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Evaluation of the Christmas Tree Industry in Western North Carolina on Surface Water Quality

Prepared by: Dr. Jill R. Sidebottom, Area Extension Specialist, North Carolina State University

Christmas tree importance to western North Carolina

Fraser fir (*Abies fraseri*) Christmas trees production in western North Carolina is an important industry, bringing an estimated $122 million in 1999 from the combined sales of Christmas trees, wreaths and roping. There are approximately 33.9 million trees grown on 22,833 acres, with the majority of the counties from most to least production being Ashe, Avery, Alleghany, Watauga, Jackson and Mitchell counties. These counties comprise 93% of the trees produced.

Pesticides used in Christmas tree production

Christmas trees are often grown on very steep slopes with shallow soils. Much of the production areas are highly erodible. Fraser fir is typically fertilized 1 to 2 times a year with fertilizers high in nitrogen and phosphorus. Averaged over all sizes and ages of trees there are 3.0 herbicide and 1.4 insecticide/miticide applications each year. Based on a 2000 Pest Management Survey, the primary herbicides used included Round-up (95% of acreage), Simazine (39% of acreage), Goal (21% of acreage), Stinger (12% of acreage), Vantage (15% of acreage), Garlon 3E (8% of acreage), Crossbow (3% of acreage) and Atrazine (3% of acreage). This averages to 1.7 pounds active ingredient of herbicides applied to every acre of Christmas trees grown in western North Carolina each year. Insecticides/miticides used included Di-Syston 15 G (50% of acreage), Lindane 20 EC (24% of acreage), Dimethoate (21% of acreage), Asana XL (17% of acreage), Lorsban 4E (8% of acreage), Savey (5% of acreage), and Morestan (3% of acreage). An estimated 4.1 pounds of active ingredient of insecticides/miticides are applied per acre per year in Christmas trees. Most of these materials are toxic to aquatic fauna. Of these, Asana and Di-Syston are particularly toxic to aquatic macroinvertebrates.

Biological assessments to evaluate water quality

Benthic macroinvertebrates are organisms without backbones that live on the bottoms of creeks and are big enough to see with the naked eye. They are recognized as reliable, low cost indicators of stream health and water quality. The following points are made about macroinvertebrate surveys at the EPA website on rapid bioassessment protocols. (http://www.epa.gov/owow/monitoring/volunteer/stream/vms40.html)

- Macroinvertebrate assemblages are good indicators of localized conditions. Because many benthic macroinvertebrates have limited migration patterns or a sessile mode of life, they are particularly well-suited for assessing site-specific impacts (upstream-downstream studies).
- Macroinvertebrates integrate the effects of short-term environmental variations. Most species have a complex life cycle of approximately one year or more. Sensitive life stages will respond quickly to stress; the overall community will respond more slowly.
- Degraded conditions can often be detected by an experienced biologist with only a cursory examination of the benthic macroinvertebrate assemblage.
- Macroinvertebrates are relatively easy to identify to family; many "intolerant" taxa can be identified to lower taxonomic levels with ease.
- Benthic macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects.
- Sampling is relatively easy, requires few people and inexpensive gear, and has minimal detrimental effect on the resident biota.
- Benthic macroinvertebrates serve as a primary food source for fish, including many recreationally and commercially important species.

- Benthic macroinvertebrates are abundant in most streams. Many small streams (1st and 2nd order), which naturally support a diverse macroinvertebrate fauna, only support a limited fish fauna.

Even regular chemical tests of the water may fail to detect transitory events, but macroinvertebrates can be affected by even subtle levels of degradation. Macroinvertebrates vary in their sensitivity to pollution. Some, like a canary in a mineshaft, will quickly die out. Others are very tolerant to different types of pollution. This variation is described by the North Carolina biotic index, which ranks aquatic fauna on a scale of 0 (most sensitive) to 10 (most tolerant) based on observations of the organisms streams in different water quality classes.

Three orders, the mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), also known as EPTs, are particularly sensitive to pollutants. The percentage of EPTs of the entire macroinvertebrate population is often used as a quick method of evaluating stream health. Streams with 50% or more EPT's are commonly viewed as being reasonable healthy (Steve Fraley, personal communication). Observing macroinvertebrates in the affected stream is not enough. Counts must be compared to a reference stream observed on the same day. Most of the aquatic insects live in water only as juveniles. The adults live outside the water, and species may all emerge in a few days. Only when comparisons are made to a reference creek can it be determined if human activity is having a detrimental impact on the creek.

