| Optioservus sp | | - | - | - | R | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | R |
| Psephenus herricki | | C | - | C | C | R | A | A | C | A | C | C | A | A | A | C | A | - | A | A | A |
| Ectopria nervosa | | R | R | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | |
| Helichus spp | | C | - | - | - | - | - | - | - | - | C | - | - | C | - | - | R | C | - | R | R |
| Gyrinus sp | | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Neoporus spp | | R | R | - | - | - | - | - | - | - | - | - | - | R | R | R | C | - | - | - | C |
| Neoporus mellitus gr | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | R | - | R | - |
| ODONATA | | | | | | | | | | | | | | | | | | | | | |
| Argia spp | | R | C | R | - | R | - | C | C | - | - | - | - | R | R | - | - | R | R | R | R |
| Calopteryx sp | | C | A | - | R | - | - | C | - | - | - | - | - | - | - | - | C | R | R | - | - |
| Enallagma spp | | C | - | C | R | - | - | - | - | - | - | - | - | R | - | - | - | R | - | - | - |
| Ischnura sp | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C | - | R | - | R |
| Gomphus sp | | R | C | - | - | - | - | - | - | - | - | - | - | - | - | - | R | R | - | - | R |
| Progomphus obscurus | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - |
| Stylogomphus albistylus | | R | R | - | - | - | - | - | - | - | C | - | - | C | - | - | C | C | - | R | - |
| Hagenius brevistylus | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - |
| Neurocordulia obsoleta | | - | R | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Somatochlora sp | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | C | A | C | - |
| Boyeria vinosa | | C | C | C | - | - | R | R | - | - | R | - | - | R | - | - | R | - | - | - | R |
| Basiaeschna janata | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | C | R | - | - |
| Cordulegaster sp | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - |
| MEGALOPTERA | | | | | | | | | | | | | | | | | | | | | |
| Nigronia serricornis | | C | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R |
| Sialis sp | | - | - | - | - | R | - | - | - | - | R | - | - | C | - | - | A | A | A | R | C |

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| DIPTERA: MISC | Site: | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Morgan |
| Anopheles sp | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | R |
| Dixella Indiana- | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R |
| Chaoborus sp | | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - |
| Antocha spp | | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - |
| Tipula spp | | A | C | R | C | R | R | R | R | R | - | - | - | R | - | - | - | C | C | C | R |
| Hexatoma sp | | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Limonia sp | | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - |
| Atrichopogon sp | | - | R | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Palpomyia complex | | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | R |
| Prosimulium spp | | R | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Simulium spp | | C | C | C | - | R | R | - | - | - | - | - | - | - | - | - | R | R | R | A | R |
| Chrysops sp | | - | - | - | - | - | - | R | - | - | - | R | R | - | - | - | - | - | - | - | - |
| Tabanus sp | | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Empididae | | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | | | | | | | | | | | | | | | | | | | | | |
| DIPTERA: CHIRONOMIDAE | | | | | | | | | | | | | | | | | | | | | |
| Ablabesmyia spp (2) | | A | C | C | R | - | R | - | - | - | R | - | - | R | - | R | C | A | C | C | C |
| Conchapelopia group | | C | R | - | C | R | R | C | - | - | - | R | R | C | - | - | C | C | C | A | R |
| Labrundinia sp | | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | R | - |
| Natarsia sp | | - | - | - | - | - | - | - | - | - | R | R | R | R | - | - | - | R | R | C | - |
| Nilotanypus sp | | - | - | - | - | - | - | - | - | - | - | C | R | - | - | - | R | - | - | - | - |
| Procladius sp | | - | C | C | R | - | - | - | - | - | - | - | - | - | - | - | R | C | R | - | - |
| Tanypus carinatus | | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - |
| Brillia sp | | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | R | - | - | - |
| Xylotopus par | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - |
| Corynoneura spp | | R | - | - | R | - | - | - | R | - | - | C | - | - | - | - | - | - | - | - | - |
| Thienemaniella spp | | C | R | C | - | - | C | R | - | - | - | - | - | C | - | - | - | - | R | R | - |
| Cricotopus bicinctus | | - | R | C | - | - | - | R? | - | - | - | C | - | - | - | - | - | - | - | - | - |
| Cricotopus C/O sp 6 | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | R | - |
| Nanocladius spp (2-3) | | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Orthocladius spp | | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| O (Eudactylocladius) dubitatus | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | A | - |
| O. (Euorthocladius) sp | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R |
| Parametriocnemus lundbecki | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C | - | R | - | - |
| Psectrocladius spp | | - | - | - | - | - | - | R | R | - | - | - | - | - | - | - | - | - | - | - | - |
| Rheocricotopus robacki | | C | R | C | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Synorthocladius sp | | - | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Tvetenia bavarica gr | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - |
| Potthastia longimanus | | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - | - |

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| Chironomus sp | | - | R | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - |
| Cryptochironomus spp | | A | - | - | - | - | R | - | - | - | - | - | - | - | - | - | R | R | R | R | R |
| Crytotendipes sp | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | C | R | - | - |
| Dicrotendipes spp | | - | - | C | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - |
| Endochironomus? | | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Microtendipes spp | | - | - | - | R | R | - | - | - | - | C | - | - | C | R | - | A | C | A | A | C |
| Paracladopelma spp | | R | - | - | - | - | - | A | - | - | - | - | - | R | - | - | - | - | - | - | - |
| Paratendipes sp | | - | - | C | R | - | - | - | - | - | R | - | - | R | - | - | - | C | C | C | C |
| Phaenopsectra spp | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - |
| Phaenopsectra flavipes gr. | | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - |
| Polypedilum aviceps | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - |
| Polypedilum flavum | | A | - | R | A | A | C | - | R | R | - | C | C | - | C | - | - | A | C | A | C |
| Polypedilum halterale | | A | A | - | - | - | - | - | - | - | - | - | R | R | - | - | - | - | - | - | - |
| Polypedilum illinoense | | - | - | - | R | - | - | C | - | - | - | - | - | - | - | R | - | C | - | - | - |
| Polypedilum fallax | | - | C | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Polypedilum scalaenum | | R | - | R | - | - | - | - | - | - | - | - | - | - | - | - | R | C | C | C | R |
| Stenochironomus sp | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C | - | - | R |
| Tribelos sp | | R | - | - | C | - | - | R | R | R | C | - | - | R | - | - | C | A | A | A | R |
| Cladotanytarsus sp | | R | - | - | - | - | - | C | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Micropsectra spp | | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| Rheotanytarsus spp | | C | C | C | C | R | A | C | - | - | - | - | - | - | - | - | R | - | R | R | |
| Stempellina spo | | R | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Stempellinella sp | | C | - | - | - | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Tanytarsus spp | | A | C | C | C | C | R | - | - | - | - | - | R | R | - | - | - | A | R | R | - |
| | | - | - | | | | | | | | | | | | | | | | | | |
| OLIGOCHAETA | | | | | | | | | | | | | | | | | | | | | |
| Limnodrilus spp (hofmeisteri) | | A | C | A | - | - | R | - | - | - | C | C | R | R | - | - | R | - | - | R | - |
| Ilyodrilus templetoni | | - | - | A | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - |
| Spirosperma nikolsyii | | R | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - |
| Nais spp | | C | - | C | - | - | R | C | - | - | - | R | R | - | - | - | - | - | - | - | - |
| Lumbriculidae | | - | R | C | - | R | C | R | - | - | - | - | - | R | - | - | C | - | R | R | C |
| Lumbriculus variegates | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - |
| Enchytraeidae | | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | - |
| Megadriles | | - | - | - | - | - | - | - | - | C | - | C | C | R | - | - | - | R | R | - | - |
| Cambarinicolidae | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | R | - | C | - |

