Final Report
Development of Policy for Protection of Intermittent Streams through the 401 Water Quality Certification Program

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Version 1.2, 7/21/2005

Introduction

Any discussion of small, headwater streams must begin with a definition of flow regimes. Currently, there is no universally accepted set of definitions of stream types, so comparisons between studies must be made with care. North Carolina DWQ defines a perennial channel as one with water all year around and an intermittent channel as one that has water for a significant part of the year, but is dry for some part, during a year of normal rainfall (15A NCAC 2B.0233). Many, but not all, of the scientific community use the term ‘perennial’ to mean a stream that flows all year and ‘intermittent’ or ‘temporary’ to denote a channel that stops flowing, but does not dry up. The term ‘dry channel’ appears to more closely correspond to the DWQ definition of intermittent. The term ‘headwater stream’ can mean a combination of all of the above.

Headwater streams (1^{st} and 2^{nd} order) drain 55-85% of a watershed (Gregory, USFWS 2000) so they are very important conveyances of water and chemical constituents. The small size of the stream ensures a large amount of water-sediment contact, which removes nitrogen from runoff via nitrification and denitrification by bacteria in the sediments (Mulholland et al 2001, Peterson et al 2001). This increased contact also allows a higher rate of adsorption of phosphorus to soil particles in the headwater stream bed than in larger streams (James Gregory, pers comm.). Sweeny (USFWS 2000) has calculated that if the nutrient reduction functions of these headwater streams were removed (streams filled), it would be nearly impossible to successfully implement a nutrient reduction strategy in the watershed. Wallace (USFWS 2000) has also found that these headwater streams are a major source of organic carbon (food) to aquatic ecosystems (up to 1 kg carbon exported downstream/ m of stream). For instance, up to half of the organic carbon flowing through aquatic ecosystems originally started as leaf litter in headwater streams that was broken down and converted to more usable forms of carbon by the bacteria, fungi and invertebrates in these headwater streams.

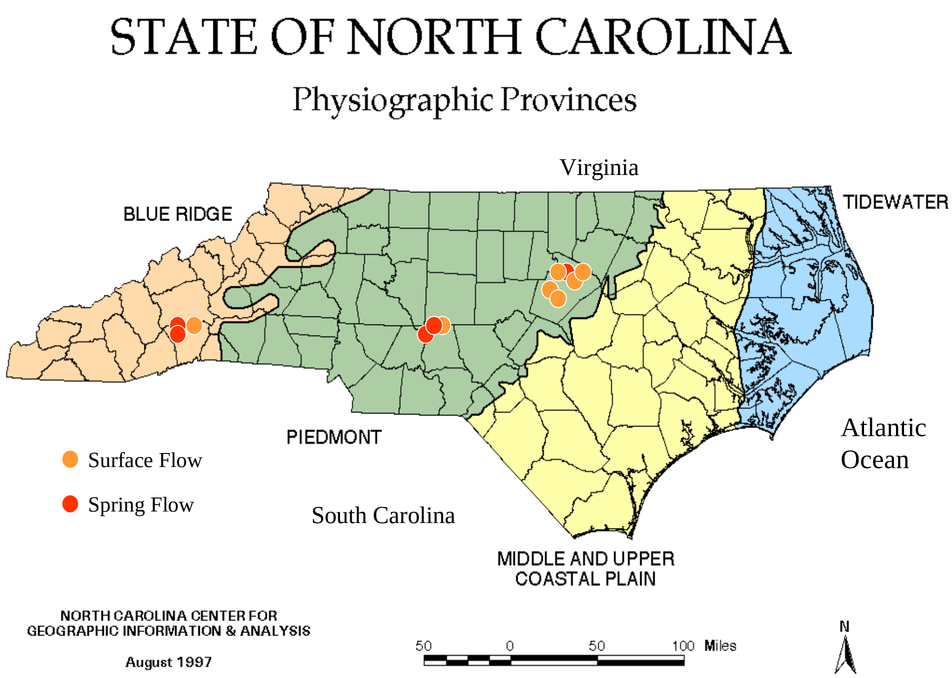
Many studies have found that there are few taxa specifically adapted to the intermittent segments of streams. Most of the species found in intermittent reaches are more drought tolerant taxa That also are common in perennial reaches (Boulton and Lake 1992a; Boulton and Suter 1986; Clifford 1966; del Rosario and Resh 2000; Delucchi 1988; Delucchi and Peckarsky 1989; Feminella 1996; Fritz and Dodds In press; Miller and Golliday 1996). There are some taxa, such as amphipods, isopods and the dipteran *Dasyhela*, that can become numerically dominant in intermittent streams due to a lack of predators (Clifford 1966; Dodson 1987).