The potential of Christmas tree production to impact stream health

Di-Syston 15 G (disulfoton), used to control the balsam twig aphid and spruce spider mite in the spring, is highly toxic to stream fauna. However, disulfoton use is just one part of Christmas tree production that can impact stream health. Others pesticides, particularly esfenvalerate (Asana) which is also highly toxic to fish and macroinvertebrates, can have an impact. Sedimentation is the primary form of surface water pollution in North Carolina. Christmas trees are grown on steep, highly erodible slopes. Sedimentation from land clearing and site preparation, farm roads or soil left without vegetation due to herbicide use is a major concern. However, with improvements to ground cover management through the use of lower-than-labeled, suppressive rates of post-emergent herbicides (chemical mowing), sedimentation from Christmas tree farms is far less than it was 15 years ago. Fertilizers are applied every year to Christmas trees of all ages, and run-off into streams could be a problem, especially during storms. The final form of pollution is thermal pollution from the loss of vegetative cover on the creek. Some Christmas tree farms were once cattle farms where the vegetation was already removed from stream banks.

Macroinvertebrate surveys cannot distinguish between the possible sources of pollution. However, such surveys can determine if there is an impact. If none is observed, than none of these potential sources are causing a problem.

DEHNR study

In 1998, David Lenant with the Division of Water Quality Biological Assessment Unit of the Department of Health and Natural Resources of North Carolina conducted an evaluation of Christmas tree farming and cattle grazing on water quality in the New River basin in Ashe and Alleghany Counties. Seven small streams (mostly 2 meters wide) and four medium-sized streams (5-14 meters wide) were evaluated for benthic macroinvertebrates using 10 composite samples: two kick-net samples, three bank sweeps, two rock or log washes, one sand sample, one leafpack sample, and visual collections from large rocks and logs. The purpose of these collections was to inventory the aquatic fauna and produce an indication of relative abundance. These samples were taken in May 1998 after fertilizers and pesticides had been applied. Some sites were revisited in August 1998 to determine the seasonal variation in macroinvertebrates. The conclusions were that "Christmas tree farming has little negative effect on the fauna of adjacent stream with the use of integrated pest management and adequate stream buffer zones. However, Christmas tree farming often occurs in the same area as cattle grazing, with trees on the higher ground and cattle grazing adjacent to the stream. The effect of cattle grazing on stream quality may be more substantial than any effect of runoff from Christmas tree farming."

The inability to sort out confounding effects of Christmas trees, cattle grazing, residential areas and other land uses were cited as a problem with this study.

Current study

The DEHNR study did not find any serious impact of Christmas tree production on stream health. However, samples were only taken once on a limited number of farms in a limited area.

The objective of this study were to further determine how Fraser fir production is impacting stream health and water quality based on aquatic insect samples. An additional objective was to educate Christmas tree growers and County Extension Agents on the macroinvertebrate sampling techniques and factors affecting stream health. Of particular interest was if Di-Syston use was causing any effect.

MATERIALS AND METHODS

Benthic macroinvertebrate samples were taken from December 1998 through September 1999 in Alleghany, Watauga, Avery, Mitchell and Jackson counties. Streams were monitored below Christmas tree farms of varying sizes and production practices. In each case, samples were compared to those from a reference stream, which was either a similar, near-by stream from undisturbed woods or upstream of the farm. These pair comparisons were made on the same day. Sample dates taken after April would have been after Di-Syston had been applied.

Alleghany County

Christmas tree site. This site drained a catchment with an estimated 60% of the land used for Christmas tree production. About 100 acres of Fraser fir are found in this watershed. Reeves Branch is located at the intersection of NC 18 and NC 113. The farm had previously been a diary farm. The stream bank had been eroded and vegetation stripped. Currently, only grass grows along the banks. Trees were treated with Di-Syston 15 G in May 1999. David Lenant also sampled this stream in May and August of 1998.

Reference stream. The reference stream is Meadow Fork Creek on SR 1193. Samples were taken from a forested area. This creek was also sampled by David Lenant and was used as the control for smaller streams.

