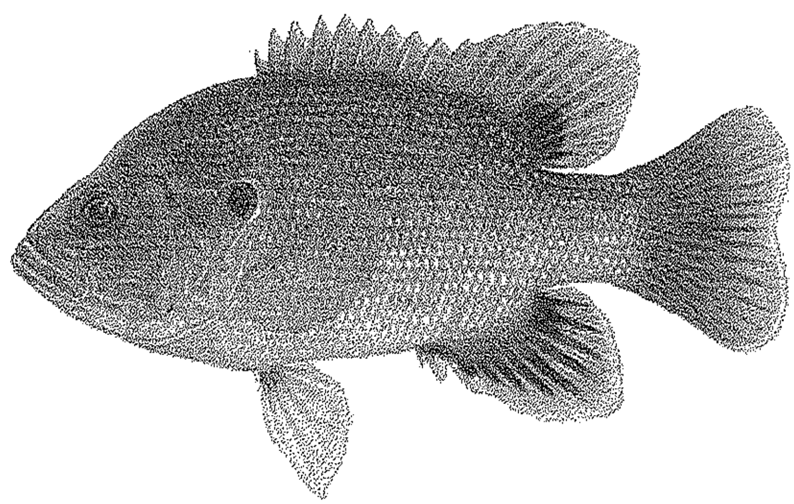
Assessment of Fish Community Health in Meeting of the Waters Creek, University of North Carolina at Chapel Hill Summer, 2001



M. Jamila Batchelder
Ecology Curriculum
UNC Chapel Hill
December 14, 2001

Introduction:

The University of North Carolina at Chapel Hill (UNC-CH) is located in a rapidly developing area, of the United States. This growth is detrimentally affecting the region's streams, and with them, the fish populations that inhabit them. Degradation to streams in urban settings can come in many forms including water pollution from sediment, nutrients, metals, and other pollutants produced in urban systems, increased runoff and storm water velocity due to increased impervious surfaces, and changes in temperature and woody debris inputs due to the removal of trees (Riley 1996).

These changes to streams can negatively affect fish species. Increases in sediment reduce the particle size of stream substrate, destroying the habitat of macroinvertebrates, an important food source, as well as degrading spawning habitat. Other pollutants (such as lead, pesticides, and petroleum) can be poisonous to fish and to benthic macroinvertebrates. Increased runoff leads to increased flows during storms, which can wash out many fish (Johnson et al. 1997). Increased temperatures, as well as the decrease in dissolved oxygen that often results, can be lethal to many fish species (Barton et al. 1985). Decreased woody debris can limit habitat complexity and cause a loss of sheltered refuges for fish during high flow periods (Roth et al. 1996). Because fish communities are sensitive to changes within a stream, they are frequently used as indicators of the level of degradation that exists within a stream (NCDENR 2001).

UNC-CH, like the region that it is located within, is growing, and with this growth has come increased development of the UNC-CH campus. As this growth occurs, the University is attempting to protect the natural resources found on the University Campus and the surrounding areas. Of particular interest is Meeting of the Waters Creek, a stream that flows through the UNC-CH campus. In order to protect this stream and its biotic resources, it is necessary to understand the condition of the biotic community, and to examine how this community is being affected by development on the UNC-CH campus. This report will examine the current state of the fish community within Meeting of the Waters Creek, and will make recommendations on what steps can be taken to better protect this ecological resource.

Study Site:

Six sites were sampled in this study - four sites on Meeting of the Waters Creek on UNC-CH property, and two control sites (one on Bolin Creek on Estes Rd. and one on Morgan Creek at Hwy. 54). Meeting of the Waters Creek drains the UNC-CH campus and flows through the botanical garden after leaving campus. The sites on Meeting of the Waters Creek were designated UNC-4, UNC-2, UNC-7 and UNC-12 (see Figure 1)

UNC-4 is located in the upper reach of the stream beside the Belltower Parking Lot. Its average width is 1 meter. This site has a narrow width of riparian vegetation, and flows through a heavily developed area. The creek flows into a pipe before flowing beneath Kenan Stadium.

Site UNC-4 = Coker Woods

UNC-2 is located further downstream, beside Boshamer Field. The average width of the stream was approximately 2 meters. This site is surrounded by a forested area, but beyond the forested buffer, the area around this stream is highly developed. This site is downstream from a pipe carrying runoff from campus. The substrate within the stream at this site consists mostly of bedrock. The site frequently smelled of sewage. Other site conditions include a substantial amount of trash and a some artificial structures in the stream channel. There is some undercutting of the bank.