Early researchers hypothesized that as a stream dried, taxa either emerged, migrated downstream into pools or burrowed into the hyporheos (moist sediments under the stream bed) (Williams 1977, 1984; Williams and Hynes 1974). Additional work has shown that while each of these methods are utilized by a few taxa, most of the community stays in place and either survives short periods of dessication, or dies, if the dry period is too long (del Rosario and Resh 2000; Delucchi 1988, 1989; Extence 1981).

Site Selection

Initially, eight small, minimally impacted watersheds located in local parks were selected in Wake County North Carolina (Northern Outer Piedmont (Griffith et. al. 2002)). Each stream was divided into segments (5-10) based upon the presence of distinct features in the landscape, usually a head cut. The location of each stream segment is detailed in Appendix 1. Each stream segment was scored by two people using the DWQ stream determination form (NCDWQ 1999) and the site was assigned the average of the two scores. The transition from ephemeral to intermittent stream was indicated by a rating score of 19; while the transition from intermittent to perennial was assigned with a rating score of 29

Figure 1. Map of Study Stream Locations in North Carolina.



(Lawson et. al. 2002). Two rain gages, one near five watersheds and one near three, were installed and monitored from 2003 until 2005. Wells were installed within each stream segment in 2002 and were monitored weekly from 2003 to 2005 (Williams 2005).

In 2004, seven additional streams from other ecoregions (Carolina Slate Belt, Broad Basins, and Southern Crystalline Ridges and Mountains; Griffith et al. 2002) were identified, rated and sampled. (Figure 1)

Sampling Methods

Biological sampling of benthic macroinvertebrates occurred three times per year in the ephemeral, intermittent and perennial stream reaches in each study catchment. Sampling times were selected to sample seasonal differences as well as varying flow conditions: (1) May - when base flow is decreasing due to increased evapotranspiration, (2) September – when base flow is at the seasonal low in perennial streams and has stopped in intermittent streams, and (3) late February – when base flow is near the seasonal high in both intermittent and perennial streams.

Different macroinvertebrate sampling methods were employed depending on the presence or absence of water in the stream reach being sampled (Figure 2). Irrespective of water level, an area of 200 cm^2 of the stream bed, to a depth of 10 cm, was collected. The invertebrate community was separated from the sediment by elutriation through a 300 micron mesh screen in the field and the sediment was returned to the streambed. Macroinvertebrates were returned to the laboratory for sorting enumeration and identification.

Figure 2. Sampling Equipment

Wet sampling, i.e. when there was water in the channel, consisted of two additional samples, which were kept separately from the quantitative samples. Two sweeps were taken with a dip net - one in a pool, one in a riffle, if the features existed. Additionally 10 rocks were washed down and sieved through a 300 micron mesh net to collect attached invertebrates. These samples were returned to the laboratory in 70% ethanol, where sorting and identification took place.

In summer 2002 only, two liters of groundwater was extracted from each sampling site and strained through a 300 micron mesh sieve. Samples were preserved in 70% ethanol and transferred to the lab for enumeration and identification.

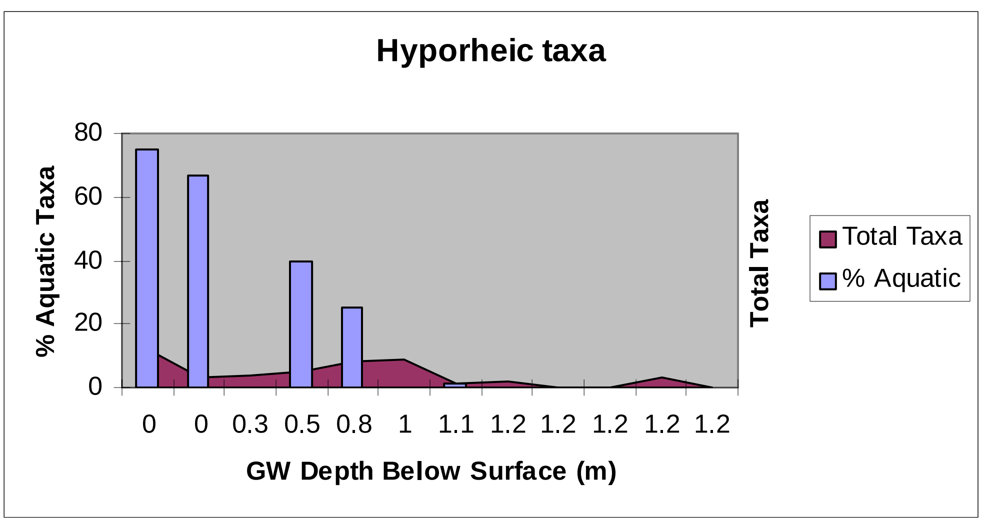
A stratified random sampling design was used to select four stream segments for sampling within each stream. For each stream, one sample was collected in the ephemeral, one in the intermittent, and two in the perennial.

Results and Discussion

Hyporheos

Williams (1984) and Williams and Hynes (1974) reported that the hyporheos no longer serves as a refuge to drying when the water table drops below 0.5m below the surface. This observation was confirmed by hyporheic sampling conducted in the summer when groundwater levels dropped below the bed of intermittent segments and aquatic taxa became sparser with depth; none being found below 1 m. (Figure 3)

Figure 3. Groundwater Taxa by Depth

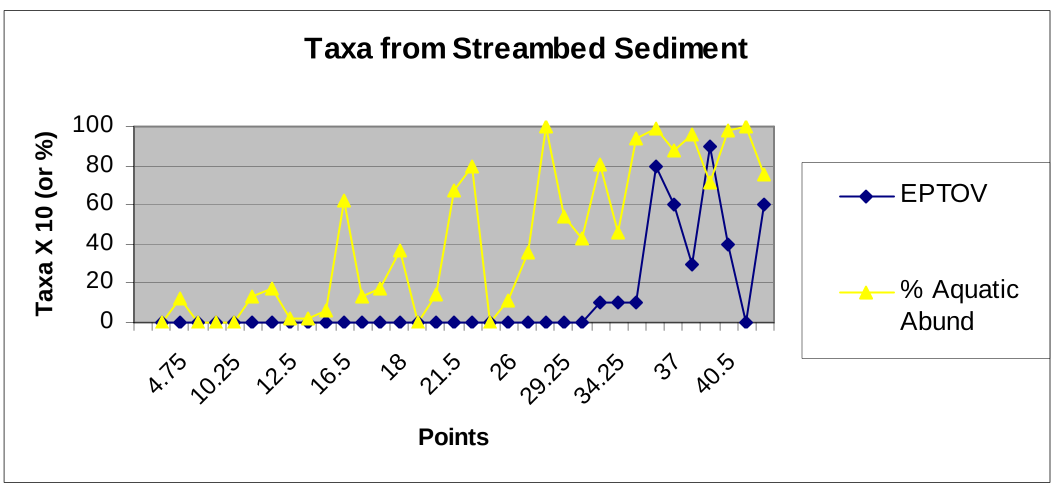


Perennial Streams

There appear to be shorter intermittent stream segments in North Carolina than originally thought. In urban and urbanizing areas, however, increasing impervious surfaces leads to more surface water runoff, and less infiltration and baseflow, creating more and longer intermittent stretches. In undeveloped areas, however, especially in the mountains, many streams begin as perennial springs. Intermittent, or wet weather, springs can also be found. These intermittent and perennial springs score 10-15 points lower on the DWQ stream determination form (Figure 4 -16.5 points) than stream segments of similar permanence formed from primarily surface water runoff. It would seem sensible, therefore, to have a stream determination policy that relied both on the presence of aquatic indicator taxa, when its wet, and the presence of well developed geomorphic stream features when the stream segment is dry.

We have also found that rather than being discrete communities, biota in ephemeral, intermittent and perennial segments mostly are distributed along a gradient (Figure 4 triangles) – the more tolerant or drought resistant the species, the further up the Ephemeral/Intermittent/Perennial (E/I/P) continuum it can be found. This community continuum shifts up and down the stream depending on the wetness or dryness of the year. Also, there is a suite of taxa (Figure 4 diamonds) whose later instars only occur in perennial water. The presence or absence of these perennial indicator taxa can be used to predict the permanence of water in a stream.

Figure 4. Aquatic Abundance and Perennial Indicator Taxa of Pooled Piedmont Stream Segments by Stream Points, Summer 2002.



One of the first concrete policy changes to come out of this grant was an update of the current policy for determining intermittent and perennial streams. This new policy, based largely on this work, envisions three tiers of decision making in determining if a stream is perennial. First, are there large indicator organisms, such as fish, crayfish, amphibians, clams or large tadpoles? Second, do the biogeomorphological characteristics of the stream channel rate 30 points or more on our most recent version of the DWQ stream classification form? Finally, are there benthic macroinvertebrates in the stream that require water for their entire, near year-long life cycle? Examples of these perennial indicator invertebrates are: Mayflies, Caddisflies, non-winter Stoneflies, Dragonflies, Damelflies, Dobsonflies, Craneflies, Phantom Craneflies, riffle beetles, water pennies and gilled snails

The redefinition of a perennial stream was approved and implemented in March 2005. The new definition is:

A stream channel is perennial when any of the following criteria are met:

1. Biological indicators such as fish, crayfish (in channel), amphibians (larval salamanders and large, multi-year tadpoles), or clams are present. If only crayfish or fingernail clams are present, a numerical value of at least 18 on the geomorphology section of the most current version of the DWQ stream classification form is required.

OR

2. A numerical value of at least 30 points is determined from the most recent version of the DWQ stream identification form[3].

OR

3. More than one benthic macroinvertebrate that requires water for entire life cycles are present as later instar larvae[4]. A list of the benthic organisms commonly collected by DWQ biologists during perennial stream determinations are shown in Tables 1 and 2.

Table 1. Ephemeroptera, Plecoptera and Trichoptera (EPT) perennial stream indicator taxa

	Ephemeroptera (Mayflies)	Plecoptera (Stoneflies)	Trichoptera (Caddisflies)
Family	Baetidae	Peltoperlidae	Hydropsychidae
	Caenidae	Perlidae	Lepidostomatidae
	Ephemerellidae	Perlodidae	Limnephilidae
	Ephemeridae		Molannidae
	Heptageniidae		Odontoceridae
	Leptophlebiidae		Philopotamidae
	Siphlonuridae		Polycentropidae
			Psychomyiidae
			Rhyacophilidae

Table 2. Additional indicators of perennial stream features.

	Megaloptera	Odonata	Diptera	Coloptera	Mollusca
Family	Corydalidae Sialidae	Aeshnidae Calopterygidae Cordulegastridae Gomphidae Libellulidae	Ptychopteridae	Elmidae Psephenidae	Unionidae Ancylidae Planorbidae Pleuroceridae
Family Genus			Tipulidae *Tipula* sp.	Dryopidae *Helichus* (adult)	

Source: NCDWQ Identification Methods for the Origin of Intermittent and Perennial Streams. Version 3.1

Intermittent Streams

Intermittent streams are defined as streams that, during a year of normal rainfall, have water in them for several months, but also are dry for some period of time[1]. In forested catchments, the intermittent segment of a stream is usually relatively short (less than 100 feet). However in developed watersheds and some ecoregions such as the Triassic Basin, where runoff is more rapid, these segments can be longer. DWQ has not required mitigation for impacts to intermittent streams because, in the past, it was argued that aquatic organisms could not live in stream segments that regularly dried up and therefore there was no aquatic life to protect.

The summer of 2002, when sampling started, the State experienced its worst drought in over 50 years. Perennial sites, which citizens had not seen go dry in 20 years, were without water. The drought broke that fall and 2003 was a wetter than normal year. Consequently, the intermittent segments stayed wet all year. Finally, 2004 was a year of close to normal rainfall and most intermittent segments were dry again.

Figures 5 and 6 show the Average Aquatic Abundance and Taxa Richness (respectively) for Ephemeral, Intermittent and Perennial stream segments for summer, winter and spring 2002-2004. These graphs demonstrate that intermittent segments support significant levels of aquatic life, even when the stream is dry (summer of 2002 and summer 2004).

In nearly all cases, intermittent stream segments in the Piedmont have more aquatic life and a greater number of aquatic species than ephemeral reaches, but less than perennial segments. Recovery from the 2002 drought can be seen in all reaches through spring 2003. Recovery was less in perennial segments than

[1] Definitions of ephemeral, intermittent and perennial streams are those used in 15A NCAC 2B.0233(2).

Figure 5. Seasonal Aquatic Abundance in Ephemeral, Intermittent and Perennial stream segments.

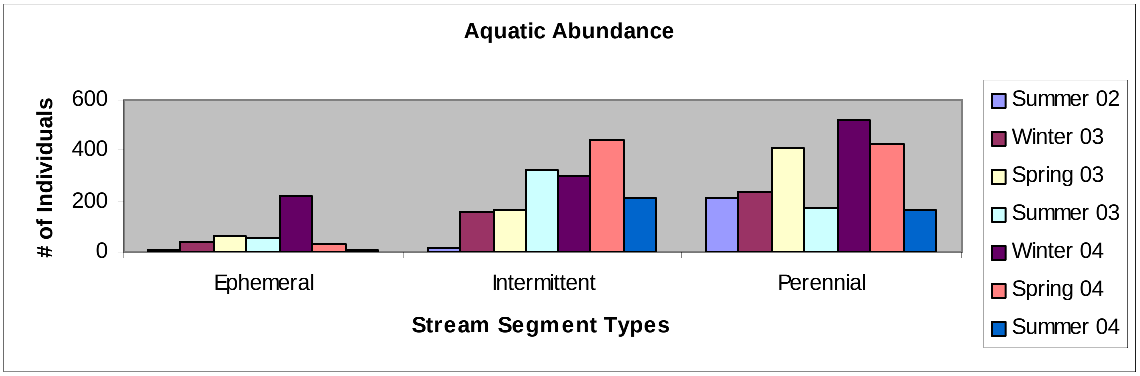
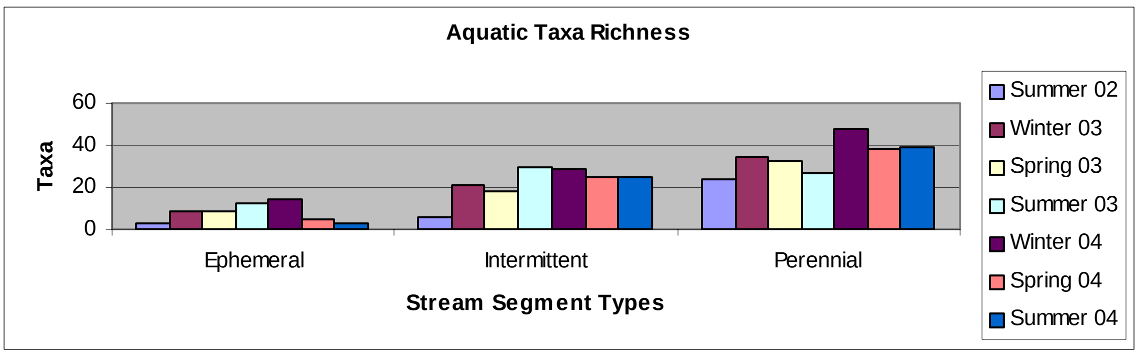


Figure 6. Seasonal Aquatic Taxa Richness in Ephemeral, Intermittent and Perennial stream segments.



in ephemeral and intermittent reaches where drying was more severe. Seasonal patterns, recruitment in winter and spring with stress-related depressions in taxa richness and abundance in summer, were more obvious in perennial reaches than upstream areas. This is probably because periodic drying is a larger stressor than seasonal changes in these upstream segments. It appears to take two years or more for the abundance of aquatic organisms in a segment that has dried to return to levels comparable to segments that never dried. This agrees well with Jack Feminella's (1996) observation that it takes 3-5 years for a stream segment to recover from drying.

Most taxa in ephemeral reaches were terrestrial: ants, spiders, millipedes, earthworms and terrestrial fly larvae. Table 1 shows that ephemeral segments supported few aquatic taxa (mean 3.8). There are usually a few aquatic taxa present, however these are mostly small, elongate, diptera (fly) larvae, such as *Palpomyia,* that survive in the damp spaces between the sand grains in the streambed, and most of these were found in the winter. Intermittent stream segments in both the Piedmont and the Mountains have half of the aquatic taxa and 57% of the aquatic diversity of small perennial streams. This could be due to the effects of drying, reduced habitat heterogeneity, or both.

Table 1. Mean Taxa Richness and Abundance in Ephemeral, Intermittent and Perennial reaches in Mountains and Piedmont

	Aquatic Taxa		Aquatic Abundance	
	Piedmont	Mountains	Piedmont	Mountains
Ephemeral	4	3	34	6
Intermittent	16	15	162	239
Perennial	30	32	286	402

Intermittent stream segments have a much more even mix of terrestrial and aquatic species, with the exact composition shifting as the water table rises above the stream bed or falls below it. When the water table is above the elevation of the stream bed, the stream is wet and short-lived aquatic species, such as amphipods, isopods, winter stoneflies, diving beetles (family Dytiscidae), and various dipteran (fly) larvae, dominate the community. Most of these aquatic organisms are also found downstream in the perennial reaches; only a few species (e.g. the diperans *Dasyhela* family Dolchopodidae and the larvae of the aquatic beetle *Helichus*) live only in the intermittent segments. Terrestrial species, as listed above, dominate the community when the water table falls below the surface of the streambed and the intermittent segment dries up. Species living downstream in perennial reaches include nearly all of the species found in intermittent segments, plus a suite of species that require water year around to complete their life cycles. These groups include: mayflies, stoneflies (non-winter), caddisflies, dobsonflies, dragonflies, damselflies, some beetles (riffle beetles and water pennies), most mollusks, large dipterans (Ptychopteridae and *Tipula*), larval salamanders and fish. This group of organisms has been used to refine DWQ’s stream determination methodology.   Clams (family Sphaeridae) and crayfish (family Astacidae), which have been used in the past as indicators of perennial water, have been found during this study to be able to live in lower intermittent areas as well as perennial reaches due to their adaptations to avoid dessication – a shell for the clam and the ability to burrow down to the groundwater for the crayfish.

Intermittent streams are the exception, rather than the rule in undeveloped catchments in the mountains. Most streams in the mountains, as well as some in the piedmont, start as perennial springs. Some, usually short, intermittent segments do exist, and are formed from two very different sources: wet weather springs and overland runoff from development.

Two wet weather springs have been located and monitored for one year in the mountains.   Data from the spring off the Blue Ridge Parkway is typical. Figures 7 and 8 are the taxa richness and abundance (respectively) at an intermittent segment and two perennial segments. The trend with wet weather springs is similar to that of piedmont intermittent systems that are more surface water-driven. When the segment is dry, there is little aquatic life in the segment (mostly dipteran taxa between the sand grains), but when water is flowing in the reach the abundance of aquatic life is comparable to downstream perennial reaches, even if the diversity is about half that in the perennial stream.

Figure 7. Taxa richness at sites off the Blue Ridge Parkway.