Sample dates. 1/7/99, 2/2/99, 3/10/99, 4/15/99, 5/25/99, 7/13/99, 8/19/99

Avery County

Christmas tree site. This site is below several Christmas tree farms, houses, horse, cattle and sheep farms on the North Toe River. Christmas trees have been grown in this watershed since the 1970s. Approximately 100 acres of Fraser fir drain into this area. Many of the Christmas tree farms in this area do not have extensive ground covers around their trees, resulting in an increased potential for erosion. Most regularly use Di-Syston. The sample site was located on Wes Brewer Road.

Reference stream. The reference stream was further up the river above Luther Rock campground. After several samples were taken it was discovered that there was a small Christmas tree farm just above where these samples were taken. Only four or five rows were adjacent to the stream bank.

Sample dates. 1/6/99, 2/8/99, 3/5/99, 4/7/99, 5/21/99, 6/16/99

Jackson County

Christmas tree site. This stream, on Tanassee Creek Road is below a 1,100 acre farm originally planted in Fraser fir in 1960. Currently approximately 400 acres are in Fraser fir. This site has an excellent buffer and bridges over the stream. Di-Syston is used, although other insecticides are preferred, many of which are applied with an air-blast mistblower.

Reference stream. The reference stream is further down Tanassee Creek Road in Transylvania County. The stream drains through national forest.

Sample dates. 1/25/99, 3/18/99, 5/20/99

Mitchell County

Christmas tree site. Green Creek, off of Green Creek Farm Road, drains through a 300-acre Christmas tree farm. There are also a few houses and a small tobacco field upstream of the sample site. Di-Syston is applied on the majority of the farm. Several branches of the creek run through the farm with only weeds growing next to the stream bank. The sample area was farther downstream where several branches had joined, though still only 8 to 10 feet from Christmas tree production. Grading occurred in June, which affected stream quality.

Reference stream. The reference stream is further upstream on a branch that drains through woods above the Christmas tree farms. This portion of the stream is smaller than the sampled area below the Christmas tree farm.

Sample dates. 1/14/99, 3/1/99, 4/8/99, 5/18/99, 6/25/99, 9/1/99

Watauga County

Christmas tree site. Spice Branch, on Church Hollow Road drains through residential areas and past a 20-acre Christmas tree farm and nursery. This farm, which has produced Fraser fir and various landscaping plants since 1965, is on one side of the stream with houses on the other. A farm pond drains into the stream just above the Christmas tree farm. The stream bank has good cover from trees and shrubs.

Reference stream. The reference stream is just upstream of the Christmas tree farm and the farm pond. It is also in the shade.

Sample dates. 12/14/98, 1/12/992/11/99, 3/15/99, 4/28/99, 6/2/99, 7/6/99

Three samples were taken with a kick-net from riffles and compiled to make a single sample. A random 1/6-portion of the sample was taken and all the macroinvertebrates were counted and identified to order. At least 100 macroinvertebrates were counted in each sample. If there were not 100 in the first portion, a second 1/6 portion was taken and so on until at least 100 were counted. These counts were converted to a percentage of the total. These percentages, and not the actual counts, are reported. The total number of macroinvertebrates in the entire sample was estimated by multiplying the number of macroinvertebrates counted by the number of 1/6 portions counted.

Representatives of mayflies, stoneflies, and caddisflies from three sites, Alleghany, Jackson and Mitchell County, were collected and identified to species where possible by Steve Fraley, a consultant with the Tennessee Valley Authority with over eight years experience in identifying macroinvertebrates in the Southern Appalachians. These sites were chosen for further evaluation because there were few other land uses besides Christmas trees impacting these sites.

Data were analyzed using ANOVA to determine the effect of site and sample date on the percentages of mayflies, stoneflies, caddisflies, and riffle beetles collected below Christmas trees and from the reference creek at each site.

RESULTS

Below Christmas trees farms, there was a statistically lower percentage of stoneflies and a higher percentage of riffle beetles as compared to the total population (Table 1a-e). There were also more total insects below the Christmas tree farms than in the reference creek. These differences did not change over time through the course of the study except at the Mitchell County site. There was no apparent effect of spring pesticide and fertilizer use on macroinvertebrate counts which should have been observable by the May sample dates. The only exception was the Jackson County site where there were no statistically significant differences between the reference stream and the stream below Christmas tree production (Table 1c.).

At the Mitchell County site, there were no stoneflies found below Christmas trees in June or August. This corresponds to grading in a field to re-establish the creek bank that had been filled in by the previous land owner.

A total of 84 organisms were identified to genus and species where possible, collected at the Alleghany, Mitchell and Jackson County sites. There was a similar range of tolerance values of the EPT's identified to species below Christmas trees farms as compared to the corresponding reference streams (Table 2). Several pollution intolerant species with biotic indices less than 1.0 were found below Christmas trees including:

Mayflies: *Drunella cornuta, Drunella tuberculata, Ephemerella rossi, Ephemerella* sp. df. *subvaria, Cinygmula subaequalis, Paraleptophlebia adoptive, Paraleptophlebia* sp. cf. *guttata*.

Stoneflies: *Haploperla brevis, Leuctra* sp., *Remenus bilobatus, Yugus bulbosus*

Caddisflies: *Micrasema charonis, Goera* sp. cf. *fuscula, Goera* sp., *Parapsyche cardis, Lepidostoma* sp., *Dolophilodes* sp., *Rhyacophila minor*, and *Neophylax mitchelli*.

DISCUSSION

This study differs with the DEHNR study in that a less extensive survey was taken over a longer period of time. There was an extensive inventory of macroinvertebrates in all habitats in the DEHNR study. Only riffles were sampled in this study. However, multiple observations were made both before any fertilizers or pesticides were applied and after. With the DEHNR study macroinvertebrate counts were not made but only relative abundances according to following three classifications, rare (1-2 specimens), common (3-9 specimens), or abundant (10 or more specimens).

In this study, an impact of Christmas tree production on benthic macroinvertebrates was observed. There were a lower percentage of stoneflies and fewer types of stoneflies. There was a higher percentage of riffle beetles and more total insects. These changes were observed at every site except the Jackson County site.

However, although the percentages were lower, the actual counts were sometimes higher. For instance, on the 1/7/99 sample date in Alleghany County, 17% of the macroinvertebrate populations were stoneflies in the reference creek while only 9% were stoneflies in Reeves Branch at the Christmas tree farm. This represents an estimated 87 stoneflies collected in the reference creek sample and 167 in the sample below the Christmas tree farm.

The primary difference between the Jackson County site and the others is the riparian buffer. There is an extensive buffer surrounding the creek at this site. The grower has also taken great pains to construct good bridges over the creek. Native trout are frequently found.

At the other sites the streams are exposed to the sunlight. There are fewer leaves getting into the creek. This could result in a lower percentage of stoneflies, which typically feed on leaves in the water. The greater exposure to the sun would also increase the carrying capacity of the stream resulting in more total insects (Steve Fraley, personal communication). The temperature which was monitored at the Alleghany County site was higher and had greater fluctuations below the Christmas tree farm as compared to the reference creek.

The riffle beetles typically found were identified as *Optioservus* sp. (larvae) (tolerance value = 2.3), *Oulimnius latiusculus* (tolerance value = 1.7), and *Promoresia elegans* (tolerance value = 2.1). These have relatively low tolerance values, but according to David Lenant (personal communication), may indicate a problem with sedimentation. Sedimentation may also affect stonefly numbers (Steve Fraley, personal communication). This was observed with the disappearance of stoneflies during the summer at the Mitchell County site which corresponded with grading occurring upstream.

Macroinvertebrate surveys both in this study and the DEHNR study indicate there is not a serious effect of Fraser fir production on surface water quality in western North Carolina. Slight shifts in macroinvertebrate populations do occur. It is speculated the primary cause is an increase in water temperature and change in food source due to a loss of cover over the streams, and to sedimentation from farm roads and herbicide use.

Tables 1a – 1e. An estimate of total insects and percentage of groups of macroinvertebrates found above and below Christmas tree farms.

Key for Tables 1a – 1e.
A = above Christmas trees, values from the reference stream
B = below Christmas trees
Values are percentages of total macroinvertebrates
Others include waterpennies, dragonflies, watersnipes, craneflies, midges, blackflies, worms, water mites, crawdads, snails, flatworms, and bloodworms.
Total insects were estimated by multiplying the insects counted by the number of $1/6^{th}$ portions of the sample counted.

