ALGAL SUCCESSION IN THE TRINITY RIVER UNDER SUMMER AND AUTUMN EFFLUENT DOMINATED CONDITIONS

Prepared by the Trinity River Authority of Texas in cooperation with the Texas Commission on Environmental Quality with the Assistance of Dr. James Grover, University of Texas at Arlington.

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TABLE OF CONTENTS

TABLES

FIGURES

APENDICES

INTRODUCTION

The Trinity River runs through Central Texas from its origins of four forks near the Red River and the Oklahoma State Line to Trinity Bay where it empties into the Gulf of Mexico. Annual rainfall in the upper portions of the basin averages around 33 inches, most of which occurs in a relatively few number of storm events with little or no precipitation during summer months. These climatic conditions have established a seasonal pattern of summertime low flows over much of the basin.

Located at the junction of three of the river's four forks is the Dallas-Fort Worth metropolitan area, with a population of approximately five and a half million. Cumulative wastewater discharges into the river from the Dallas-Fort Worth area averages approximately 450 million gallons per day. During periods of low flows, which typically occur during the summer but can occur at any time of the year, the river is effluent dominated. Under such conditions nutrient concentrations within the river are significantly elevated over background conditions.

Although conventional wisdom holds that algal abundance is directly related to nutrient concentrations, recent observations suggest that algal populations are smaller immediately downstream of wastewater treatment plants despite the corresponding rise in nutrient concentrations. There are several intuitive and satisfactory explanations for this phenomenon. First, the influx of wastewater, which in most cases is devoid of algae, provides an immediate dilution effect. This effect in some cases is dramatic, representing a many-fold dilution. Another explanation is that the surface to volume ratio decreases as more water is added. This often limits the photic zone to the top of the water column, severely limiting the amount of light available for algae to use. In this scenario, light and not nutrients is limiting.

Little is known however, of what happens as the water progresses downstream. If the dilution effect is the only cause for decreases in algal concentrations, then the community should rebound and, taking advantage of the abundant nutrients downstream from the municipal point source, increase respective to their upstream concentrations. If on the other hand physio-morpholocigal factors are limiting their growth, then a rebound of the algae found upstream is not likely. Should algal populations rebound, the question then becomes one of looking at spatial changes in algal community structures, or algal succession.

"Succession" and "periodicity" are major themes in the ecological study of algal communities (Reynolds 1984). The term succession refers to changes over time, or in this case distance, in the abundance of populations in different taxonomic groups, while the term periodicity highlights that these changes are often reproducible over annual seasonal cycles. Algal succession is particularly well studied in natural lakes of the temperate zone (Sommer et al. 1986), where the algal biota is often dominated by small flagellated organisms in winter, giving way to a bloom of fast-growing diatoms in spring, a clear-water phase of low algal density in late spring, with subsequent development of diverse populations depending in part on lake trophic status. Eutrophic lakes often experience dominance by large colonial cyanobacteria, often mixed with large dinoflagellates, while oligotrophic lakes maintain a diverse summer community of many algal types. Autumn can bring dominance by diatoms or cyanobacteria, giving way to the winter flora of small flagellates. In general, such seasonal patterns are forced by events that affect light and nutrient supply, such as thermal stratification and destratification, and by activities of zooplankton grazers and the fish that prey on them.

Reservoirs (i.e. manmade impoundments) have occasionally been studied. At least superficially, they appear to have successional patterns that resemble those of natural lakes (Figures 1 and 2), although the driving mechanisms are not as well supported. Much less is known about algal succession in flowing-water systems; rivers are especially poorly studied, despite the development of substantial planktonic algae in many mainstem, large-channel rivers (Reynolds 1990). One of the few studies available, that of the River Seine in France (Garnier et al. 1995), shows a clear succession from diatoms early in the growing season to green algae later. Shifts in nutrient supply, namely a seasonal reduction in silicon supply relative to nitrogen and phosphorus, were suggested as one factor underlying this succession.

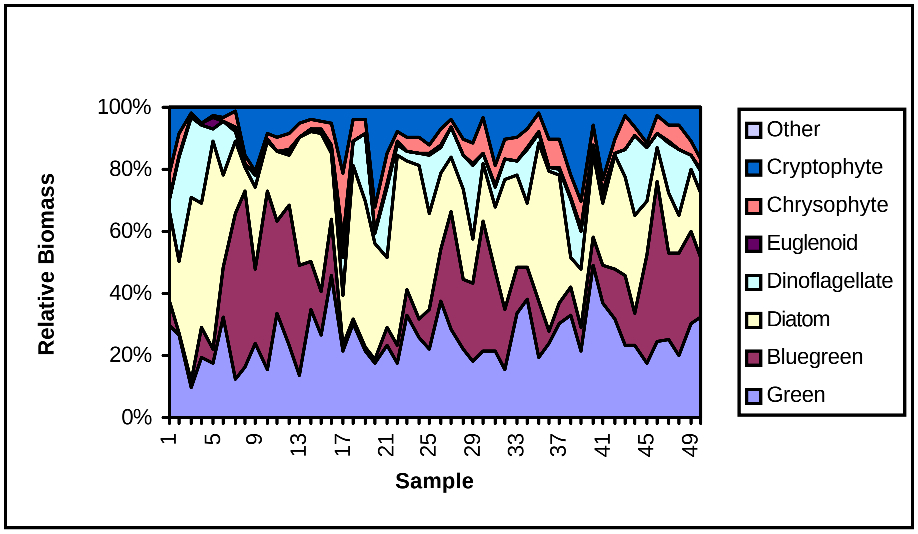

Figure 1. Algal succession in Eagle Mountain Lake, a Trinity basin reservoir. Samples were collected from March 1998 to October 2000 (Grover and Chrzanowski, unpubl.). There are concerns that Eagle Mountain Reservoir may have unhealthy concentrations of algae.

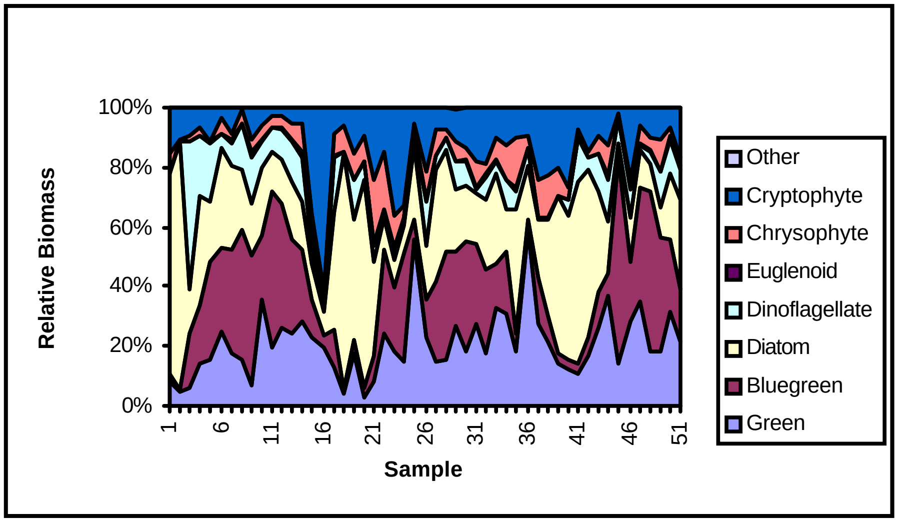

Figure 2. Algal succession in Joe Pool Lake, a Trinity basin reservoir. Samples were collected from March 1998 to October 2000 (Grover and Chrzanowski, unpubl.). Joe Pool Lake has been identified by the TCEQ as having one of the most limited algal populations, as measured by concentrations of chlorophyll a, in the State relative to other Texas reservoirs.

Such major shifts in algal composition in a river could have implications for its possible uses. Diatoms (and some groups of flagellated algae) are generally an excellent food source for benthic and suspended filter feeding animals. Gelatinous coatings that reduce digestibility protect many species of green algae, making them poorer food. Should a river become dominated by cyanobacteria, its capacity to support a food web should be even lower, due to the generally poor digestibility and frequent toxicity of these algae.

Because relative supplies of nitrogen, phosphorus and silicon could influence succession among different algal types in rivers, wastewater discharges could alter or induce algal succession. Wastewater typically supplies little silicon, while supplying abundant nitrogen and phosphorus at a relatively low N:P ratio. By itself, this nutrient spectrum could be expected to stimulate dominance by cyanobacteria (Smith 1983), possibly leading to impaired uses downstream.

The study herein detailed was undertaken to provide some initial understanding of spatial algal succession in the Trinity River and a preliminary assessment of possible wastewater influences.

MATERIALS AND METHODS

A series of nineteen sampling sites were selected from the Beach Street bridge over the West Fork of the Trinity in Tarrant County to the HWY 7 bridge over the Main Stem near the city of Crockett in Houston County (figure 3). Sites were selected to provide samples from the river representing a progression of effluent dominance. The uppermost site was located above all major point sources. Successive sites downstream included one or more sample sites between each major point source through the Dallas-Fort Worth area. Additional samples were included to provide information on how water chemistry and algal communities change in a downstream fashion below Dallas and additional significant point-source inputs.

An additional site was included on the East Fork of the Trinity. This site differs from the others in that it is not on the Main Stem and therefore is not in series with them. The site was included to provide information on water chemistry and algal community composition in the East Fork, which empties into the Main Stem below Dallas.

The study was undertaken in two phases, both of which were conducted under low flow conditions during the summer and autumn of 2002.

Phase one consisted of a single sample event at each site. The results of this sampling indicated two reaches along the main-stem of the river which experience significant changes in algal community structure. Phase two sampling targeted these two reaches as well as the East Fork site. During the second phase, three sample runs were conducted at each of these reaches. Each of the main-stem reaches including three sites. Table 1 contains a complete list of the sample sites along with ancillary information, including the dates and phases during which each was sampled.

At each site, during both phases, water samples were collected and analyzed for conventional water chemistry parameters (table 2). All samples were collected just below the waters surface and were analyzed by the TRA CRWS laboratory. 100 ml samples for algae identification and enumeration were also collected. Upon collection, these samples were preserved with formalin-Lugol's solution, and delivered to Dr. James Grover at the University of Texas at Arlington. An attempt to measure irradiance was also made at each site, however this proved impractical since most samples were collected from high bridges, leading to significant complications from strong winds and swift river currents. