An Assessment and Analysis of Benthic Macroinvertebrate Communities Associated with the Appearance of *Didymosphenia geminata* in the White River Below Bull Shoals Dam

A Summary Report of Findings
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Table of Contents

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Introduction:

The White River below Bull Shoals dam is located in the Ozark Mountains in north- central Arkansas. There are 6036 square miles of drainage area above the dam. The lake is one of four multiple-purpose projects constructed in the upper White River Basin for flood control and power generation. Due to the need for power generation, flows in White River can fluctuate widely from about 100 cfs to 22,000 cfs.

The White River below Bull Shoals dam contains one of the most famous trout fisheries in the world. Along with its tributaries, it is considered the best fishery for trophy brown trout in the world.

The AG&FC has established two catch and release areas where no trout harvest is allowed. Located in the first 1/2 mile below Bull Shoals dam and on a 1-mile section at Rim Shoals, rainbows there now survive to trophy size which they attain quickly due to their rapid growth. The designated trout waters extend from Bull Shoals dam to the town of Guion, a distance of about 80 miles. Below Guion, the White contains excellent cool and warm water fish populations. Largemouth, smallmouth and spotted bass are the most important sport fisheries.

In late spring / early summer of 2005, several area residents and business owners along the White River, directly below the Bull Shoals dam, notified ADEQ with concerns of a whitish-brown paper-like substance hanging from trees and docks after a typical surge or release of reservoir water. Samples of this material were collected by ADEQ biologists and determined to be *Didymosphenia geminata*.

D. geminata is a diatom algae that attaches itself to stable cobble and secretes a copious mucopolysaccharide stalk. During high flows, the long fibrous masses can become dislodged and swept downstream and accumulate on available debris or fixtures.(4) The result is a whitish brown fibrous material that looks like wet "toilet"paper. The *D. geminata* stalks can be problematic due to it's resistance to grazing by invertebrates and resistance to decomposition. The stalks, which persist even after cell death, are large mucopolysaccaride masses which trap fine sediment. (4)
D. geminata prefers a habitat with cool water and high exposure to UV-B radiation. Also, a stable flow regime and small to medium cobble substrate are preferred. These ideal conditions are commonly located in lake-fed rivers, or in regulated rivers below reservoir impoundments. (1)

This particular algae is known to be an invasive and nuisance species in many regions across the world including, most notably, New Zealand and the western U.S. *D. geminata* is thought to be the cause of a decline in western U.S. Trout fisheries, therefore it is important for us to understand and determine the effects of *D. geminata* on Arkansas trout-supporting streams.

Purpose of Study:

A 13 mile reach of the White River below Bull Shoals dam has been affected by *D. geminata*. This affected reach is a prominent trout fishing area with many guided- fishing establishments, public fishing accesses, bed and breakfast establishments, as well as many other businesses relying on trout fisheries as a source of revenue.

A macroinvertebrate analysis was performed to determine any current or future impacts to the biological communities.

Location of Sampling Locations and Physical Description:

Study area:
White River below Bull Shoals dam along the Marion - Baxter county line
Planning Segment: 4I
HUC: 11010003
(See Appendix C: Map of White River Study Area)

Newland's Pool
Location: - approximately 2.3 mi. downstream of Bull Shoals dam
Substrate: larger cobble in deeper water; medium cobble towards shallow water

White Hole
Location: approximately 6.2 miles downstream of Bull Shoals dam
Substrate: medium to large gravel /small cobble; fine sand/sediment abundant

WildCat Shoals
Location: approximately 11.0 mi. downstream of Bull Shoals dam
Substrate: almost entirely bedrock interspersed with medium to large gravel / small cobble

Cotter
Location: approximately 15.3 mi. downstream of Bull Shoals dam
Substrate: Medium cobble; sandy substrate
Public access under Hwy 62B bridge; an active swimming and fishing area.

Methods of Investigation

In-situ Water Quality

Ambient water temperature, dissolved oxygen (DO mg/L), dissolved oxygen % saturation, and pH were measured with a YSI© 6000 series sonde multi-parameter probe. Each sonde instrument was deployed for a period of 48 hours at each macroinvertebrate sampling location. Data collected by the sonde was downloaded and analyzed using Excel.

Due to a sonde instrument malfunction, USGS monitoring station #07054527 (White River below Bull Shoals dam near Fairview) was used to replace the ADEQ White Hole sampling location sonde data.

Water Chemistry

Water chemistry samples were collected at or near each sampling location and analyzed for anions, metals, and routine parameters.

Macroinvertebrates:

At each stream sampling location, collections were made via an Ellis-Rutter™ Portable Invertebrate Box Sampler (PIBS) sampler fitted with a 350-m mesh size net. The PIBS sampler has several advantages over the standard Surber ™ sampler which makes it a desirable choice for the collection of aquatic macroinvertebrates. Sample area was 0.10 m^2 per replicate. Two samples were taken at each station; one in an area primarily consisting of native vegetation (submergent aquatic vegetation, SAV), and one from an area influenced by *D. geminata* algae. Due to the varying flow patterns caused by fluctuating amounts of water released from the Bull Shoals impoundment, samples were preferably collected where water flow was continuous more than 50 % of the time. This was done to ensure that macroinvertebrate communities had sufficient time to colonize, allowing for a more accurate analysis of the sampling location. This collection method was not entirely feasible due to high concentrations of *D. geminata* in some areas. In these areas, the only native vegetation available was located near the shallow banks of the stream where water flow was not continuous more than 50% of the time. For this reason, metrics were also calculated for the aggregate of both samples.

Samples were placed in 1-liter plastic containers, preserved in 15% formalin, and returned to the laboratory for processing. All samples were divided into 8 sections within a 6 in diameter Petri dish. One section was removed and used as a subsample. Samples were then picked under a Zeiss™ stereo-microscope and detrital material was discarded only after a second check to insure that no macroinvertebrates had been missed. All macroinvertebrates were identified to lowest practical taxonomic level and enumerated. Several benthic macroinvertebrate metrics were then calculated for each station.

Description of Macroinvertebrate Metrics:

Taxa Richness - Reflects the health of the community through a measurement of the variety of taxa present. Generally increases with increasing water quality, habitat diversity, and habitat suitability. However, the majority should be distributed in the pollution sensitive groups, a lesser amount in the facultative groups, and the least amount in the tolerant groups. Polluted (stressed) streams shift to tolerant dominated communities.

Percent Facultative- The percentage of taxa capable of functioning under varying environmental conditions.

Modified Hilsenhoff Biotic Index (HBI) - This index was developed by Hilsenhoff (1977) to summarize overall pollution tolerance of the benthic arthropod community with a single value. Calculated by summarizing the number in a given taxa multiplied by its tolerance value, then divided by the total number of organisms in the sample.

HBI= $(\sum ni+ai)/ N$ where "ni" is the number of specimens in each taxonomic group, "ai" is the pollution tolerance score for that taxonomic group, and "N" is the total number of organisms in sample.

The HBI is based on categories of macroinvertebrates depending on their response to organic pollution. Macroinvertebrates are given a numerical pollution tolerance score "ai" ranging from 0

to 5. In 1987, Hilsenhoff re-evaluated the pollution tolerance scores and expanded the range from 0 to 10. The value is based on field and laboratory responses of these organisms toward organic pollution. Taxa with a zero (0) value are extremely intolerant of low dissolved oxygen and organic pollution; taxa with scores of 2 through 9 are tolerant to varying degrees; taxa which can survive great amounts of pollution are scored 10.
Because both pollution sensitive and tolerant forms are present in "clean" waters, it is the absence of the sensitive coupled with the presence of the tolerant, which may indicate damage. This is the basis of the *Biotic Index*.

Water quality based on Family Biotic Index (adapted from Hilsenhoff, (1977).

Biotic Index	Water quality	Degree of organic pollution
0.00–3.50	Excellent:	No apparent organic pollution
3.51–4.50	Very good:	Possible slight organic pollution
4.51–5.50	Good:	Some organic pollution
5.51–6.50	Fair:	Fairly significant organic pollution
6.51–7.50	Fairly poor:	Significant organic pollution
7.51–8.50	Poor:	Very significant organic pollution
8.51–10.0	Very poor:	Severe organic pollution

Ratio of Scraper and Filtering- Collector Functional Feeding Groups - This ratio reflects the riffle/run community food-base and provides insight into the nature of potential disturbance factors. The relative abundance of scrapers and filtering collectors indicate the periphyton community composition, availability of suspended Fine Particulate Organic Material (FPOM) and availability of attachment sites for filtering. Filtering collectors are sensitive to toxicants and should be the first group to decrease when exposed to steady sources of toxicants such as metals, organics, extreme high or low levels of dissolved oxygen, that are bound to fine particles.

Ratio of Ephemeroptera, Plecoptera, Trichoptera (EPT) and Chironomidae Abundances -This metric uses relative abundance of these indicator groups as a measure of community balance. Good biotic condition is reflected in communities having a fairly even distribution among all four major groups and with substantial representation in the sensitive groups Ephemeroptera, Plecoptera, and Trichoptera. Skewed populations with large amounts of Chironomidae in relation to the EPT indicates environmental stress.

Percent Contribution of Dominant Taxa - This is also a measure of community balance. A community dominated by relatively few species would indicate environmental stress. A healthy community is dominated by pollution sensitive representation in the Ephemeroptera, Plecoptera, and Trichoptera groups.

EPT Index - This index is the total number of distinct taxa within the Orders Ephemeroptera, Plecoptera, and Trichoptera. The EPT Index generally increases with increasing water quality. The EPT index summarizes the taxa richness within the pollution sensitive insect orders.

Simpson's Diversity Index - This index ranges from **0** (**high** diversity) to **1** (**low** diversity). A healthy benthic macroinvertebrate community should have a **lower** Simpson's Diversity Index value. $\mathbf{C = 1- \sum(n_i/N)^2}$

Shannon-Wiener Diversity Index - Measures the amount of order in the community by using the number of species and the number of individuals in each species. The value increases with the number of species in the community. A healthy benthic macroinvertebrate community should have a higher Shannon-Wiener Diversity Index.

$H' = - \sum (n_i / N) \log (n_i / N)$

Where **" n_i "**is the number of individuals of a given taxa, **" N "** equals the total number of individuals in the sample, and **" s "** equals the total number of taxa in the sample. This index, which usually varies from 0 to 5.

***Note: Within the observation portions of the text, there are two numbers separated by a slash mark; # /#. The first number (#,#) is the actual calculated Shannon -Wiener diversity index for that particular site. The second number (#,#) is the calculated highest possible Shannon - Wiener diversity index for the number of taxa present at that particular site.*

Number of Taxa Represented in Sample	Maximum Diversity Index possible with the given number of taxa per site
1	0.00
2	1.00
3	1.59
4	2.00
5	2.32
6	2.59
7	2.81
8	3.00
9	3.17
10	3.32
11	3.46
12	3.59
13	3.70

Shannon-Wiener Evenness - Measures the evenness, or balance of the community by scaling one of the heterogeneity measures relative to its maximal value when each species in the sample is represented by the same number of individuals. Ranges from 0 (low community balance) to 1 (high ecommunity balance).