Table 1a. An estimate of total insects and percentage of groups of macroinvertebrates found below a Christmas tree farm and in a near-by reference creek in Alleghany County.

	1/7/99		2/2/99		3/10/99		4/15/99		5/25/99		7/13/99		8/19/99	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Estimated total number of insects	510	1854	342	2106	792	1638	426	3576	354	1110	534	690	154	966
% Total EPTs	90	72	77	67	74	75	85	51	66	37	57	57	65	36
% Riffle beetles	3	22	4	31	8	21	4	38	3	57	10	19	11	46
% Others	7	6	19	2	18	4	89	11	31	6	33	24	24	18
EPTS by order														
% Mayflies	65	59	47	56	55	67	51	48	55	30	29	44	41	24
% Stoneflies	17	9	21	3	14	3	27	1	5	2	17	4	16	4
% Caddisflies	8	4	9	8	5	5	7	2	6	5	11	9	8	8

Table 1b. An estimate of total insects and percentage of groups of macroinvertebrates found below areas of Christmas tree production and above production areas on the North Toe River in Avery County.

	1/6/99		2/8/99		3/5/99		4/7/99		5/21/99		6/16/99	
	A	B	A	B	A	B	A	B	A	B	A	B
Estimated total number of insects	210	630	618	792	792	948	456	936	618	756	384	1170
% Total EPTs	89	69	81	47	94	55	75	77	71	73	71	59
% Riffle beetles	3	13	2	27	1	26	8	10	8	10	12	10
% Others	79	18	17	26	5	19	17	13	21	170	17	31
EPTS by order												
% Mayflies	41	48	51	36	75	46	60	71	57	60	58	50
% Stoneflies	38	6	19	8	15	3	8	3	9	3	10	6
% Caddisflies	10	15	11	3	4	6	7	3	5	10	3	3

Table1c. An estimate of total insects and percentage of groups of macroinvertebrates found below a Christmas tree farm and in a near-by reference creek in Jackson County.

	12/5/98		3/18/99		5/20/99	
	A	B	A	B	A	B
Estimated total number of insects	258	696	204	768	240	804
% Total EPTs	69	70	48	80	59	77
% Riffle beetles	5	21	22	9	12	13
% Others	26	9	30	11	29	10
EPTS by order						
% Mayflies	44	44	22	56	41	63
% Stoneflies	18	18	16	10	11	9
% Caddisflies	7	8	10	14	7	5

Table 1d. An estimate of total insects and percentage of groups of macroinvertebrates found below a Christmas tree and above the farm on Green Creek in Mitchell County.

	1/4/99		3/1/99		4/8/99		5/19/99		6/25/99		9/1/99	
	A	B	A	B	A	B	A	B	A	B	A	B
Estimated total number of insects	774	900	840	708	1218	858	606	732	1260	342	300	546
% Total EPTs	91	91	95	92	44	89	64	85	89	82	90	78
% Riffle beetles	0	2	0	2	0	2	0	2	0	2	0	5
% Others	9	7	5	6	56	91	36	13	11	16	10	17
EPTS by order												
% Mayflies	50	63	50	64	30	73	27	67	78	36	51	44
% Stoneflies	26	9	31	19	7	4	27	3	4	0	10	0
% Caddisflies	15	19	14	9	7	12	10	15	7	46	29	34

Table 1e. An estimate of total insects and percentage of groups of macroinvertebrates found below areas of Christmas tree production and above the farm on Spice Creek in Watauga County.

	12/4/98		1/12/99		2/11/99		3/15/99		4/28/99		6/2/99		7/6/99	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Estimated total number of insects	303	1056	1482	1944	126	1362	1392	1404	1404	1728	366	642	342	648
% Total EPTs	60	82	60	43	70	44	85	65	66	55	76	42	59	45
% Riffle beetles	10	1	3	14	5	33	7	15	24	31	11	26	24	35
% Others	30	17	37	43	25	23	8	20	10	14	13	32	17	20
EPTS by order														
% Mayflies	19	40	26	20	19	23	74	57	53	47	43	27	20	10
% Stoneflies	26	30	25	14	36	7	7	6	8	6	29	13	36	7
% Caddisflies	15	12	9	9	15	14	4	2	5	2	4	2	3	28

Table 2. Species identified at the Mitchell, Alleghany, and Jackson County sites.