Site UNC-2 = Boshamer Outfall

UNC-12 is downstream of the Dean Smith tributary. Its average width is two meters. There is some vegetation on one side of the stream, but Manning Dr. runs along the other side of the site, leaving very little riparian vegetation along one side of the stream. This site is downstream from a culvert beneath Manning Dr. that drains runoff from the Dean Smith Center, the hospitals, and the new dormitory construction sites. The substrate at this site is mostly silt, and this site was at times extremely turbid. On some sampling dates sediment in the water gave the water a brown color, but on some occasions the water took on a very milky color. There are a few areas of undercutting in the banks at this site. This site is located in the Pinetum.

Site UNC-12 = DS of Manning Dr

UNC-7 is located just upstream of the botanical garden. Its average width is 2.5 meters. This site is located in a area with only light development, and large amounts of forested area, but immediately upstream from this site is Hwy. 54, and above that the Pinetum and the highly developed UNC-CH campus. The substrate at this site is mostly gravel and boulders with some sand. There is some woody debris within the stream channel, as well as root structures along the banks.

Site UNC-7 = DS of Fordham Blvd & US of Laurel Hill Dr

The Morgan Creek control site has an average stream width of 3.5 meters. Substrate at this site consists primarily of silt and cobbles. The stream at this site drains a moderately developed area of Orange County. The area around the stream is heavily wooded, but the site is

Morgan Creek control site in headwaters, west of Carrboro

located just downstream of Hwy. 54.

Bolin Creek drains residential areas of the town of Carrboro. The Bolin Creek control site is located in a greenway, and the adjacent riparian area is covered with dense forest and some residential development. The stream has an average width of 3 meters. The substrate at this site is mostly cobbles, boulders, and silt. I was informed that some construction is occurring upstream from this site.

Bolin Creek control site - upstream of Estes, per map in Gerci report

Sampling Methods:

Samping began July 1, 2001, shortly after the largest storm event of the summer. Sampling continued through to August 30, 2001. There was one other major storm event in early August, between the third and fourth sampling dates. Each site was sampled five times. Sites were sampled approximately once every two weeks. If there was rain, sampling was postponed for safety reasons. After major storms, streams were too turbid for effective sampling, so sampling was conducted several days later when the streams became clearer.

At each site, a 25 meter stretch was marked off. A blocking net was placed at the downstream end of the stretch to prevent fish from leaving the sampling area. After the net was in place, a backpack electroshocking unit was used to collect the fish. A low voltage of electricity (600 V) was pulsed into the water at a frequency of 30 Hz. The electricity stunned the fish allowing them to be caught in a dip net. Sampling was conducted by two people, one administering the electricity, the other catching fish in the net. Sampling began at the downstream end of the stretch of stream, and moved upward through the stretch. The average time taken to conduct one pass of an entire stretch was approximately 15 minutes. Three passes were conducted in order to catch as many of the fish in a stretch as possible. Fish were then identified and released. Because excessive electroshocking can be harmful to fish, a given stretch of stream was sampled only once per month. During the time when a given stretch was being "rested", an adjacent stretch of 25 meters was sampled.

Data Analysis: For each sampling event, the abundance of fish and species richness (number of different species) was calculated for each site. In addition, the percentage of species that are less tolerant of pollution was determined for each site. Information about the tolerance of the species was obtained from the North Carolina Department of Water Quality (NCDENR 2001). The average abundance, species richness, and percent intolerant species for the entire summer was calculated for each site. An analysis of variance (ANOVA) was calculated to determine if there was a statistical difference in the values of these variables between the different sites. Any differences were then analyzed in relation to patterns in the field-measured physical and chemical characteristics of the sites to explore what factors might be shaping the fish communities at these sites (field-measured physical and chemical characteristics were measured at several times during the summer). In addition to analyzing the average values for the whole summer, the changes in abundance, over the course of the sampling period were examined. These were compared particularly to the patterns in rainfall events.

Results:

The results of this study showed major differences in the fish communities at the different sites. The following is a description of the characteristics of the fish communities at each site:

UNC-4: This site was sampled only once, and contained no fish. Its very small size was not suitable habitat for most fish, and therefore it was determined that it would be unlikely that any fish would be collected at this site.

UNC-2: This site had an average abundance of 15.2 fish, and an average species richness of 4.60. The mean percentage of species less tolerant to pollution was 44.4% (Table 6). Abundance was at its lowest value of 5 on the first sampling day, and then increased over the next two sampling dates, to a maximum value of 28. On the fourth sampling date abundance dropped to 13, and then increased slightly on the last sampling day to 15 (Figure 3). A more detailed description of the results at this site can be found in Table 1.

UNC-12: This site had the fewest fish, with an average abundance of 4 fish, and an average species richness of 2.4. The mean percentage of less tolerant fish was 18.2% (Table 6). Abundance stayed fairly constant at this site. Like UNC-2, it was at its lowest on the first date with an abundance of 3, and increased greatly on the second date to 6. Unlike UNC-2, it did not continue to increase on the third date, but dropped back to an abundance of 3. On this day the site was extremely turbid with a milky sediment. Abundance increased slightly to 4 on the last two sampling days (Figure 3). A more detailed description of the results at this site can be found in Table 2.

UNC-7: This site had the most fish of any of the UNC-CH sites, with an average abundance of 25.8. Its species richness was 3, and it mean percentage of less tolerant fish was

5.6%, the lowest of any of the UNC sites (Table 6). The changes in abundance through the summer showed a pattern similar to that of UNC-2 and UNC-2, with its lowest value on the first day (20). On this day, At least 15 dead fish were observed in the stream. This occurred very shortly after a large storm event. Like UNC-2, abundance increased on the second and third sampling date, to a maximum of 35, before dropping back off on the fourth sampling date to 23. On the fifth sampling date, there was a slight increase to 26 (Figure 3). A more detailed description of the results at this site can be found in Table 3.

Morgan Creek Site: This site had the greatest abundance (with an average abundance of 108.2) and the greatest species richness (with an average species richness of 13.6). On average, 83.8% of the fish found at this site were less tolerant of pollution (Table 6). Like all the other sites, it had the lowest abundance on the first day, at 102 fish, and then increased over the next two sampling days to a maximum of 113. This increase was much more slight than at the UNC-CH sites. There was a slight drop on the fourth day to 109 and then a slight increase on the fifth day to 110 (Figure 3). A more detailed description of the results at this site can be found in Table 4.

Bolin Creek Site: This site also had much higher abundance and species richness than the UNC-CH sites, with averages of 93 and 12.8 respectively. The percentage of less tolerant species was also higher than Meeting of the Waters sites, with an average of 74.4 (Table 6). The pattern of changes in abundance through the season was similar to those seen at the UNC-CH sites, with a low value of 82 on the first day, increasing to a maximum value of 104 on the third sampling day, dropping to 94 on the fourth date, and then increasing slightly to 98 (Figure 3). These changes were more pronounced than the Morgan Creek site, but not as dramatic as some of the changes seen at the UNC-CH sites. A more detailed description of the results at this site can be found in Table 5.

ANOVA analysis: The results of the ANOVA indicate that there are significant differences between the UNC-CH sites and the control sites. All sites differed significantly (with a statistical level of confidence above 95%) from the control sites in all three of the parameters measured - average abundance, average species richness, and average percentage of less tolerant species. In addition, UNC-2 had a significantly greater percentage of less tolerant species than the other two UNC-CH sites. The average values of each metric for each site can be found in Table 6 and in

Figure 3.

A final observation about differences between the fish communities at the different sites relates to the age distributions that were observed. At the Morgan Creek site and Bolin Creek site many young-of-the-year fish (YOY) were seen (these were not included in the fish recorded as a very high percentage will not live to adulthood). At UNC-4 and UNC-5 there were no YOY, and there were very few at UNC-7.

The results of the water quality measurements are detailed in the report on macroinvertabraaates prepared by Christy Geraci. The most relevant result of these measurements to the analysis of the fish community was that UNC-2 had substantially higher conductivity than all other sites.

Discussion:

These results indicate that the fish communities at the UNC-CH sites are severely impaired, with significantly lower values than the control sites in abundance, species richness, and in the percentage of species less tolerant of pollution (Table 6, Figure 3). Low values in each of these metrics indicates a degraded site (NCDENR 2001). Abundance declines in a degraded site as less fit individuals within the fish population are unable to survive the stresses of pollution and habitat degradation. As degradation becomes more severe, very few individuals can survive the extreme conditions, leading to the severely depressed abundance values present at the UNC-CH sites. As abundance drops, some species of fish, both those that are rare and those that are intolerant of pollution, cease to be present in the population. Other species thrive in the degraded conditions and come to dominate the population, outcompeting other fish. This leads to the lower species richness and percentage of less tolerant species, seen at polluted sites such as those on the UNC-CH campus.

These metrics of community health indicate that the UNC-CH sites have unhealthy fish populations. However, they cannot pinpoint what aspect of environmental degradation is harming the fish population. The additional measurements of water quality, analysis of storm events, as and observations in the field can give some clues as to what the problems in the UNC-CH streams may be.

Several factors can contribute to patterns in fish community structure seen at the UNC-

CH sites. These can include poor water quality due to inputs of various chemical pollutants, sewage, and sediment; high flows from storm water runoff; differences in the physical habitat conditions: and finally the ecological legacy of poor water quality and habitat conditions in the past can play a role in shaping fish communities in the present (Roth et al. 1996; Harding 1998).

Water Quality:

All UNC-CH sites face water pollution in the form of chemicals and sewage from leaky pipes, as well as sediment from the construction projects on campus. Water pollution problems can be chronic (such as a steady low-level of sewage pollution) or acute (such as a large input of pollution or sediment washed into a stream during a storm event (Lake 2000). Both forms of pollution can be harmful to fish. While chronic low-level pollution may not kill a fish, it could lead to a decrease in breeding success, a decrease in benthic macroinvertebrate abundance (an important food source for many fish), and emigration of fish away from the polluted site. All of these factors can contribute to lower community health, though some hardier fish will be able to survive the conditions. Acute pollution can reach pollution levels high enough to kill a fish, though it may be possible for more aggressive fish species to recolonize the site at a later date when the pollution subsides. UNC-CH sites suffer from both chronic and acute pollution, and both appear to be affecting the fish population.

UNC-2 appears to be the site most chemically polluted on a chronic basis. It smelled of sewage on each sampling date. In addition, conductivity was particularly high at this site, a attribute common to polluted streams. UNC-12 also appeared to be chronically polluted with sediment. The substrate at this site was dominated by silt, and the water was always more turbid than the other sites. These two sites had much lower abundance values than the other sites sampled (including UNC-7, see Table 6), and this may be a result of chronic the chemical pollution and sedimentation found at these sites. Another indicator of possible chronic pollution was the lack of breeding success suggested by the absence of juvenile fish at these sites.

Storm Water:

Acute pollution, particularly in the form of storm water runoff, is also a problem facing UNC-CH sites. The UNC-CH sites are located within a highly developed watershed with a large amount of impervious surfaces. During rain events, water does not absorb into the this land or runoff at the more moderate rate that might be found in a less developed area. Instead, the water discharges very rapidly into the stream, carrying with it all matters of pollution, particularly sediment. The high flows can wash fish downstream, and the high levels of pollution can harm fish, even kill them. These problems can become compounded as the water flows downstream, and the pollution and runoff from a greater area of the watershed accumulate. Fish abundances at all UNC-CH sites decreased dramatically after rain events (Figure 3), indicating that the acute storm events were harmful to the population. The Bolin Creek site, with a construction site upstream, showed the same pattern, possibly due to inputs of sediment from the construction site during storms.

The effect of these acute events may help to explain a peculiar pattern seen in the UNC-CH sites. UNC-2, which appeared to be the most polluted, had the highest species richness and percentage of less tolerant fish of the UNC-CH sites, while UNC-7, which appeared to be the least polluted, had the very low species richness and percentage of less tolerant species (Figure 3). Perhaps the accumulated pollution and runoff during rain events made the furthest downstream site (UNC-7) intolerable for many fish species. This hypothesis might explain the large number of dead fish found at UNC-7 after the major storm of the summer.

Besides storms, there was another, more mysterious acute event that occurred at UNC-12. On sampling day 3, July 26, 2001, this site was extremely turbid and fish populations dropped to their lowest levels of the summer (Table 2). The source of the sediment, how it got into the stream, and whether this was an isolated incident is unclear, but it appears to have had a very negative affect on the fish community. This site had the most unhealthy fish population of any site that was sampled (Table 2).

Habitat:

While some aspects of the physical habitat seemed less natural at UNC-2 and UNC-12, overall, habitat did not appear to be severely degraded at the UNC-CH sites, with the exception of heavy siltation and UNC-12. There were undercut banks and woody debris at all sites, creating complex habitat suitable for many fish species.

History:

Because fish are longer lived than many other aquatic species, it is impossible to ignore the effects of history. Patterns in fish populations seen today may in part reflect patterns in water quality from previous years. It may take many years for a fish population to recover to full health (Harding et al. 1998). This point is important to keep in mind when working to improve conditions in Meeting of the Waters Creek - improvements will not happen overnight, but will take time and a continual dedication to reducing environmental degradation.

Recommendations:

In order to restore health to the fish communities of Meeting of the Waters Creek, both the chronic and the acute sources of pollution must be addressed. Identifying and eliminating the source of the sewage leak into the stream is critical. From the patterns observed in this research, sedimentation appears to be the primary problem facing fish communities at the UNC-CH sites. Setting strict rules for the management of sediment at construction sites, and more importantly monitoring these sites and enforcing these rules, is necessary to reduce sedimentation at these sites. Furthermore, managing the amount of runoff by reducing impervious surfaces would also improve the health of the fish community.