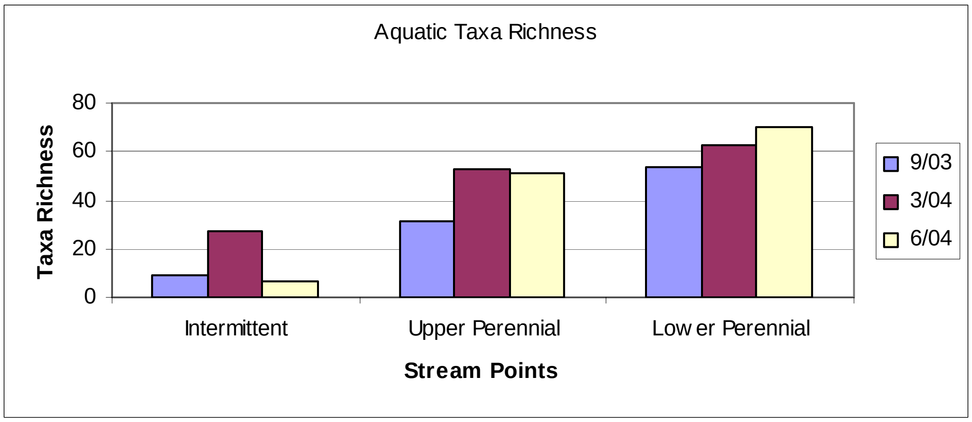
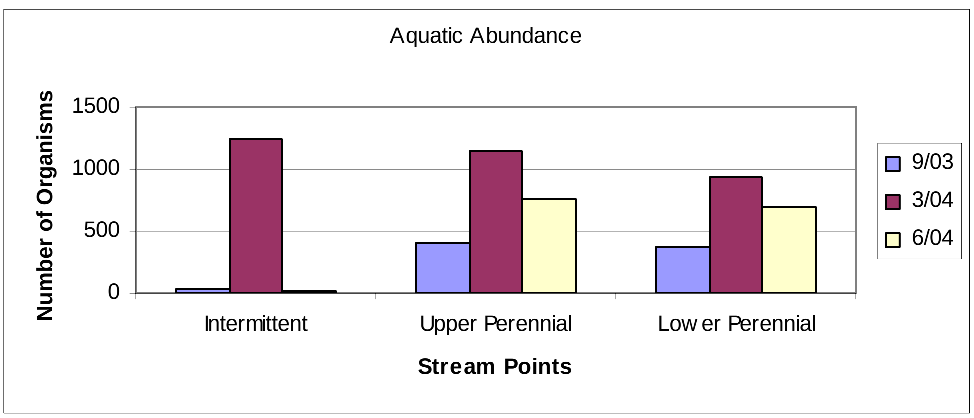


Figure 8. Aquatic abundance at sites off the Blue Ridge Parkway.



Two streams arising from overland flow were sampled, one near Asheville and one in the Uwharrie mountains in Montgomery county. Data from these sites (Figures 9 and 10) show a similar pattern, but increased aquatic life in mountain streams, compared to the Wake County streams (Figures 5 and 6). Like Wake County streams, there was little aquatic life in ephemeral segments, with increasing numbers of species and individuals as the stream developed throughout the short intermittent reaches to the perennial. The main difference is how quickly the streams turn perennial, and how much aquatic life the streams support. The Wake County perennial stream segments supported190-450 aquatic organisms from 22-45 species. The mountain stream segments supported 200-1200 aquatic organisms from 22-70 species.

Figure 9. Taxa Richness of Mountain Streams.