Evenness is calculated by taking the ratio of observed diversity of a collection to the maximum it could have, given the same number of species as a reference point. This maximum value is attained when individuals are divided among the species as evenly as possible Pielou (1969). The populations' evenness (**J'**) is determined by the formula
J'=H'/log s where **H'**=diversity and **s**=number of species
**Note: J' is usually highest where the diversity was highest*

Similarity Index: [a modified version of Odum's Sim. Index (Odum, Eugene. Fundamentals of Ecology. 1971)]
Similarity Index, (S), is an index of similarity between two samples were used to calculate an index (%) comparing the relationships between two lines. The number of species common to both sites are divided by the sum of the total species for each site to determine the similarity (see Bray and Curtis, 1957).

S=2C/A+B

From the number of taxa identified in sampling location, the Index of similarity was then calculated between the two locations, using the formula:
S = Similarity Index; A = Number of species in site A ; B = Number of species in site B ; C = Number of species found in both site A and site B
** *As similarity value nears 0, then less similar ; As similarity value nears 1, then more similar*

Herptobenthos is the number of burrowers (i.e. Chironomidae, Oligochaeta) + sprawlers (i.e. Planorbidae, Asellidae). This metric is expected to increase due to perturbation. (Burrowers + Sprawlers: BU+SP)

Haptobenthos is the number of clingers (i.e. Glossomatidae, Elmidae) + Crawlers (i.e. Hydracarina). This metric is expected to decrease due to perturbation. (Clingers + Crawlers: CLG+CR)

Results of Study

Water Quality Analysis

During the October, 2005 sample, dissolved oxygen levels indicate a potential problem near Newland's pool and Fairview. Diurnal dissolved oxygen levels fell below the standard of 6 (mg/l) in trout supporting streams.
There were no obvious sources of perturbation / pollution revealed in the water quality analysis
**The results of the in-situ and dissolved oxygen measurements are located in table #4 and graphs 15-18.*

Macroinvertebrate Analysis:

Newland's Pool

Location: - approximately 2.3 mi. downstream from Bull Shoals dam
Substrate: Larger cobble in deeper water; medium cobble towards shallow water
D. geminata coverage: 100% in areas submerged by water greater than 50 % of the time
D. geminata length: >6in., but mostly >12in.; >20 mm thick on substrate.

Vascular Submergent Vegetation (SAV) sample: (SAV predominately Certophyllum – "Coontail")
- Dominant taxa #1 Gastropoda
- Dominant taxa #2 Chironomidae

D. geminata sample:
- Dominant taxa #1 Chironomidae
- Dominant taxa #2 Gastropoda

Aggregate :
- Dominant taxa #1 Chironomidae
- Dominant taxa #2 Gastropoda

** Note: The only submergent aquatic vegetation located at this site was near the bank where water was present < 50 % of the time. A submergent aquatic vegetation sample was taken from this area. However, macroinvertebrates may not have colonized to full potential*

Observations:
It is evident that *D. geminata* out-competes other submergent aquatic vegetation.
Gastropods mainly feed on living or decaying plants, algae, or other detritus by scraping or filtering material from rocks or water column. It could be theorized that D. geminata is not as palatable to Gastropods as other *native* algae or plant species. This *could* be a possible cause for the inversion of the dominant taxa between the submergent aquatic vegetation samples and the *D. geminata* samples.

-Taxa Richness: decreased from the submergent aquatic vegetation sample (10) to the D. *geminata* sample (5); the number of different taxa decreased in the presence of D. *geminata.*
-Shannon-Wiener Diversity Index: submergent aquatic vegetation sample = **2.52**/3.70; *D. geminata* sample = **1.34**/2.59; Aggregate = **1.62**/3.70
-Simpson's Diversity Index: submergent aquatic vegetation = 0.228; *D. geminata* = 0.521; Aggregate = 0.280
**Note: where 0= high diversity ,1= low diversity*

-Similarity Index between submergent aquatic vegetation and D. *geminata* sample sites is 0.65; macroinvertebrate population dynamics are ~65% similar to each other
**As similarity value nears 0, then less similar ; As similarity value nears 1, then more similar*
- HBI: submergent aquatic vegetation sample; 6.38 (fair)
- HBI: D. *geminata* sample; 6.22 (fair)
- HBI: Aggregate; 6.31 (fair; increased perturbation)

White Hole:
Location: approximately 6.2 miles downstream from Bull Shoals dam
Substrate: Medium to large gravel /cobble; fine sand/sediment abundant
D. geminata coverage: 85% in areas submerged by water greater than 50 % of the time
D. geminata length: >4in; >20mm thick on substrate

Submergent aquatic vegetation (SAV) sample:
Dominant taxa #1 Asellidae
Dominant taxa #2 Chironomidae
D. geminata sample:
Dominant taxa #1 Hydracarina
Dominant taxa #2 Asellidae
Aggregate:
Dominant taxa #1 Chironomidae
Dominant taxa #2 Gastropoda

Observations:
-Taxa Richness: decreased from the submergent aquatic vegetation sample to the D. *geminata* sample; the number of different taxa decreased in the presence of D. *geminata*.
-Shannon-Wiener Diversity Index: submergent aquatic vegetation = **2.14**/3.32 ; *D. geminata* site = **2.07**/3.00; Aggregate = **1.72**/3.32
-Simpson's Diversity Index : submergent aquatic vegetation = 0.286; *D. geminata* = 0.286; Aggregate = 0.227
**This may be due to the similar diversity indices, but varying types of taxa. When these sites are combined it shows the differences in types of taxa more clearly.*
-Similarity Index: between submergent aquatic vegetation and D. *geminata* sample sites is 0.67; macroinvertebrate population dynamics are ~67% similar to each other
**As similarity value nears 0, then less similar ; As similarity value nears 1, then more similar*
- HBI: submergent aquatic vegetation sample; 6.84 (fairly poor)
- HBI: D. *geminata* sample; 6.45 (fair)
- HBI: Aggregate; 7.0 (fairly poor; increased perturbation)

WildCat Shoals
Location: approximately 9.0 mi. downstream from Bull Shoals dam
Substrate: Almost entirely shale / bedrock
D. geminata coverage: 50% in areas submerged by water greater than 50 % of the time
D. geminata length: <3in.; 5-10mm thick on substrate; early stages of colonization

Submergent aquatic vegetation (SAV) sample:
Dominant taxa #1 Chironomidae

Dominant taxa #2 Brachycentrus

D. geminata sample:
Dominant taxa #1 Chironomidae
Dominant taxa #2 Gastropoda

Aggregate sample:
Dominant taxa #1 Chironomidae
Dominant taxa #2 Gastropoda

Observations:

- **Taxa Richness:** values were constant from the Submergent aquatic vegetation sample to the D. *geminata* sample; the number of different taxa stayed constant in the presence of D. *geminata.* *This may be attributed the the lack of suitable habitat for *D. geminata*. As mentioned above, the majority of substrate was comprised of bedrock; *D. geminata* prefers smaller to medium cobble. The submergent aquatic vegetation samples were taken closer to the bank where water is not constant more than 50 % of the time; macroinvertebrate communities possibly have not had time to colonize in these areas.
- **Shannon-Wiener Diversity Index**: Submergent aquatic vegetation site = **1.22**/3.32; *D. geminata* site = **1.42**/3.17; Aggregate = **1.23**/3.59
- **Simpson's Diversity Index**: Submergent aquatic vegetation = 0.577; *D. geminata* = 0.462; Aggregate = 0.460
- **Similarity Index:** between submergent aquatic vegetation and *D. geminata* sample sites is 0.74; macroinvertebrate population dynamics are ~74% similar to each other

** As similarity value nears 0, then less similar ; As similarity value nears 1, then more similar*

- **HBI**: Submergent aquatic vegetation sample; 5.12 (good)
- **HBI**: D. *geminata* sample; 6.27 (fair)
- **HBI**: Aggregate for both samples combined; 6.21 (fair; increased perturbation)

Note: During the October, 2005 sampling event, we were notified of a bank stabilization project which was funded by and contracted through WildCat Shoals, while permitted by the USACE There was a noticeable increase in aquatic vegetation within the shallower areas with cobble substrate, as well as new establishment of aquatic vegetation in areas where it was lacking prior to the bank stabilization project. This could potentially benefit the macroinvertebrate community at this particular site.

Cotter:

Location: approximately 15.3 mi. downstream from Bull Shoals dam
Substrate: Medium cobble
D. geminata coverage: < 5% in areas submerged by water greater than 50 % of the time
D. geminata length: < 2in; < 0.5mm thick on substrate; early stages of colonization
Most of the *D. geminata* masses located at this site were actually mats that detached and floated downstream during a high flow event. The floating mats of D. geminate were excluded from the estimated coverage and length percentages. The percentages above only apply to D. geminate colonies establishing on the substrate at the Cotter site.

Submergent aquatic vegetation (SAV) sample: (predominantly Ceratophyllum – "Coontail")
Dominant taxa #1 Chironomidae
Dominant taxa #2 Gastropoda

Observations:
Metrics calculated for the Cotter sampling site indicate greater perturbation or stress compared to the upstream sampling sites with higher densities of *D. geminata*. This may indicate another unknown source of perturbation affecting the Cotter location.

- Taxa Richness = 10
- HBI = 6.18 (fair; increased perturbation)
- Shannon-Wiener Diversity Index: = **1.11**/3.32
- Simpson's Diversity Index: = 0.612

Note: During the October, 2005 sampling event, small colonies of D. geminata were noticed on the cobble substrate and floating docks. The colonies were very small filaments (<0.5 – 1.0 inches in length).

Macroinvertebrate Analysis Summary:
During the macroinvertebrate collection, a 0.10 m^2 sample of D. geminata was collected using the P.I.B.S. sampler. The sample was processed and dried in the ADEQ lab. The sample was dried (100°C) for 24 hours and weighed. (Ash-free Dry Mass was not used for the purposes of this report). The results were as follows: (see Table 2)
Sample size: 0.10 m^2 ; Dried wt: 81 g /ft^2 ; Estimated stream width: 300 ft;
Estimated weight per linear mile: 283,000 pounds dry weight per linear mile

Newland's Pool is the site in closest proximity to the dam and is the initial site of D. geminata colonization. Newland's Pool in dominated by D. geminata with very little native submergent aquatic vegetation. The total number of taxa is significantly lower at this site compared to downstream sites. This may be indicative of the dense D. geminata mats throughout the stream reach causing decreased suitable habitat for the macroinvertebrates. The Shannon-Wiener Index within the SAV indicates a fairly balanced macroinvertebrate community; D. geminata indicates a fairly unbalanced macroinvertebrate community; and the aggregate indicates a moderately balanced macroinvertebrate community. The Simposon's diversity index indicates the SAV sample had fairly high diversity; D.geminata sample had fairly low diversity; while the aggregate had moderate diversity. HBI scores ranged from 6.77 to 7.14 with an HBI score of 7.14 for the aggregate. An overall HBI score of 7.14 indicates fairly poor habitat suitability and increased levels of perturbation (The only available SAV sample area was near the bank of the stream; flow in this area is present less than 50% of the time.) The predominant taxa compromising this site was Chironomidae and Gastropoda. The amount of available food for young trout was negligible compared to the downstream sampling locations.

White Hole is directly downstream of Newland's Pool. White Hole in predominantly D. geminata with moderate amounts of native submergent aquatic vegetation. The total number of taxa is below the average of the sample areas, but significantly higher than Newland's Pool. This may be indicative of a decrease in the thickness and frequency of dense D. geminata mats throughout the stream reach due to later stages of colonization. The Shannon-Wiener Index within the SAV indicates a moderately balanced macroinvertebrate community; D. geminata indicates a fairly unbalanced to moderately balanced macroinvertebrate community; and the aggregate indicates a fairly unbalanced to moderately balanced macroinvertebrate community. The Simposon's diversity index indicates the SAV sample had fairly high to moderate diversity; D.geminata sample also had fairly high to moderate diversity; while the aggregate had moderate diversity. HBI scores ranged from 6.63 to 7.49 with an HBI score of 7.20 for the aggregate. An overall HBI score of 7.20

indicates fair habitat suitability and increased levels of perturbation. The dominant taxa compromising the SAV site are Asellidae and Chironomidae; D. geminata was dominated by Hydracarina and Asellidae; Aggreagate was dominated by Chironomidae and Gastropoda. The amount of available food for young trout increases the farther downstream of initial colonization.

Wild Cat Shoals is directly downstream of White Hole. Wild Cat Shoals is predominantly bedrock; a substrate apparently not suitable habitat for D. geminata. At the time of sampling, colonizing D. geminata was only found within the SAV areas located near the bank and small pockets within the bedrock. The total number of taxa is significantly higher than any of the other sampling locations. Certain taxa, such as Brachycentrus, were more prominent in this area, possibly due to the lack of suitable habitat for other taxa. Brachycentrus inhabit areas with a high velocity regime and attach themselves to stable substrate in order to feed upon particulate matter within the water column. The bedrock substrate and minimal SAV decreases the suitability for organisms (Asellidae) which tend to cling to plant material. (Chironomids were observed on any available substrate including other organisms). The Shannon-Wiener Index within the SAV indicates a fairly unbalanced macroinvertebrate community; D. geminata indicates a fairly unbalanced to moderately balanced macroinvertebrate community; and the aggregate indicates a fairly unbalanced to moderately balanced macroinvertebrate community. The Simposon's diversity index indicates the SAV sample had fairly low to moderate diversity; D.geminata sample also had moderate diversity; while the aggregate had moderate diversity. HBI scores ranged from 6.60 to 7.45 with an HBI score of 7.17 for the aggregate. An overall HBI score of 7.17 indicates fairly poor habitat suitability and increased levels of perturbation. The main reason for decreased HBI scores is due to the dominance of certain organisms preferring bedrock substrate habitat. The dominant taxa compromising the SAV site are Chironomidae and Brachycentrus; D. geminata was dominated Chironomidae and Gastropoda; Aggreagate was dominated by Chironomidae and Gastropoda.

Cotter is directly downstream of Wild Cat Shoals. At the time of sampling, D. geminata was in early stages of colonization and was minimally present within the SAV areas. Therefore, only one sample was taken from this site; SAV only. The total number of taxa is average compared to the other sampling locations, but higher than Newland's Pool and White Hole. The Shannon-Wiener Index within the SAV indicates a fairly unbalanced macroinvertebrate community. The Simposon's diversity index indicates the SAV sample had fairly low diversity. The SAV had a HBI score of 7.71 indicating poor habitat suitability and increased levels of perturbation. Cotter is a highly accessed area for fishing and swimming activities; this could be a source of the increased perturbation. The dominant taxa compromising the SAV site are Chironomidae Gastropoda.

Newland's Pool aggregate sample had a Shannon-Weiner index which indicated a moderately balanced macroinvertebrate community. This is caused by a high Shannon Weiner Index value within the SAV sample and a very low value within the D. geminata sample. The high Shannon Weiner Index value within the SAV may be attributed to the sample area being exposed to a constant stream- flow *less than 50% of the time*. As mentioned before, the macroinvertebrate community had not yet had sufficient time to re-colonize..

Percent community abruptly changes within the Newland's Pool samples; from fairly even distribution between taxa within the SAV sample to a predominance of one taxa (Chironomidae) within the D. geminata sample. This can be attributed to the change in habitat; shallower water near the bank had an abundance of SAV, while the main channel had a high density of very thick D. geminata. Chironomidae appears to be the only organism that can adapt to the changing substrate and burrow through the D. geminata, also reaching the sand/ silt substrate below.

Within the Newland's Pool samples, there was a high variance between total taxa; SAV sample had ten total taxa, while the D. geminata sample dropped to 5 total taxa. This also characterizes the

unsuitable habitat conditions created by an over abundance of D. geminata. As the density of D. geminata increases, the number of taxa and total organisms decreases.

Discussion and Concerns:

Diets of both Brown and Rainbow trout are dependant upon the age and size of trout The diet of juvenile trout may predominantly consist of macroinvertebrates, while the adult trout may feed upon macroinvertebrates as well as other fish, in particular the sculpin. Sculpins also rely on macroinvertebrates as their main food source.
If macroinvertebrate communities decrease significantly, this can adversely affect the size and/or number of sculpins, as well as the size and number of smaller trout. Therefore, it is possible that these circumstances could cause a domino effect and adversely affect growth and reproduction of the trout population in the White River below Bull Shoals dam.

The trout population within the White River below Bull Shoals dam is primarily "put and take". The Arkansas Game and Fish Commission stocks Brown and Rainbow trout below the dam. Natural reproduction in the rainbow trout population has never been verified. However, there is a small "wild" population of Brown trout that spawns in the White River directly below the Bull Shoals dam.

This wild population of Brown trout may be negatively affected by D. geminata in the area below the dam due to a lack of suitable conditions for spawning areas. The female trout digs several redds (spawning beds) for egg depositiong the eggs. She turns on her side and beats her tail against the bottom, moving the gravel away to create a depression longer than her body and about half as deep. As the female digs, male trout release milt to fertilize the eggs. The fertilized eggs then settle into the depression until hatching.

Developing salmonid eggs and young-of-year trout require have similar requirements as adult trout (dissolved oxygen between 6 and 8, clean water flow, limited disturbance) and may be negatively impacted due to lower dissolved oxygen cause by dense mats of D. geminata. The colonization of D. geminata can cause diurnal dissolved oxygen concentrations to fall below levels needed for sufficient growth and development of embryos and frey. This can cause a decrease of the over all population density and the growth rate of individual fish.

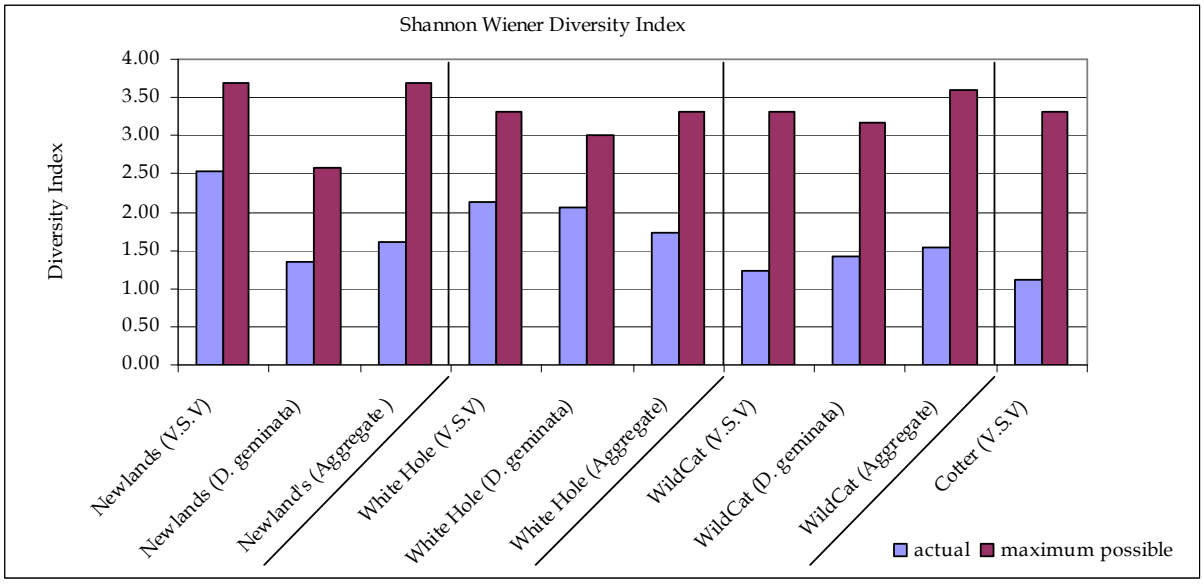
A potential decrease in the wild population of Brown trout may be negligible, since the trout are not primarily self sustaining in the White River, however a potentially serious affect of the trout population may be growth rate and, subsequently, the maximum size of trout. Due to a decreased number of suitable prey organisms available, there is the potential for decreased growth rates of trout populations within the waters below Bull Shoals dam. Unfortunately, there is not sufficient historical age and growth data available for the trout within the White River for comparison or predictions.

The data and information collected throughout this study may assist in defining the problems within another area recently impacted by early colonizing D. geminate; the Little Red River below Greers Ferry Lake. This area is also supplemented for Rainbow trout, but had a predominantly wild population of Brown trout. At this time, there have been no further studies or analysis have been performed on the Little Red River below Greers Ferry.

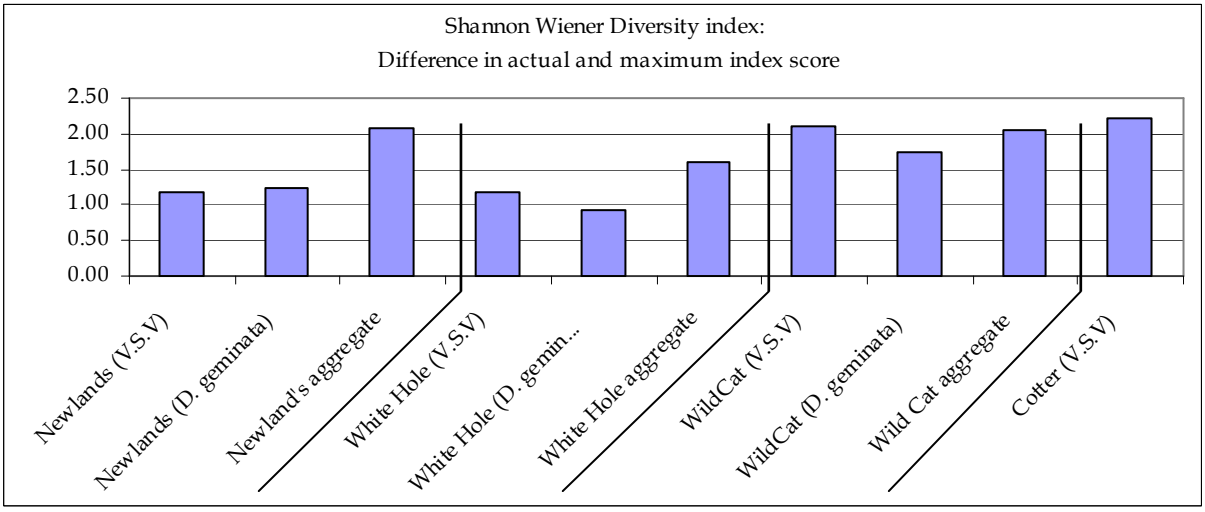
Recently, there have been unconfirmed sightings of D. geminate within the tailwaters of the White River below Table Rock Lake in Missouri. There is also speculation that D. geminate may also be present in the tailwaters of the White River below Beaver Lake. Neither of these sightings have been confirmed by ADEQ.

Appendix A

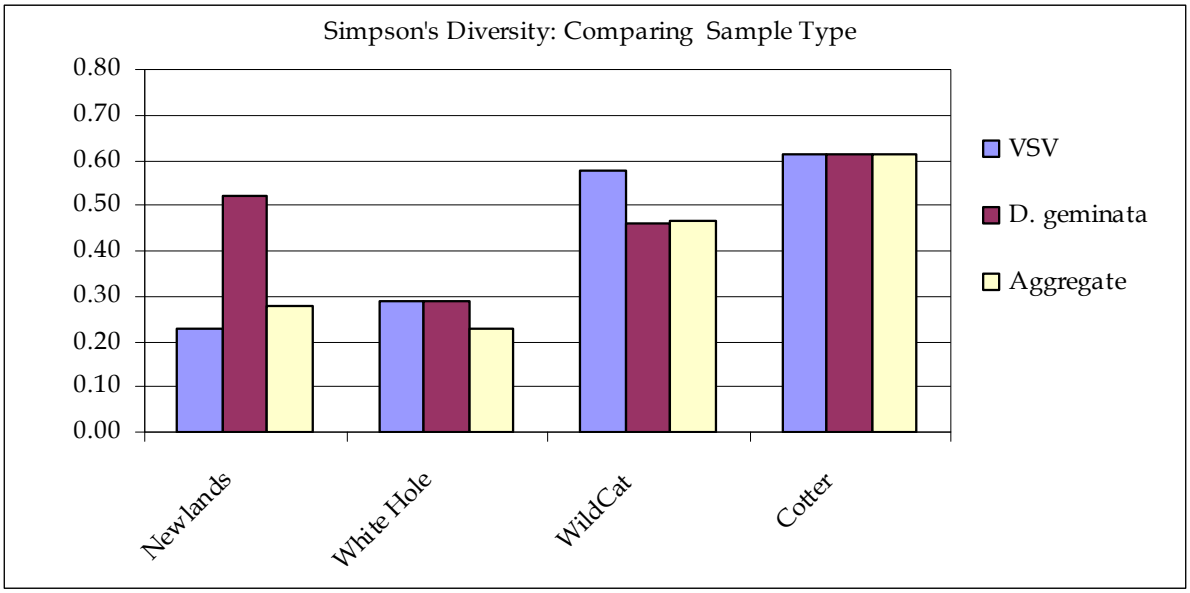
Note: (VSV) vascular submergent vegetation; same as (SAV) submergent aquatic vegetation



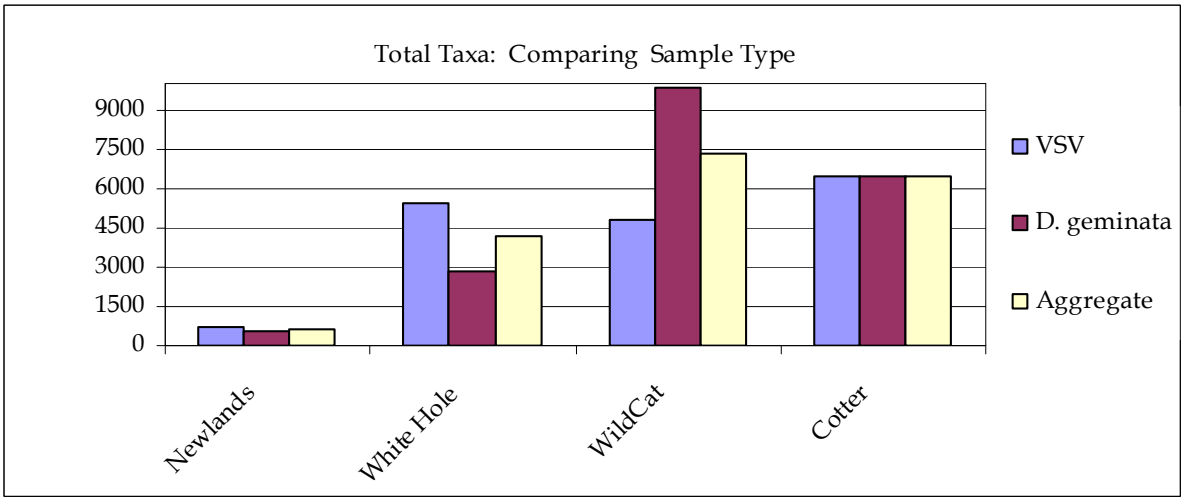
Graph 1



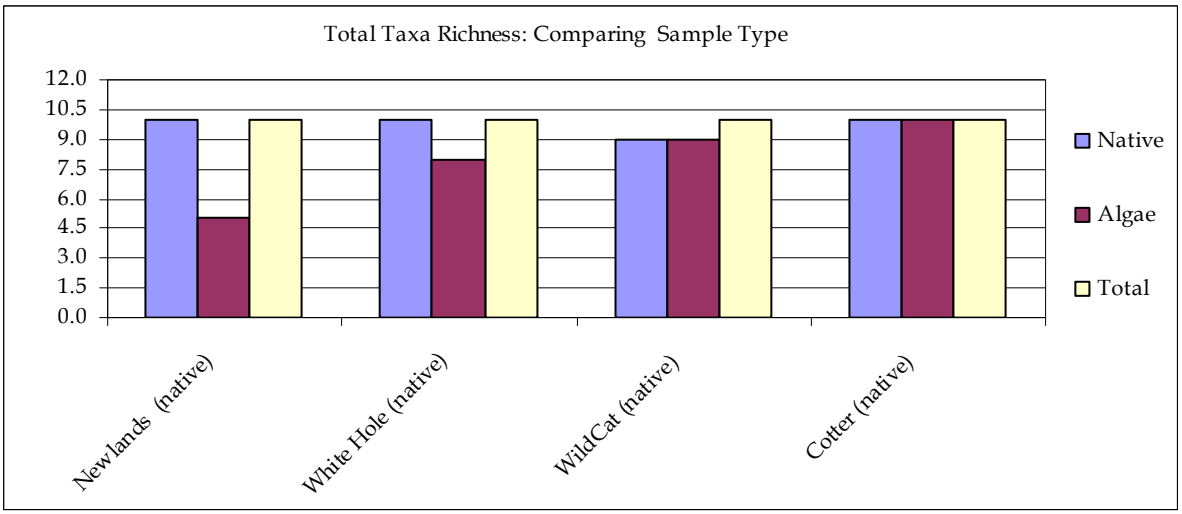
Graph 2



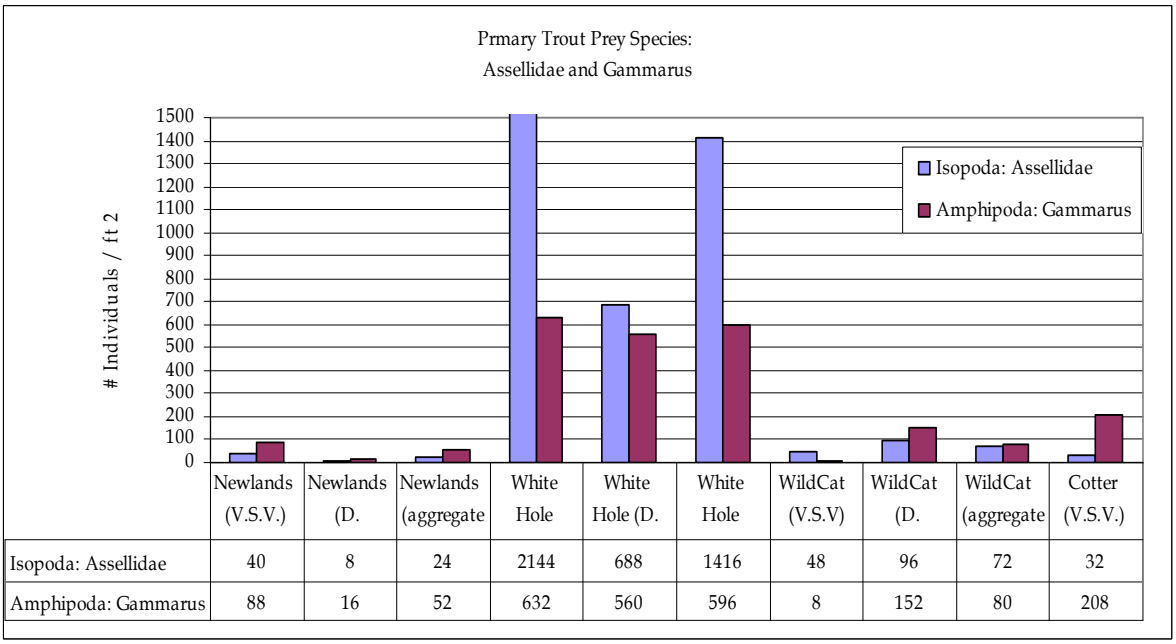
Graph 3



Graph 4

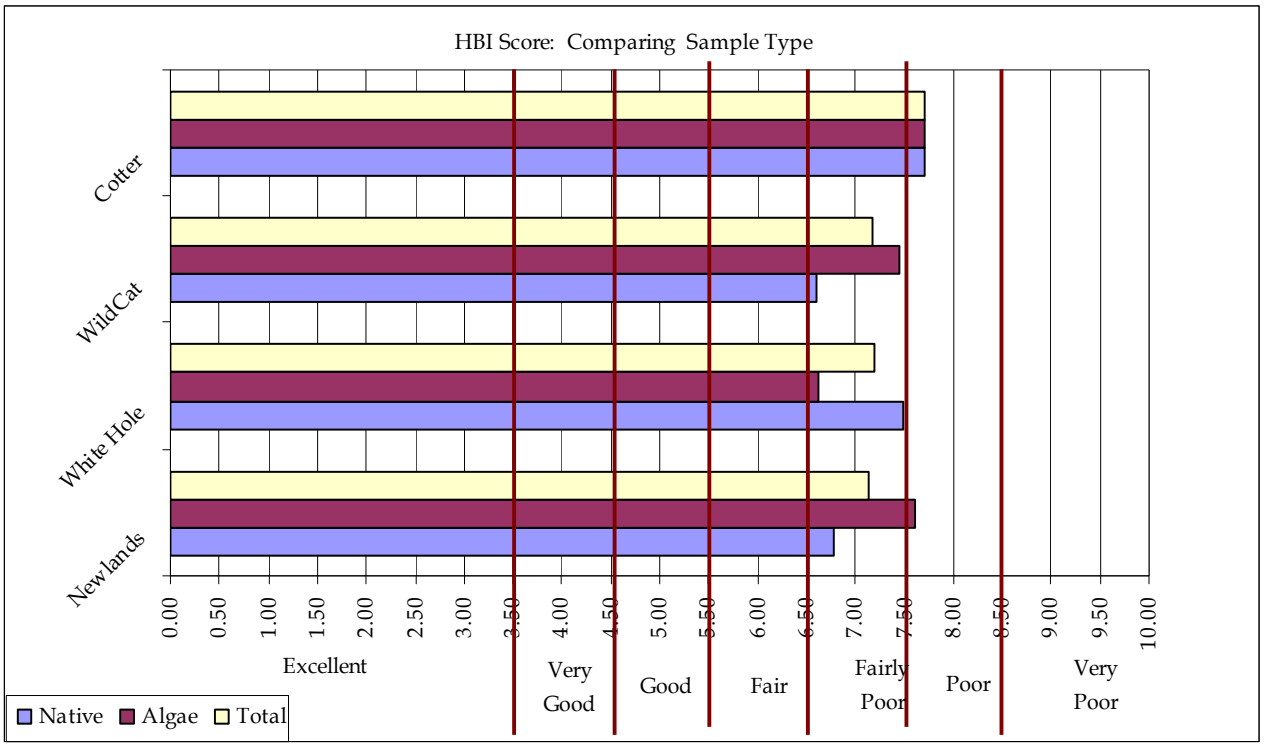


Graph 5

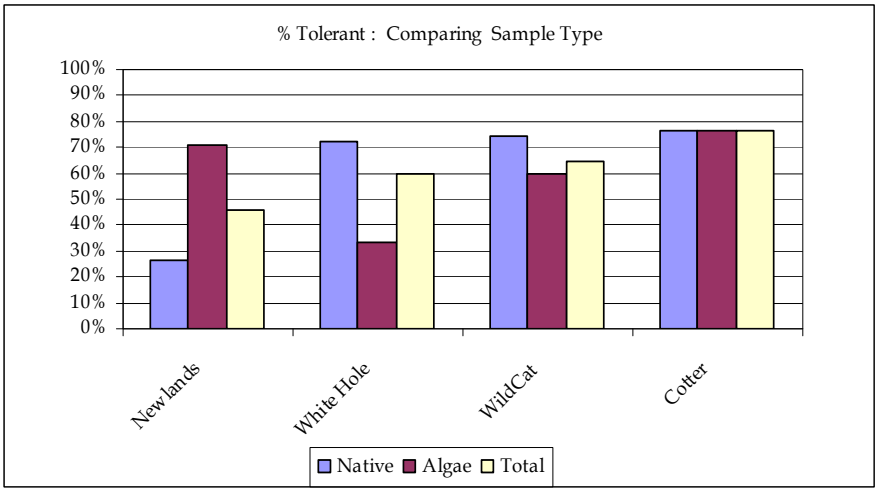


	Newlands (V.S.V.)	Newlands (D.	Newlands (aggregate	White Hole	White Hole (D.	White Hole	WildCat (V.S.V)	WildCat (D.	WildCat (aggregate	Cotter (V.S.V.)
Isopoda: Assellidae	40	8	24	2144	688	1416	48	96	72	32
Amphipoda: Gammarus	88	16	52	632	560	596	8	152	80	208

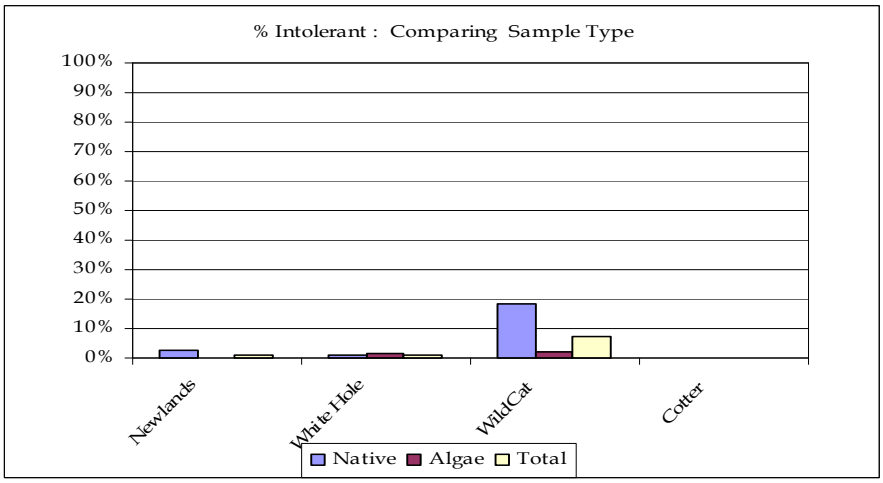
Graph 6


HBI Score: Comparing Sample Type
Cotter
WildCat
White Hole
Newlands
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
6.00
6.50
7.00
7.50
8.00
8.50
9.00
9.50
10.00
Excellent
Very Good
Good
Fair
Fairly Poor
Poor
Very Poor
Native
Algae
Total

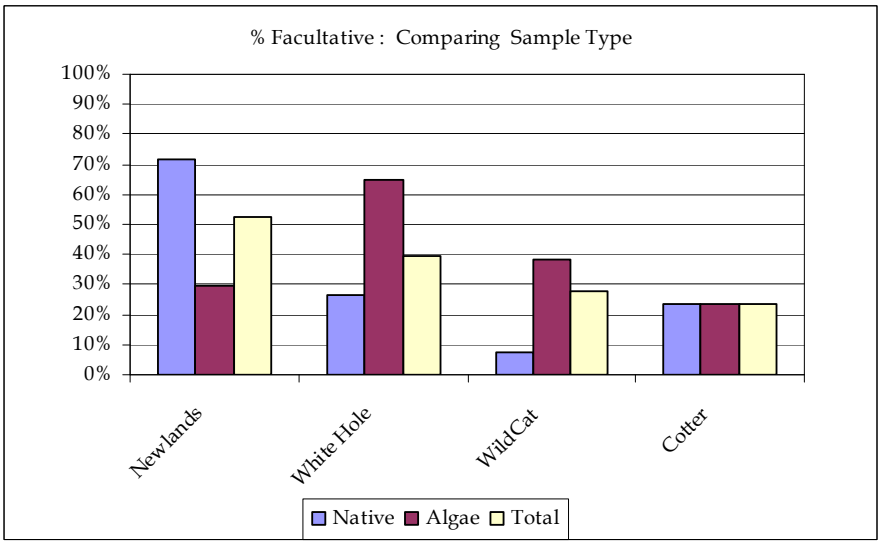
Graph 7



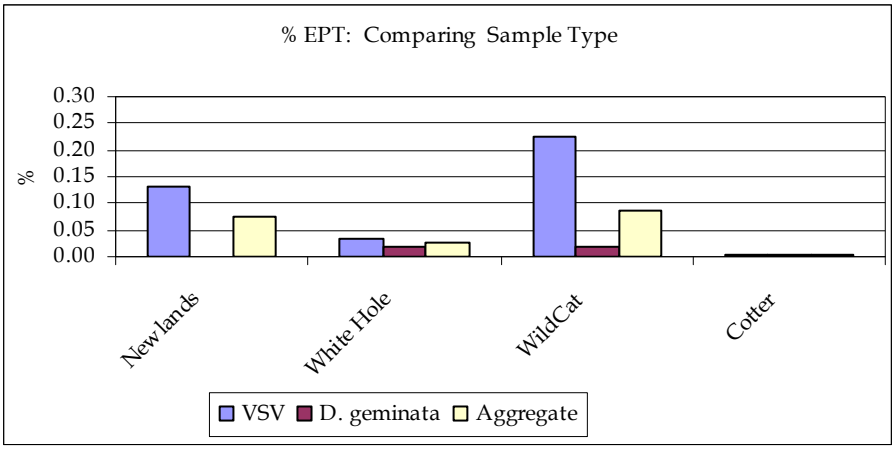
Graph 8



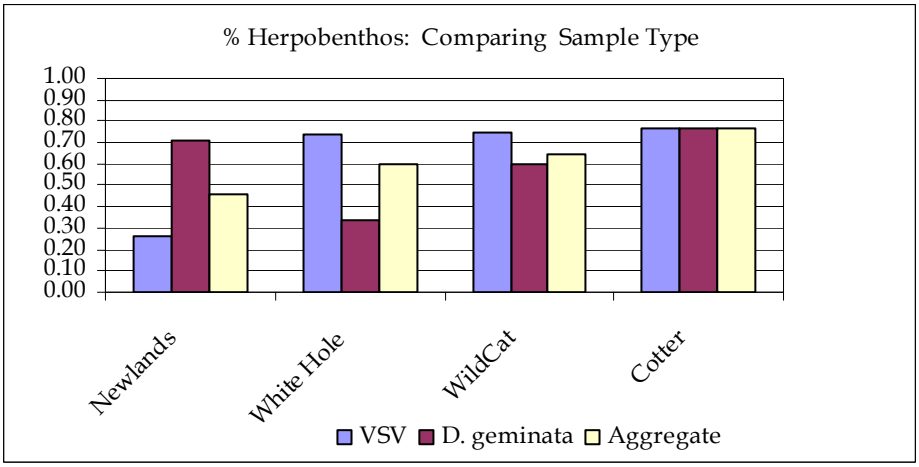
Graph 9



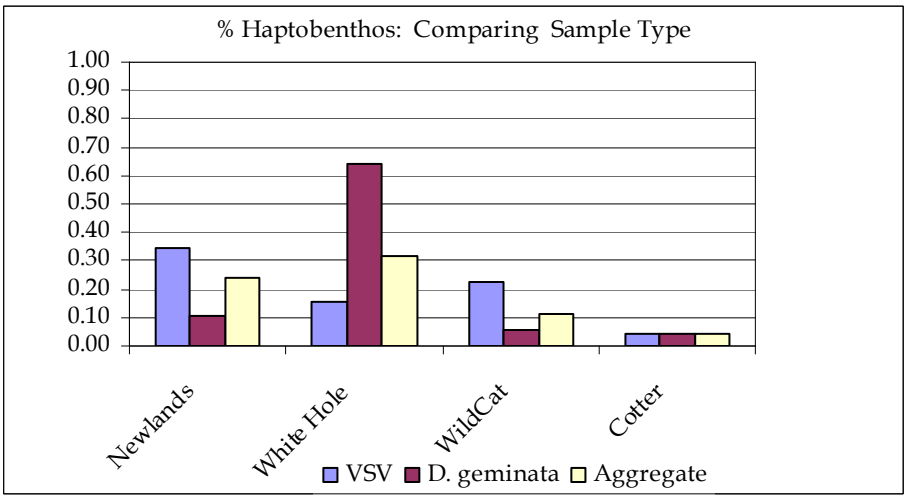
Graph 10



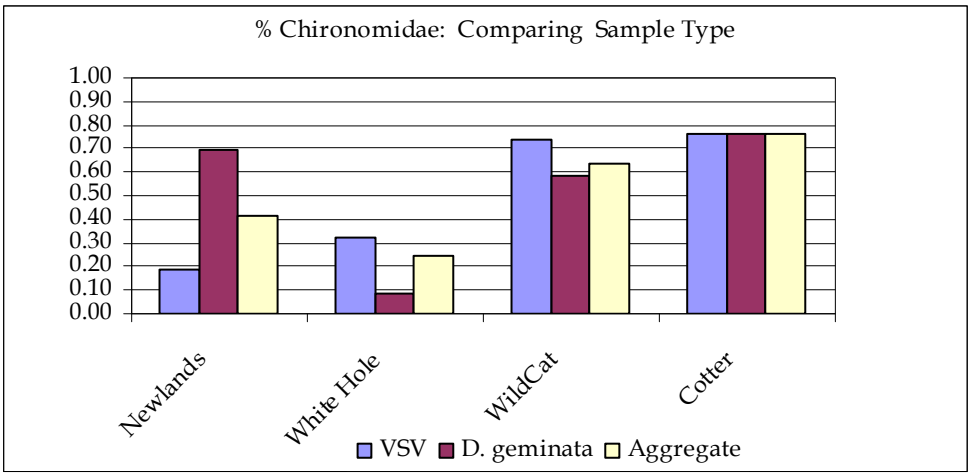
Graph 11



Graph 12

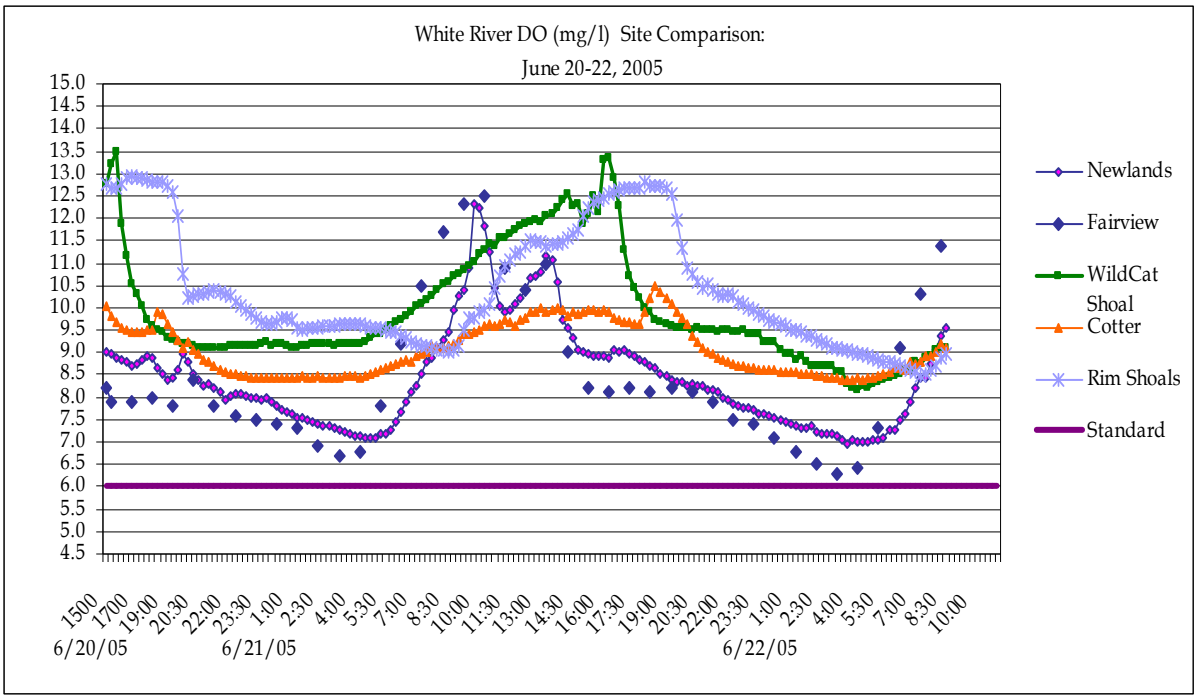


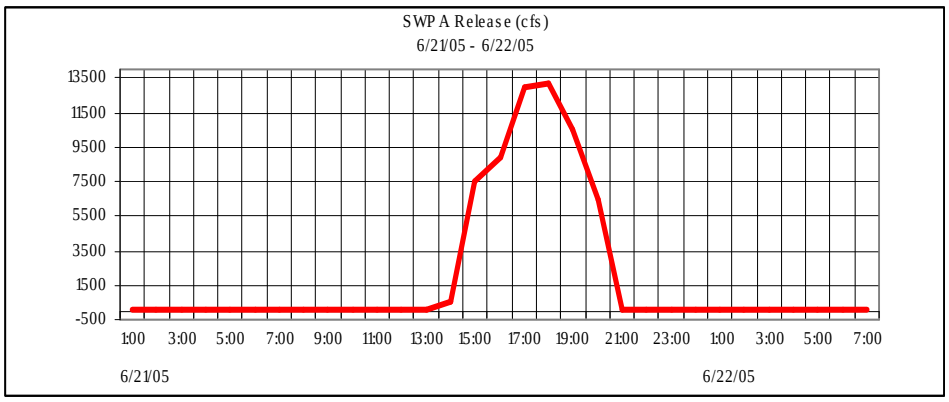
Graph 13


% Chironomidae: Comparing Sample Type
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Newlands
White Hole
WildCat
Cotter
VSV
D. geminata
Aggregate

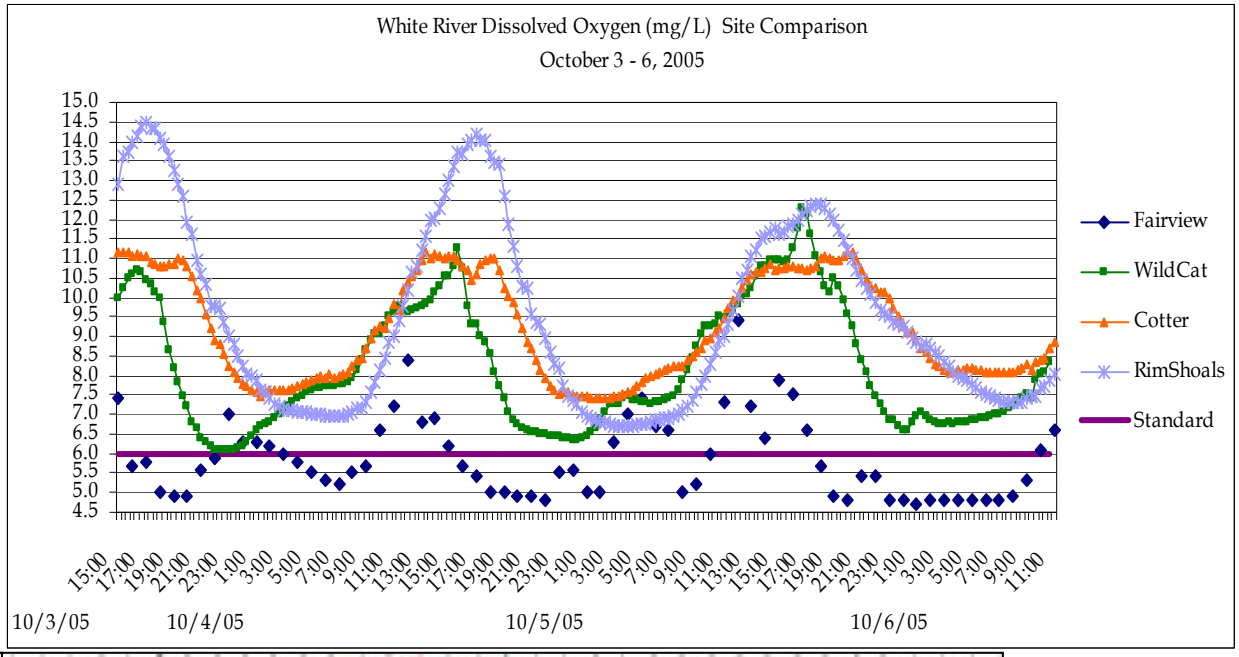
Graph 14

Graph 15 and 16 June 20-22, 2005 Dissolved Oxygen and Related Flow





Graph 17 and 18 October 3-6, 2005 Dissolved Oxygen and Related Flow



Appendix A

Appendix B

Table 1: Location of Sample Sites

Macroinvertebrate and/ or Sonde Sample Site Location	**Latitude**	**Longitude**
State Park / Jim Griffin Access	36.3551	-92.5947
Riverside RV Park	36.3435	-92.5833
Newland's Trout Dock	36.3452	-92.5855
Gaston's Resort	36.3486	-92.5528
White Hole	36.3297	-92.5343
Cotter	36.2703	-92.5400
Rim Shoals	36.2550	-92.4750
WildCat	36.3200	-92.5700

Water Quality Sample Site Location	**Latitude**	**Longitude**
WHI0048C	36.2433	-92.5461
WHI0047	36.3663	-92.5790
Riverside RV Park	36.3435	-92.5833
State Park / Jim Griffin Access	36.3551	-92.5947
White Hole	36.3297	-92.5343
River Cliff	36.3626	-92.5895

Table 2: Estimated density of D. geminata

Dry Weight	**Est. stream width**	**Weight per linear mile**
81 grams per square foot	300 ft	283,000 pounds dry weight per linear mile

Table3: in-situ water quality data for macro sites

SWP generators off during sample period (Sites in grey were not used as macroinvertebrate sample locations)

	Newland's (Aggregate)	**Riverside RV Park**	**White Hole (SAV)**	**White Hole (D. geminate)**	**WildCat Shoals (Aggregate)**	**Cotter**	**Rim Shoals**
Date	**14-Jun-05**	15-Jun-05	**14-Jun-05**	**15-Jun-05**	**14-Jun-05**	**15-Jun-05**	15-Jun-05
Time	1330	0850	1530	1210	1645	1722	1530
D.O (mg/L)	10.2	9.18	12.05	13	13.4	11.3	13.08
D.O (% sat)	98.6%	84.0%	111.1%	128.0%	130.6%	113.3%	134.0%
water temp (C')	13.8	11.5	12	12	14.2	15.1	14.7
pH	7.37	7	7.93	7.7	7.93	7.94	8.23
% canopy	0	0	0	0	0	0	0

Table 4: Water Quality Data (During 6/1/05, 6/7/05, 7/5/05)

SampleID	WHI0048C	WHI0047	RV PARK	GRIFFIN	WHITE HOLE	RIVER CLIFF
Date	6/7/2005	7/5/2005	6/1/2005	6/1/2005	6/1/2005	6/1/2005
Time			13:25	14:00	10:30	11:20
BOD5	3.30	0.37				
Alkalinity	140	125				
Aluminum		BDL	<127	<127	<127	<127
NH-4	BDL	BDL	*0.025*	*0.025*	*0.025*	*0.025*
Arsenic		0.59	0.59	0.56	*0.5*	0.56
Barium		29.3	27	27.7	29.3	25.2
Boron		12.7	9.28	10.6	11.4	8.33
Bromide	0.04	0.22	0.2	0.21	0.2	0.21
Cadmium		BDL	*0.07*	0.15	*0.07*	*0.07*
Calcium		38.3	36.3	35.8	37.8	34
Chloride	7.02	6.84	6.6	6.75	6.75	6.75
Chromium		BDL	*0.2*	*0.2*	*0.2*	*0.2*
Cobalt		BDL	*0.25*	*0.25*	*0.25*	*0.25*
Copper		3.62	*0.25*	6.84	*0.25*	0.77
Dissolved oxygen	8.12	9.12				
Field pH	8.17	7.98				
Fluoride	0.12	0.09	0.09	0.09	0.09	0.09
Hardness		140	134	132	143	127
Iron		BDL	*7.5*	*7.5*	*7.5*	*7.5*
Lead		0.28	*0.2*	0.45	*0.2*	*0.2*
Magnesium		10.7	10.7	10.3	11.9	10.2
Manganese		5.34	2.43	0.59	3.01	0.88
Nickel		0.85	*1.00*	2.02	*1.00*	*1.00*
Nitrite+Nitrate-N	BDL	0.410	0.257	0.348	0.361	0.287
O-phos	0.010	0.012	0.019	0.017	0.013	0.014
Potassium		2.26	1.73	1.94	1.82	1.75
Silicon Dioxide		2.93				
Sodium		4.55	3.85	4.11	3.92	3.87
Sulfate	3.88	7.32	7.2	7.44	7.07	7.73
TDS	189	158	149	146	159	155
TKN	0.832	0.244	0.208	0.22	0.269	0.279
TOC	5.61	2.40	2.39	2.44	2.43	2.66
T-Phos	0.079	BDL	0.026	0.021	0.03	0.03
TSS	3.8	BDL	*0.5*	*0.5*	*0.5*	*0.5*
Turbidity	5.60	2.64				
Vanadium		0.83	*0.5*	*0.5*	*0.5*	0.51
Water temp	31.0	12.0				
Zinc		12.1	1.39	4.49	1.99	1.06

Table 5 : Macroinvertebrate Results

Site name	Expected	Newlands (VSV)	Newlands (D. geminata)	Newlands Aggregate	White Hole (VSV)	White Hole (D. geminata)	White Hole Aggregate	WildCat (VSV)	WildCat (D.geminata)	WildCat Aggregate	Cotter (VSV)
Total Taxa	decrease	673	544	609	5432	2808	4170	4808	9832	7320	6480
Shannon Weaver	increase	1.84	0.99		1.48	1.43		0.87	0.98		0.75
Simpsons Index:	decrease	0.23	0.52	0.28	0.29	0.29	0.23	0.58	0.46	0.47	0.61
Total Taxa Richness	decrease	10	5	10	10	8	10	9	9	10	10
No. Total EPT	decrease	89	0	45	184	48	116	1080	200	640	32
No. of Plecoptera	decrease	1	0	1	0	0	1	8	0	4	0
No. of Trichoptera	decrease	88	0	44	184	48	116	1072	200	636	32
% EPT	decrease	13.22%	0.00%	7.39%	3.39%	1.71%	2.78%	22.46%	2.03%	8.74%	0.49%
% Chironomidae	increase	19.02%	69.12%	41.38%	32.40%	8.83%	24.47%	73.54%	58.67%	63.55%	76.05%
% CG	either	77.27%	92.65%	84.07%	95.29%	55.84%	82.01%	77.37%	95.36%	89.45%	98.40%
% SC	decrease	1.19%	0.00%	0.66%	0.00%	0.00%	0.00%	0.00%	0.24%	0.16%	0.00%
% CF	increase	3.57%	0.00%	1.97%	1.62%	1.71%	1.65%	18.30%	1.87%	7.27%	0.12%
% Crawler:	decrease	30.91%	10.29%	21.67%	14.58%	62.39%	30.68%	4.33%	4.07%	4.15%	4.44%
% Burrowers:	increase	20.21%	69.12%	42.04%	34.32%	9.12%	25.83%	73.54%	58.91%	63.72%	76.30%
% Herpobenthos	increase	26.15%	70.59%	45.98%	73.78%	33.62%	60.26%	74.71%	59.89%	64.75%	77.04%
% Haptobenthos	decrease	34.47%	10.29%	23.65%	15.61%	63.82%	31.84%	22.63%	5.94%	11.42%	4.57%
Hilsenhoff (HBI)	increase	6.77	7.60	7.14	7.49	6.63	7.20	6.60	7.45	7.17	7.71
Hilsenhoff (HBI		fairly poor	poor	fairly poor	fairly poor	fair	fair	fairly poor	fairly poor	fairly poor	poor
% Tolerant	increase	26.15%	70.59%	45.98%	72.46%	33.62%	59.38%	74.54%	59.89%	64.70%	76.543%
% Intolerant	decrease	2.38%	0.00%	1.31%	1.03%	1.42%	1.16%	18.30%	1.87%	7.27%	0.123%
% Facultative		71.47%	29.41%	52.63%	26.51%	64.96%	39.46%	7.15%	38.24%	28.03%	23.333%
Dominant Taxa #1		Gastropoda	Chironomidae	Chironomidae	Asellidae	Hydracarina	Chironomidae	Chironomidae	Chironomidae	Chironomidae	Chironomidae
% Dominant taxa #	**1**increase	39.23%	69.12%	41.38%	39.47%	42.17%	24.47%	73.54%	58.67%	63.55%	76.05%
Dominant Taxa #2		Chironomidae	Gastropoda	Gastropoda	Chironomidae	Asellidae	Gastropoda	Brachycentrus	Gastropoda	Gastropoda	Gastropoda
% Dominant taxa #2	increase	19.02%	19.12%	30.21%	32.40%	24.50%	7.80%	18.30%	34.17%	23.77%	18.15%

Table 6: Macroinvertebrate Descriptions

Order	Family	Common Name	Tolerance		Functional Group		Habit	Habitat Preference	Food
Diptera	Chironimidae	Midge -Fly larvae	Facultative	Collector /Gatherer	Burrower	construct and attachsilt- tube case to solid object such as plant, twig, rock, logs, etc.			organic components of fine sediment
Trichoptera	Genus:Brachycentrus	Log-Cabin casebuilding Caddisfly	Intolerant	Collector/ Filterer	Clinger	Vegetation, Bedrock or cobble; creates a case which adheres to substrate facing flow to grasp fod particles			Floating organic material
Trichoptera	Hydroptilidae	Purse casemaking Caddisfly	Facultative	Macrophyte - Piercer	Crawler	Submerged aquatic plants, filamentous algae			algae; pierce filamentous algae cells and consume fluids
Trichoptera	Glossomatidae	Saddleback casemaking Caddisfly	Intolerant	Scraper	Clinger	stable stones			scrape algae from rocks; fine detritus material
Isopoda	Asellidae	Aquatic Sow bug	Tolerant	Collector /Gatherer	Sprawler	general; lotic			plant and animal matter; graze on algae; scavengers
Amphipoda	Gammaridae	Scud	Facultative	Collector /Gatherer	Crawler	general; lotic			plant and animal matter; graze on algae; scavengers
Gastropoda	Planorbidae	Ram's horn snail	Facultative	Collector /Gatherer	Sprawler	general			general
Gastropoda	(Physidae / Viviparidae	Aquatic snail	Facultative	Scraper; collector- gatherer	GN	general			general
Coleoptera	Elmidae (Adult)	Riffle beetle	Facultative	Scraper; collector- gatherer	Clinger	cobble, gravel			periphyton, detritus
Bivalvia	Spaeridae	Fingernail clam	Tolerant	Collector/ Filterer	Burrower	fine silt, sand, clay			
Arachnida	Hydracarina	Aquatic mite	Facultative	Predator	Crawler	silt, sand			pierce aquatic insects especially the larvae of true flies and micro crustaceans
Plecoptera	unknown (Adult)	Stonefly	Facultative	*	*	*			*
Decapoda	Cambaridae	Crayfish	Facultative	Generalist	GN	rock, cobble, plants, detritus			general
Oligochaeta	Annelida	Aquatic earthworm	Facultative	Colector/ Gatherer	Burrower	plants, silt, sand, detritus			bacteria, protozoa, detritus, algae

Translators:

Tolerance Value	Category
0-2	Sensitive
3-7	Facultative
8-10	Tolerant

Function Group	
PR	Predator
CG	Collector-gatherer
CF	Collector-filterer
GN	Generalist
SH	Shredder
SC	Scraper
MP	Macrophyte-piercer

Habit	
CL	Clinger
SP	Sprawler
BU	Burrower
SW	Swimmer
CR	Crawler
CG	Clinger

Appendix C

Map of White River Sampling Locations

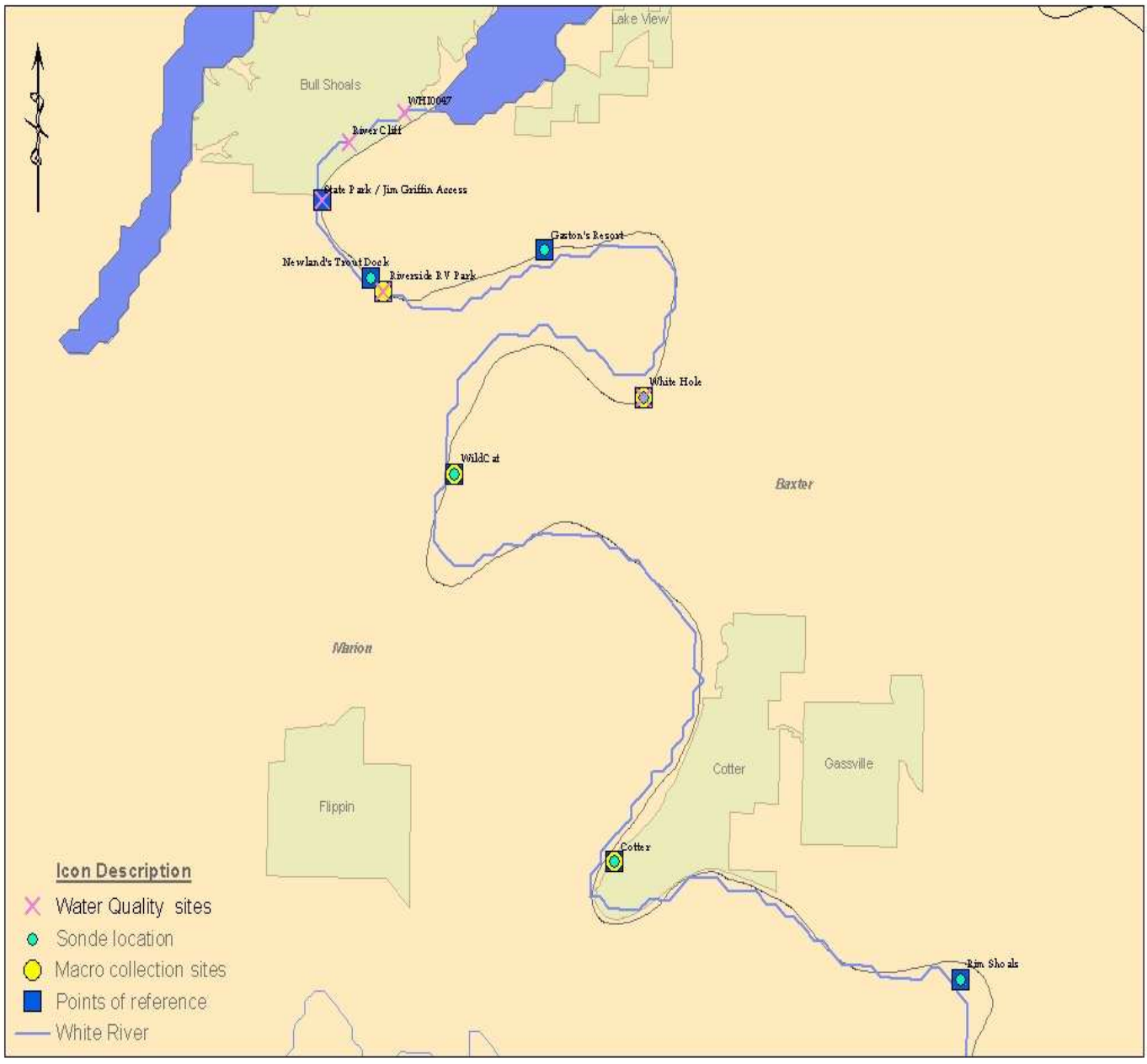


Photo 1 : Newland's Pool - D. geminata sample area

Photo 2 : Newland's Pool - D. geminata on large cobble

Photo 3 : Newland's Pool – showing river width and dense D. geminata mats

Photo 4 : Newland's Pool - D. geminata sample area; showing dense mats

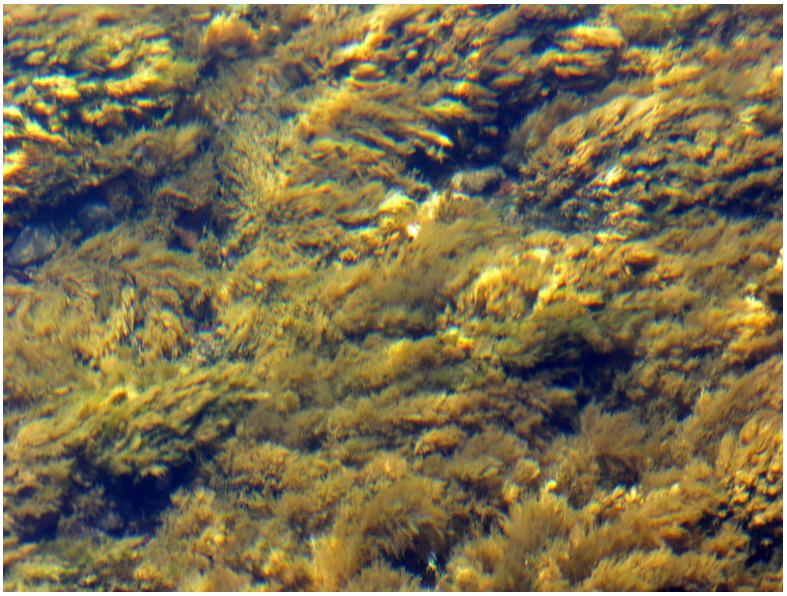


Photo 5 : Newland's Pool - SAV sample area; colonizing D. geminate growing on SAV (mostly native algae)

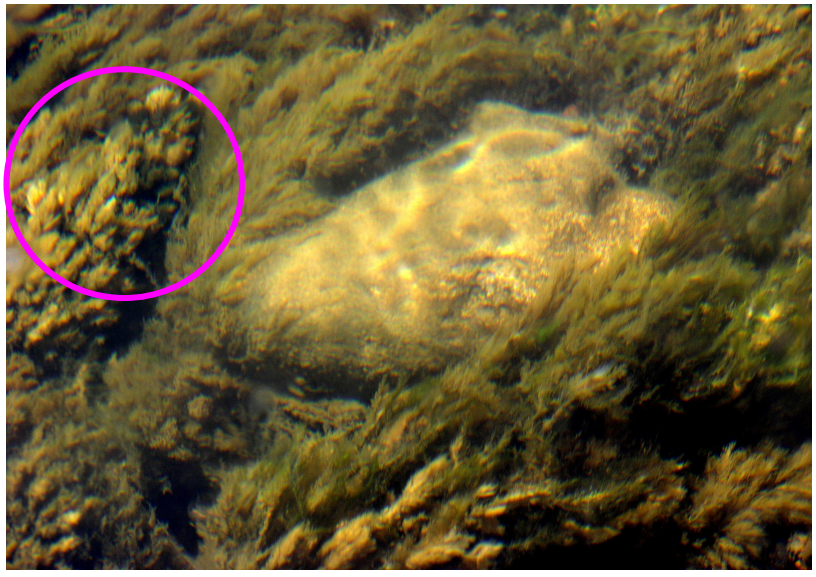


Photo 6 : Newland's Pool – newly colonizing D. geminata; surrounding substrate and SAV

Photo 7 : White Hole - D. geminata debris attached to dock support

Picture 8 : White Hole - D. geminata debris attached to dock support

Photo 9: White Hole - SAV sample area

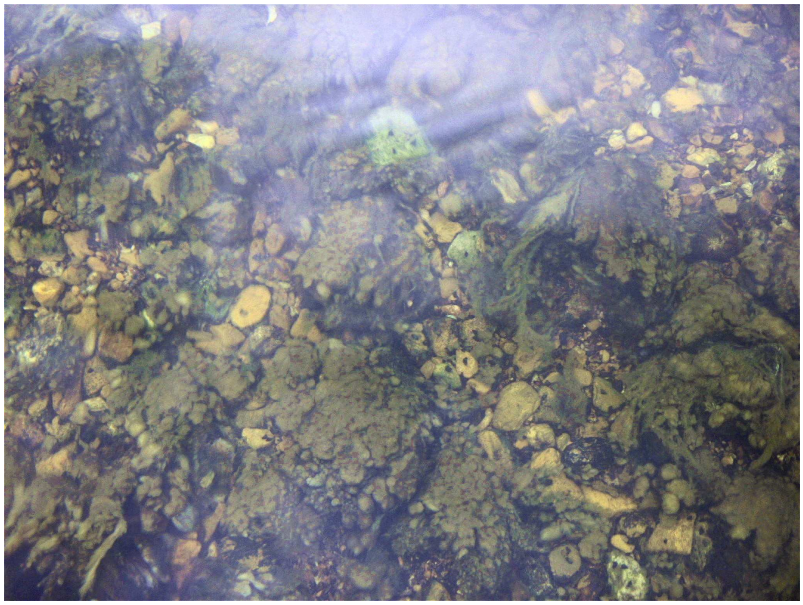
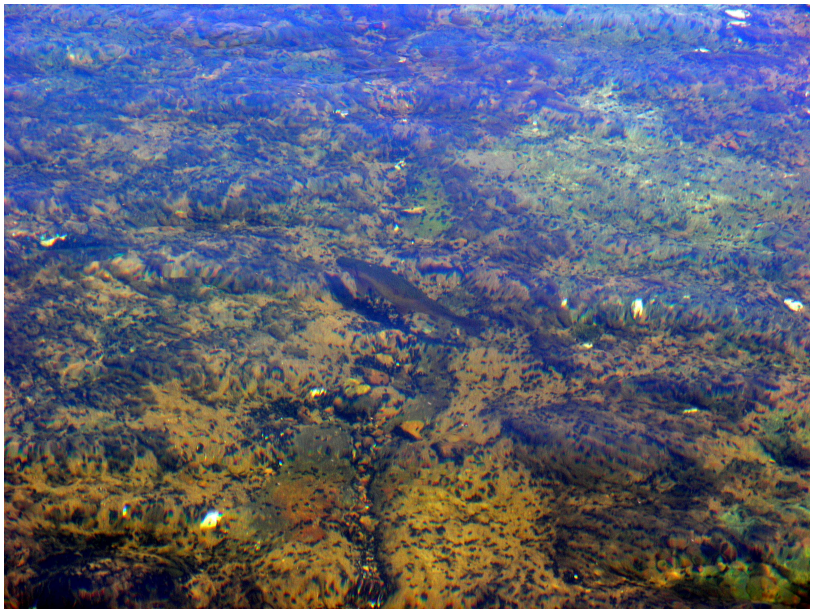


Photo 10 : White Hole - D. geminata sample area

Picture 11: White Hole – Hydracarina (water mites); found in high densities within the SAV sample

Photo 12 : Wild Cat Shoals – D.geminata sample area; newly colonizing D. geminate and high density of Gastropoda and Brachycentrus



Picture 13: Wild Cat Shoals - SAV sample area; showing high density of Gastropoda and Brachycentrus

Photo 14 : WildCat Shoals: showing "picked" sample; high density of Gastropods and Brachycentrus (highlighted in top left corner)

Photo 15 : WildCat Shoals: showing high density of Chironomidae after sample was "picked"

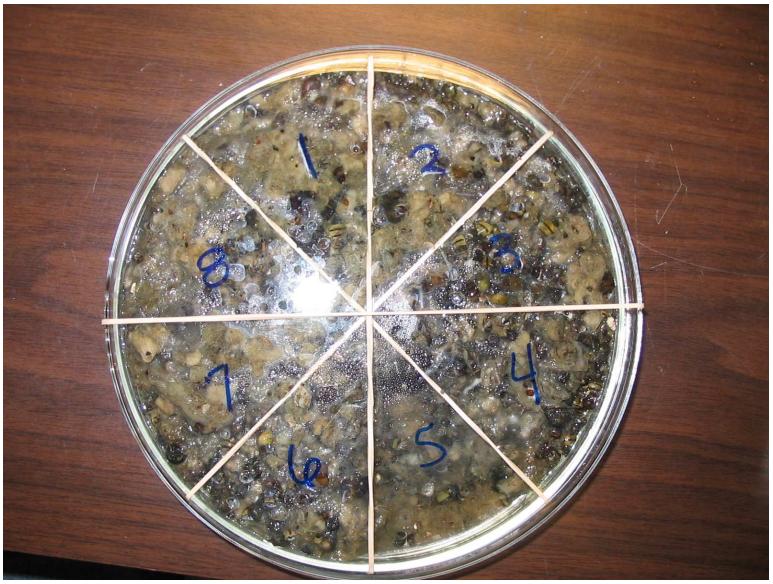
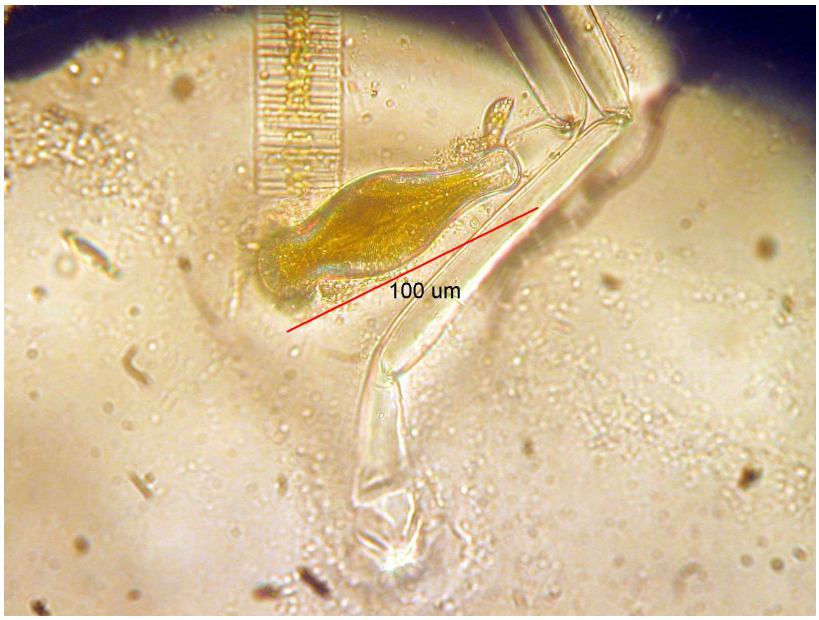


Photo 16 : WildCat Shoals: showing subsample method used due to extremely high numbers of organisms

Photo 17 : Cotter – showing D. geminata debris after a high flow event



Picture 18 : Microscopic view of D. geminata diatom; scaled

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