References:

Barton, D.R., et al. 1985. Dimensions of riparian strips required to maintain trout habitat in southern Ontario streams. North American Journal of Fisheries Management 5: 364-378.

Harding, J.S. et al. 1998. Stream biodiversity; the ghost of land use past. Proceedings of the National Academy of Sciences of the United States of America 95: 14845-14847.

Johnson, L.B., et. al. 1997. Landscape approaches to the analysis of aquatic ecosystems. Freshwater Ecology 37(1): 113-127.

Lake, P.S. 2000.

North Carolina Department of Environment and Natural Resources. 2001. Stream fish community assessment and fish tissue.

Riley, A.E. 1998. Restoring streams in cities. Island Press, Washington D.C.

Roth, N.E. et. al. 1996. Landscape influences on stream biotic integrity assessed at multiple scales. Landscape ecology 11(3): 141-156.

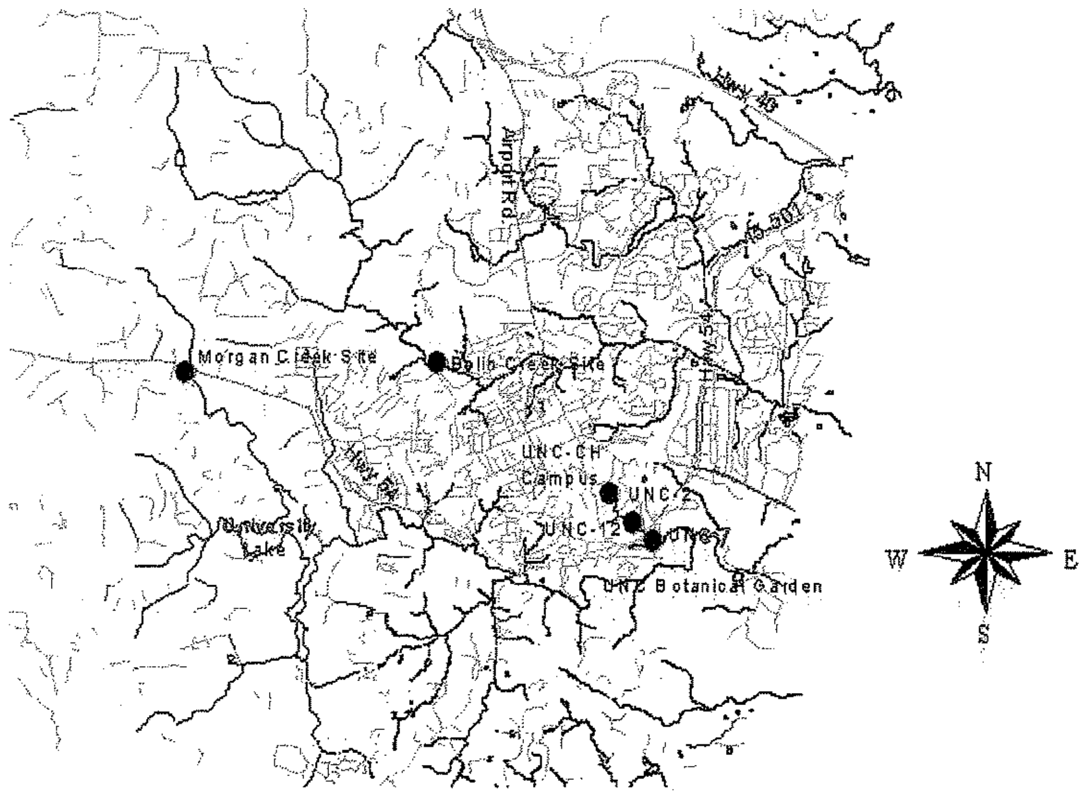


Figure 1: Sampling Site Locations

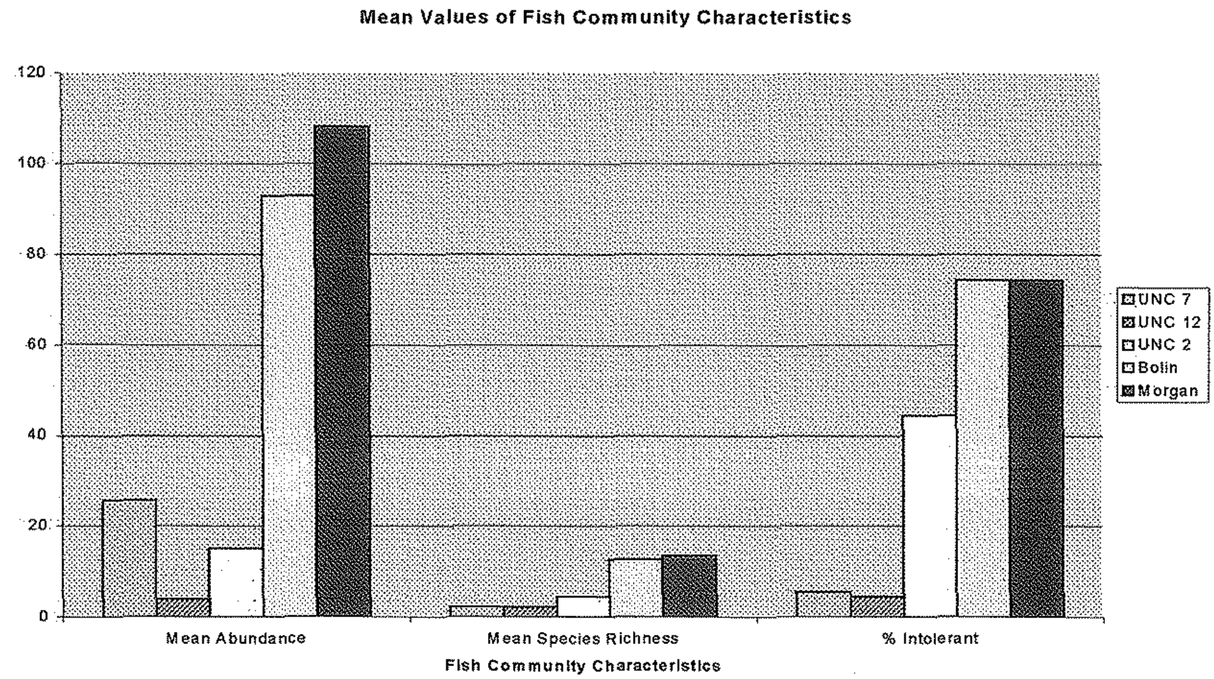


Figure 1: Mean values of abundance, species richness and percent less tolerant species at UNC sites and control sites.