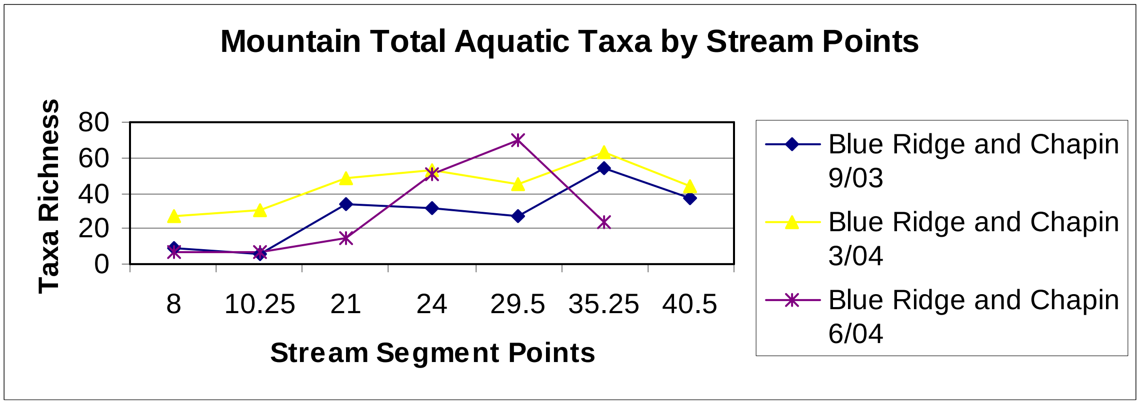
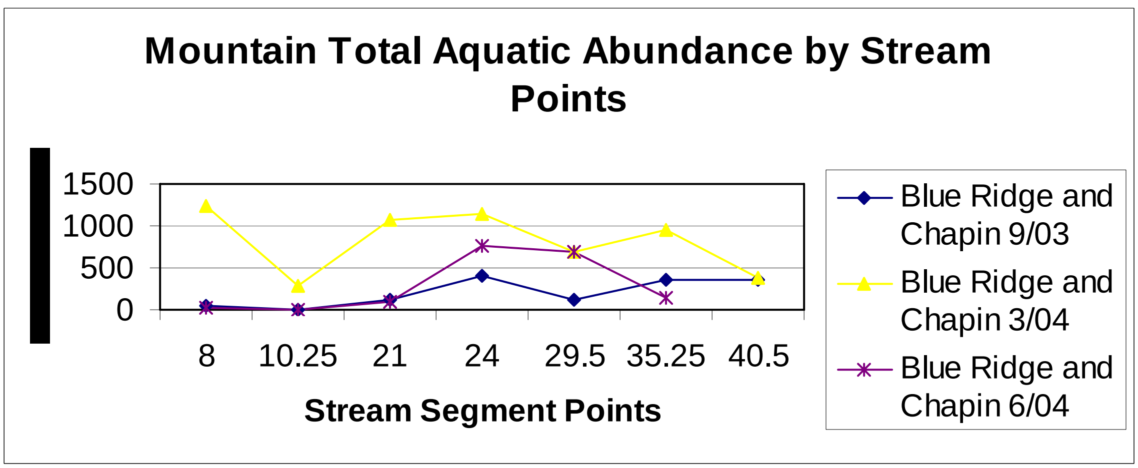


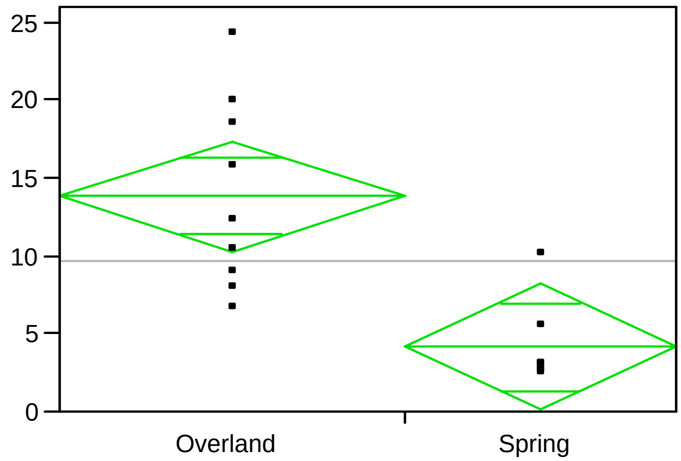
Figure 10.   Aquatic Abundance in Mountain Streams.



Watershed Sizes

The area required to support a perennial stream in this study was small. Watershed areas ranged from 2 acres to 25 acres. While there was no significant difference between watershed sizes in the mountains and the piedmont in this study, the major difference in watershed size appears to be whether the stream starts as a spring or as surface water runoff. As Figure 11 shows, the mean watershed size for a spring system was 4.2 acres, while watershed size for a stream formed by overland flow was 13.9 acres. Urban watersheds and watersheds in the Triassic Basin would be expected to require even larger drainage areas to become perennial.

Figure 11. Watershed Sizes (Acres) of Spring and Surface Water Streams



Policy Changes

Because of this work, North Carolina has changed or has started to change two of its policies on headwater streams. The NCDWQ (2005) manual, Identification Methods for the Origin of Intermittent and Perennial Stream Version 3.1, redefined a perennial stream to include the presence of perennial indicator taxa. The demonstration that intermittent stream segments support aquatic life, even when dry, has started a process in North Carolina to require mitigation for impacts to intermittent streams.

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Appendix 1.

Station	Latitude	Longitude	Ave Pts
Schenk 1	35 49 14	78 43 32	12
Schenk 2	35 49 13	78 43 34	22.75
Schenk 3	35 49 13	78 43 36	29.25
Schenk 4	35 49 14	78 43 37	36.375
Schenk 5	35 49 14	78 43 40	46.5
Schenk 6	35 49 14	78 43 43	43.5
Ums 1 1	35 51 32	78 46 09	1.5
Ums 1 2	35 51 30	78 46 09	13.25
Ums 1 3	35 51 29	78 46 07	18.5
Ums 1 4	35 51 28	78 46 07	26.75
Ums 1 5	35 51 27	78 46 06	38
Ums 1 6	35 51 24	78 46 05	31.675
Ums 1 7	35 51 23	78 46 04	37
Ums 1 8	35 51 21	78 46 05	36.5
Ums 1 9	35 51 19	78 46 06	40.125
Ums 2 1	35 50 45	78 46 32	4.75
Ums 2 2	35 50 44	78 46 30	15.5
Ums 2 3	35 50 43	78 46 29	18
Ums 2 4	35 50 43	78 46 27	26.5
Ums 2 5	35 50 42	78 46 27	33.75
Ums 2 6	35 50 41	78 46 26	35.75
Ums 2 7	35 50 40	78 46 25	32.25
Ums 2 8	35 50 40	78 46 24	38.5
Ums 2 9	35 50 40	78 46 23	40.75
Fall 1 1	35 59 46	78 37 43	5
Fall 1 2	35 59 47	78 37 44	19
Fall 1 3	35 59 48	78 37 45	21.75
Fall 1 4	35 59 49	78 37 45	30.75
Fall 1 5	35 59 50	78 37 47	33.75
Fall 1 6	35 59 51	78 37 48	33.5
Fall 1 7	35 59 52	78 37 49	23.75
Fall 1 8	35 59 53	78 37 49	24.5
Fall 1 9	35 59 53	78 37 50	22.75
Fall 1 10	35 59 54	78 37 52	40.5
Fall 2 1	35 55 44	78 38 03	5.5
Fall 2 2	35 55 45	78 38 03	16.25
Fall 2 3	35 55 46	78 38 03	17.5
Fall 2 4	35 55 47	78 38 03	29

Fall 2 5	35 55 47	78 38 04	29.75
Fall 2 6	35 55 48	78 38 03	33.75
Fall 2 7	35 55 50	78 38 03	37
Fall 3 0	35 59 48	78 38 09	10.25
Fall 3 1	35 59 48	78 38 08	13.375
Fall 3 2	35 59 48	78 38 07	21.25
Fall 3 3	35 59 49	78 38 07	27.375
Fall 3 4	35 59 50	78 38 07	25.5
Fall 3 5	35 59 50	78 38 06	32.75
Fall 3 6	35 59 50	78 38 04	39.75
Fall 4 1	35 59 41	78 38 11	12.5
Fall 4 1A	35 59 40	78 38 11	17.75
Fall 4 2	35 59 39	78 38 11	17.75
Fall 4 3	35 59 38	78 38 12	26
Fall 4 4	35 59 37	78 38 12	31
Fall 4 5	35 59 36	78 38 12	34.25
Fall 4 6	35 59 34	78 38 12	38
Fall 4 7	35 59 33	78 38 13	37.25
Fall 4 8	35 59 32	78 38 12	41.75
Fall 5 1	35 59 49	78 38 24	11.75
Fall 5 2	35 59 49	78 38 26	21.5
Fall 5 3	35 59 49	78 38 27	35.5
Fall 5 4	35 59 50	78 38 28	39
Fall 5 5	35 59 50	78 38 29	29.5
Fall 5 6	35 59 50	78 38 31	31.75
Uwharrie 1	35 30 40	79 51 21	8
Uwharrie 2	35 30 38	79 51 23	17
Uwharrie 3	35 30 36	79 51 24	25.75
Uwharrie 4	35 30 34	79 51 25	37
Uwharrie 5	35 30 33	79 51 25	37.25
Uwharrie 6	35 30 32	79 51 25	42.5

Station	Latitude	Longitude	Ave Pts
U spr 1 I	35 29 28	79 52 20	14.5
U spr 1 I/P	35 29 29	79 52 20	18.25
U spr 1 P	35 29 29	79 52 21	24.5
U spr 2 I	35 25 56	79 56 17	18.5
U spr 2 I/P	35 25 56	79 56 17	23.75
U spr 2 P	35 25 56	79 56 18	33
Blue Ridge 1	35 54 16	81 58 47	8
Blue Ridge 2	35 54 16	81 58 46	13
Blue Ridge 3	35 54 16	81 58 45	24
Blue Ridge 4	35 54 16	81 58 44	35.25
Blue Ridge 5	35 54 16	81 58 43	40
Chapins Cr 1	35 28 30	82 29 27	10.25
Chapins Cr 2	35 28 29	82 29 27	13.75
Chapins Cr 3	35 28 28	82 29 27	21
Chapins Cr 4	35 28 28	82 29 26	29.5
Chapins Cr 5	35 28 27	82 29 26	37.75
Chapins Cr 6	35 28 26	82 29 26	40.5
UT Boyd Br 1 spr Ia	35 29 04	82 38 32	14
UT Boyd Br 1 spr Ib	35 29 03	82 38 33	10.5
UT Boyd Br 1 P	35 29 04	82 38 31	39
UT Boyd Br 2 Int	35 29 20	82 38 30	23
UT Boyd Br 2 Peren	35 29 19	82 38 30	33.75