ORDERS Family *Genus species*	NC Biotic Index[1]	**Mitchell**		**Alleghany**		**Jackson**	
		Above	Below	Above	Below	Above	Below
		Dates species found at each of these sites					
EPHEMEROPTERA							
Ameletidae							
Ameletus cryptostimulus	NL[2]	3/1, 4/8		3/10			3/18
Ameletus, sp.	NL			2/2, 4/15, 5/25			
Baetidae							
Acentrella sp. cf. *turbida*	NL				8/19	5/20	
Baetis flavistriga	6.6			5/25		5/20	
B. intercalaris	5.0				4/15		
B. pluto	4.2				7/13, 8/19		
B. tricaudatus	1.5	4/8	4/8	4/15	2/2, 3/10, 4/15		3/18, 5/20
Baetiscidae							
Baetisca berneri	2.0				3/10, 4/15		
B. carolina	3.4				7/13		
B. tricaudatus	NL		3/1				
Ephemerellidae							
Drunella cornuta/cornutella	0.0	6/26			7/13		
D. tuberculata (=conestee)	0.0	6/26, 9/1	6/26	8/19			
Drunella, sp. (early instar)	0.0-0.9[3]				4/15		
Ephemerella catawba	4.3	3/1, 4/8, 5/18	5/18		4/15		5/20
E. dorothea	NL				5/25		1/25, 3/18
E. sp. cf. *inconstans*	NL				3/10		

ORDERS Family *Genus species*	NC Biotic Index[1]	**Mitchell**		**Alleghany**		**Jackson**	
		Above	Below	Above	Below	Above	Below
		Dates species found at each of these sites					
E. rossi	0.0	4/8, 5/18, 6/26	4/8	4/15	4/15		1/25, 5/20
E. sp. cf. *subvaria*	0.8		3/1		3/10		
E. sp. (early instar)	0.0-4.3		3/1, 4/8	5/25	2/2		
Eurylophella sp. (early instar)	4.3			5/25	3/10		
Ephemeridae *Ephemera* sp.	2.0				3/10, 4/15		
Heptageniidae *Cinygmula subaequalis*	0.0			5/25			5/20
Epeorus dispar	1.0				7/13	5/20	
E. pleuralis	1.8	6/26		4/15	2/2		
E. rubidus/subpallidus	1.2				7/13		
Heptagenia sp. cf. *pulla*	1.9	9/1		8/19			
Leucrocuta sp. cf. *juno* (early instar)	NL	9/1		4/15, 5/25			
Stenacron interpunctatum	6.9			5/25			
Stenonema meririvulanum	0.1	4/8					
S. pudicum	2.0		3/1, 6/26		3/10, 7/13		
S. terminatum/meririvulanum	0.1-4.1	5/18					
S. sp. (early instar)	0.1-7.1		9/1	8/19	8/19		
Isonychiidae *Isonychia* sp.	3.4	6/26, 9/1	3/1, 5/18	5/25, 8/19	7/13, 8/19		
Leptophlebiidae *Paraleptophlebia adoptive/mollis*	0.9			2/2, 3/10, 4/15, 5/25	2/2, 3/10, 4/15, 5/25	5/20	3/18
P. sp. cf. *guttata*	0.9			7/13	7/13, 8/19		
PLECOPTERA Chloroperlidae *Alloperla* sp.	1.2			3/10		3/18	
Haploperla brevis	0.9			7/13	5/25		
Sweltsa sp.	0.0			3/10, 4/15, 8/19			
Seltsa sp.? (early instar)	0.0			5/25			
Leuctridae *Leuctra* sp.	0.6	5/18, 6/26, 9/1		2/2, 3/10, 4/15, 8/19	7/13, 8/19	3/18	
Nemouridae *Amphinemura* sp. cf. *wui*	3.2			2/2, 5/25, 7/13	3/10		
Peltoperlidae *Tallaperla* sp.	1.1		3/1	2/2, 4/15, 8/19			
Perlidae *Acroneuria abnormis*	2.0				2/2, 5/25, 7/13, 8/19	5/20	
Ecoptura xantenes	3.7					3/18, 5/20	
Ecoptura xanthenes ? (early instar)	3.7			7/13			
Paragnetina immarginata	1.3				3/10		
Perlesta sp.	NL			4/15, 5/25, 7/13	7/13	5/20	
Perlodidae *Cultus* sp. cf. *decisus*	1.5		3/1, 4/8		3/10		
Isoperla bilineata	5.3	5/18		4/15	2/2, 3/10, 4/15		3/18
Malirekus hastatus	1.1	4/8, 9/1	3/1, 4/8	2/2		3/18	1/25, 3/18, 5/20
Remenus bilobatus	0.2	5/18					5/20
Yugus bulbosus	0.0	5/18, 6/26		4/15, 5/25		5/20	5/20
Yugus or *Malirekus* (early instar)	0.0/1.1	6/26		7/13, 8/19			3/18
Pteronarcyiidae *Pteronarcys sp.*	1.6	5/18	4/8		4/15		
Taeniopterygidae *Oemopteryx sp. (contorta?)*	NL			3/10			
Strophopteryx sp.	2.7	4/8			2/2		

ORDERS Family *Genus species*	NC Biotic Index[1]	**Mitchell**		**Alleghany**		**Jackson**	
		Above	Below	Above	Below	Above	Below
		Dates species found at each of these sites					
TRICHOPTERA							
Brachycentridae							
Micrasema charonis	0.7				5/25		
Micrasema sp. (early instar)	0.0-2.6			8/19			
Glossomatidae							
Glossosoma sp.	1.5	6/26	6/26, 9/1				
Goeridae							
Goera sp. cf. *fuscula*	0.1				3/10		
Goera sp. (early instar)	0.1			8/19	3/10, 4/15, 7/13		
Hydropsychidae							
Ceratopsyche (=Symphitopsyche) bronta	2.4		6/26		2/2		
C. maleodi	0.6	4/8, 9/1		7/13, 8/19			
C. sparna	2.7		6/26, 9/1		2/2, 5/25, 8/19		
Cheumatopsyche sp.	6.2		6/26		7/13		
Diplectrona modesta	2.2	4/8, 5/18, 9/1	5/18	2/2	4/15, 5/25, 7/13	5/20	3/18, 5/20
Hydropsyche sp. cf. *betteni/depravata*	7.8		4/8, 5/18		5/25, 8/19		
Hydropsyche/Ceratopsyche sp. (early instar)	2.0-7.8			2/2			
Parapsyche cardis	0.0	6/26, 9/1		8/19	8/19		
Lepidostomatidae							
Lepidostoma sp.	0.9	5/18, 6/26, 9/1		2/2, 4/15, 5/25, 7/13			3/18
Limnephilidae							
Pycnopsyche luculenta sp. group	NL			3/10			
P. scabripennis sp. group	NL			4/15			
Philoptamidae							
Chimarra sp.	2.7		3/1, 9/1				
Dolophilodes sp.	0.8		6/26, 9/1	5/25	2/2		
Polycentropodidae							
Polycentropus sp.	3.5			7/13	2/2		
Rhyacophilidae							
Rhyacophila fuscula	1.8	5/18, 9/1	3/1, 4/8	4/15, 5/25	3/10, 4/15, 5/25		3/18
R. minora	0.0					5/20	3/18
R. sp cf. *nigrita*	0.0			7/13			
Uenoidae							
Neophylax auris/etnieri	NL				3/10		
N. mitchelli	0	4/8		5/25	4/15		
N. sp. cf. *consimilis* (early instar)	1.4	5/18					
N. sp. cf. *oligius*	2.2				2/2		
Neophylax sp. (early instar)	2.2			4/15	4/15		

[1] The North Carolina Biotic Index is a listing produced by the North Carolina Division of Environmental Management for tolerances of North Carolina benthic macroinvertebrate species. The lists range from 0 (most sensitive) to 10 (most tolerant). These are based on ovservations of the average abundance of species in each of five water quality classes: Excellent, Good, Good-Fair, Fair, and Poor.

[2] NL = Species not listed in the North Carolina Biotic Index.

[3] When a specimen could not be identified to species because it is an early instar, the range of biotic indices for the genus are listed.

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