| | Date: | 09/00 | | | 09/03 | | | 09/04 | | | 09/05 | | | 08/06 | | | 07/09 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Site: | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Morgan |
| CRUSTACEA | | | | | | | | | | | | | | | | | | | | | |
| Crangonyx spp | | C | R | - | R | C | - | - | - | - | R | R | - | C | - | - | - | - | - | C | R |
| Hyallela azteca | | R | - | - | R | - | - | - | - | - | - | - | - | C | - | - | C | C | A | C | A |
| Caecidotea sp | | - | - | - | - | R | - | - | - | - | - | - | - | C | - | - | R | - | - | - | - |
| Cambarus (P.) sp. C Cooper | | - | - | - | - | - | - | R | R | - | - | - | - | - | - | R | C | A | R | C | C |
| Procambarus acutus | | C | R | R | - | - | - | - | - | - | - | - | - | R | R | R | C | C | - | - | - |
| MOLLUSCA | | | | | | | | | | | | | | | | | | | | | |
| Elimia sp | | C | R | C | C | R | - | A | R | R | C | C | - | C | C | C | A | A | C | A | - |
| Campeloma decisum | | - | - | - | C | - | - | - | - | - | - | - | - | C | - | - | A | A | - | R | - |
| Physella sp | | - | - | R | - | - | - | - | - | R | - | - | - | - | - | - | - | - | R | - | - |
| Lymnaea (?) sp | | - | R | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Helisoma anceps | | C | R | R | R | - | - | R | R | - | R | R | - | - | - | - | - | - | R | - | R |
| Sphaerium spp | | C | R | R | A | R | R | - | - | - | R | - | - | - | R | R | - | A | R | - | - |
| Ferrissia sp | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C |
| Pisidium spp | | - | - | R | - | - | - | - | - | - | - | - | - | R | R | R | - | - | - | - | R |
| Corbicula fluminea | | - | - | - | - | - | - | R | C | C | - | - | - | R | - | R | - | C | R | R | - |
| Elliptio sp | | - | - | - | - | - | - | R | - | - | - | - | - | - | - | - | R | - | - | - | - |
| OTHER | | | | | | | | | | | | | | | | | | | | | |
| Belostoma sp | | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Ranatra sp | | R | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Corixidae | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | - | - | - |
| Dugesia tigrina | | - | R | C | - | - | - | R | - | R | - | C | - | - | - | - | - | - | - | - | - |
| Cura foremanii | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | C | R | - | C | - |
| Hydrolimax grisea | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - | C | - |
| Placobdella papilifera | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | R | - |

Appendix 1.  Toms Creek and Morgan Creek Sites, July 2009

Toms Creek 1. Site 1 was located just upstream Main Street in Carrboro, but with access from Lorraine Street. This site drains a largely residential area, although there was usually some buffer zone next to the stream. The stream was highly entrenched and may have been channelized in the past to install the adjacent sewer line.

Toms Creek Site 1, July 2009.

Flow was barely discernable in this part of Toms Creek and this segment may go completely dry during the summer. Width was about 0.2 meters in flowing areas, and about 1.5 meters in pools. There was severe bank erosion in some areas. Substrate was mostly gravel in flowing segments, but there were some areas with boulder and rubble.

Toms Creek 2. Site 2 is located downstream of Berryhill Drive and the Rosewalk development.

Toms Creek Site 2, July 2009.

There is greater flow here than at Toms Creek Site 1, but mean width is still only 2 meters. The substrate is mostly rubble and boulder (70%), but areas of sand deposition were observed along the bank. This part of Toms Creek is deeply entrenched, with severe bank erosion. There is a good buffer zone at this site, but very little buffer was observed at residential areas further upstream in this catchment.

Morgan Creek 1 at Dairyland Rd. In an attempt to find a better reference, Morgan Creek was examined at 2 sites on Dairyland Road. The most upstream site too small, but the downstream site had good flow and good habitat

Morgan Creek, Dairyland Rd, July 2009

Much of this segment was very low gradient, with low current speeds, but a good riffle area was found about 50 meters upstream of the culvert.

The catchment above this site includes some dairy operations, and some problems have been documented in the past.

Morgan Creek 2 at NC 54. Morgan Creek had been used as a reference site for our samples In December 2008, although this stream had also been affected by droughts. Prior surveys by the NC Division of Water Quality generally produced a Good or Excellent bioclassification for this site.

Morgan Creek, NC 54, December 2008.

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