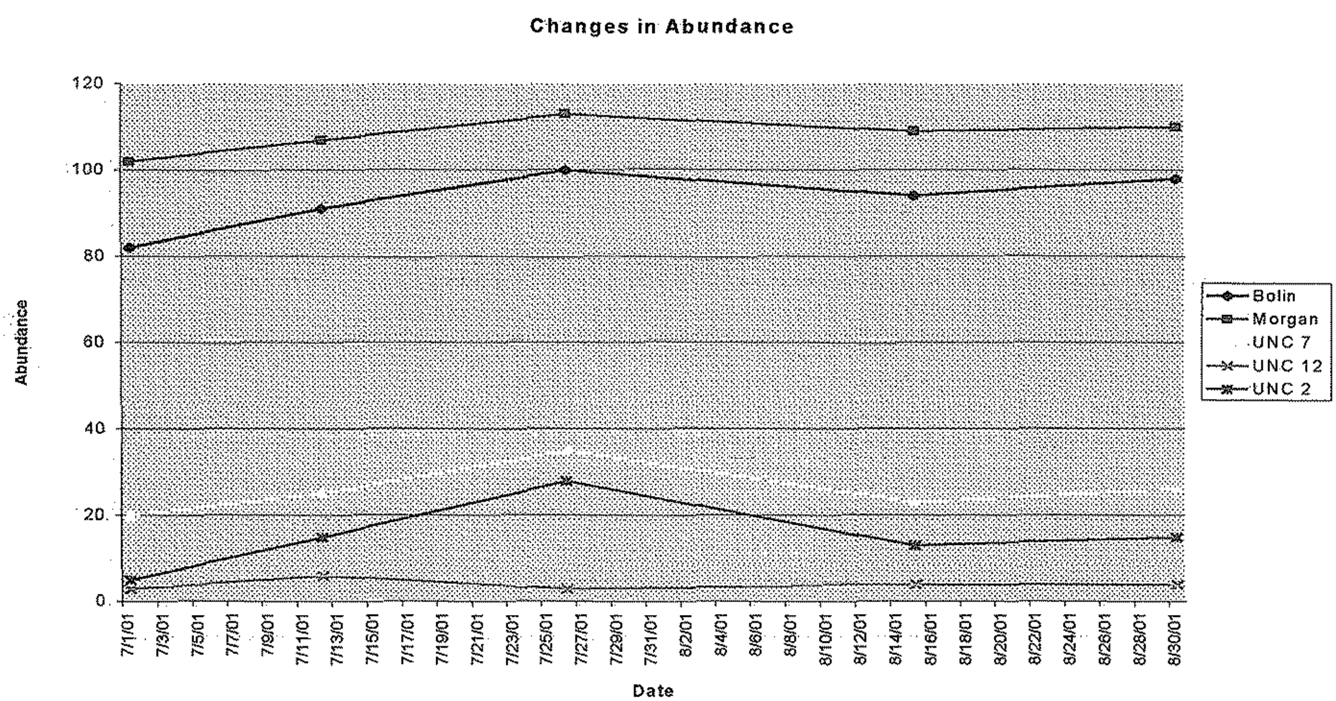


Figure 2: Changes in fish abundance through the course of the summer, 2001.

Table 1: Abundance of fish species at UNC-2 Site.

Fish Species	Common Name	UNC 2 - Meeting of the Waters Creek				
		7/1	7/11	7/26	8/15	8/30
Anguilla rostrata	American eel					
Clinostomus funduloides	Rosyside dace		1	7	2	2
Cyprinella analostana	Satinfin shiner					
Luxilus albeolus	White shiner					
Nocomis raneyi	Bull chub		2	6		
Nocomis letocephalus	Bluehead chub		2	4	2	3
Notemigonus crysoleucas	Golden shiner					
Notropis altipinnis	Highfin shiner					
Notropis amoenus	Comely shiner					
Notropis procne	Swallowtail shiner					
Semotilus atromaculatus	Creek chub	2	5	8	7	7
Erimyzon oblongus	Creek chubsucker					
Noturus insignis	Margined madtom					
Aphredoderus sayanus	Pirate Perch					
Fundulus rathbuni	Speckled killfish		3	3	1	2
Lepomis auritus	Redbreast sunfish					
Lepomis cyanellus	Green sunfish	3	2		1	1
Lepomis macochirus	Bluegill					
Lepomis gibbosus	Pumpkinseed					
Lepomis marginatus	Dollar sunfish					
Micropterus salmoides	Largemouth bass					
Etheostoma olmstedi	Tesselated darter					
Perca flavescens	Yellow perch					
Abundance		5	15	28	13	15
Species Richness		2	6	5	5	5
% Pollution Sensitive		0%	54%	77%	38%	53%

Table 2: Abundance of fish species at UNC-12 Site.

Fish Species	Common Name	UNC 12 - Meeting of the Waters Creek				
		7/1	7/13	7/26	8/15	8/30
Anguilla rostrata	American eel					
Clinostomus funduloides	Rosyside dace					
Cyprinella analostana	Satinfin shiner					
Luxilus albeolus	White shiner					
Nocomis raneyi	Bull chub					
Nocomis letocephalus	Bluehead chub		2			
Notemigonus crysoleucas	Golden shiner					
Notropis altipinnis	Highfin shiner					
Notropis amoenus	Comely shiner					
Notropis procne	Swallowtail shiner					
Semotilus atromaculatus	Creek chub			1		
Erimyzon oblongus	Creek chubsucker					
Noturus insignis	Margined madtom					
Aphredoderus sayanus	Pirate Perch					
Fundulus rathbuni	Speckled killfish		1	1	1	1
Lepomis auritus	Redbreast sunfish					
Lepomis cyanellus	Green sunfish	3	3	1	3	3
Lepomis macochirus	Bluegill					
Lepomis gibbosus	Pumpkinseed					
Lepomis marginatus	Dollar sunfish					
Micropterus salmoides	Largemouth bass					
Etheostoma olmstedi	Tesselated darter					
Perca flavescens	Yellow perch					
Abundance		3	6	3	4	4
Species Richness		1	3	3	3	2
% Pollution Sensitive		0%	33%	33%	25%	0%

Table 3: Abundance of fish species at UNC-7 Site.

Fish Species	Common Name	UNC 7 - Meeting of the Waters Creek				
		7/1	7/13	7/26	8/15	8/30
Anguilla rostrata	American eel					
Clinostomus funduloides	Rosyside dace					
Cyprinella analostana	Satinfin shiner					
Luxilus albeolus	White shiner					
Nocomis raneyi	Bull chub				1	
Nocomis letocephalus	Bluehead chub					
Notemigonus crysoleucas	Golden shiner	6	1			
Notropis altipinnis	Highfin shiner					
Notropis amoenus	Comely shiner					
Notropis procne	Swallowtail shiner					
Semotilus atromaculatus	Creek chub	12	22	30	22	24
Erimyzon oblongus	Creek chubsucker					
Noturus insignis	Margined madtom					
Aphredoderus sayanus	Pirate Perch					
Fundulus rathbuni	Speckled killfish	1	2	2		
Lepomis auritus	Redbreast sunfish					
Lepomis cyanellus	Green sunfish	1	1	2		2
Lepomis macochirus	Bluegill					
Lepomis gibbosus	Pumpkinseed					
Lepomis marginatus	Dollar sunfish					
Micropterus salmoides	Largemouth bass					
Etheostoma olmstedi	Tesselated darter					
Perca flavescens	Yellow perch					
Abundance		20	25	35	23	26
Species Richness		4	3	4	2	2
% Pollution Sensitive		10%	8%	6%	4%	0%

Table 4: Abundance of fish species at the Morgan Creek Site.

Fish Species	Common Name	Morgan Creek Site				
		7/2	7/12	7/26	8/15	8/30
Anguilla rostrata	American eel					
Clinostomus funduloides	Rosyside dace					
Cyprinella analostana	Satinfin shiner	10	4	25	15	20
Luxilus albeolus	White shiner	10	6	2	7	5
Nocomis raneyi	Bull chub	22	8	15	16	18
Nocomis letocephalus	Bluehead chub	10	4	15	11	12
Notemigonus crysoleucas	Golden shiner		1	1		
Notropis altipinnis	Highfin shiner	8	6	25	15	20
Notropis amoenus	Comely shiner	9		10	10	7
Notropis procne	Swallowtail shiner				9	
Semotilus atromaculatus	Creek chub	1		2	3	1
Erimyzon oblongus	Creek chubsucker		2		1	
Noturus insignis	Margined madtom	2	7	7		4
Aphredoderus sayanus	Pirate Perch	4	3	5	4	3
Fundulus rathbuni	Speckled killfish					
Lepomis auritus	Redbreast sunfish		13		3	8
Lepomis cyanellus	Green sunfish	2	10	10	10	11
Lepomis macochirus	Bluegill	2	13	5	4	5
Lepomis gibbosus	Pumpkinseed	1	2		2	1
Lepomis marginatus	Dollar sunfish		11	1		2
Micropterus salmoides	Largemouth bass		2		1	1
Etheostoma olmstedi	Tesselated darter	19	21	14	13	12
Perca flavescens	Yellow perch		1	1		
Abundance		102	107	113	109	110
Species Richness		13	14	13	14	14
% Pollution Sensitive		88%	76%	88%	85%	82%

Table 5: Abundance of fish species at Bolin Creek Site.

Fish Species	Common Name	Bolin Creek Site				
		7/2	7/13	7/26	8/15	8/30
Anguilla rostrata	American eel	2	1	1	1	1
Clinostomus funduloides	Rosyside dace	8	13	2	10	8
Cyprinella analostana	Satinfin shiner					
Luxilus albeolus	White shiner	15	26	10	17	15
Nocomis raneyi	Bull chub	20	23	22	14	20
Nocomis letocephalus	Bluehead chub	10	9	8	6	6
Notemigonus crysoleucas	Golden shiner					
Notropis altipinnis	Highfin shiner					
Notropis amoenus	Comely shiner			2	15	8
Notropis procne	Swallowtail shiner					
Semotilus atromaculatus	Creek chub				1	
Erimyzon oblongus	Creek chubsucker					
Noturus insignis	Margined madtom	5	4	9	3	6
Aphredoderus sayanus	Pirate Perch				2	
Fundulus rathbuni	Speckled killfish				1	1
Lepomis auritus	Redbreast sunfish	8	10	2	5	8
Lepomis cyanellus	Green sunfish	2	1	3	3	3
Lepomis macochirus	Bluegill		1	1		1
Lepomis gibbosus	Pumpkinseed					
Lepomis marginatus	Dollar sunfish	1	1			
Micropterus salmoides	Largemouth bass			1		
Etheostoma olmstedi	Tesselated darter	5	3	13	5	8
Perca flavescens	Yellow perch					
Abundance		82	91	100	94	98
Species Richness		12	12	13	14	13
% Pollution Sensitive		80%	68%	70%	78%	76%

Table 6: Average values of three fish metrics at UNC and control sites.

Site	Mean Abundance	Mean Species Richness	Mean % Intolerant Species
UNC-2	15.2	4.6	44.4
UNC-12	4	2.4	18.2
UNC-7	25.8	3	5.6
Morgan Creek Site	108.2	13.6	83.8
Bolin Creek Site	93	12.8	74.4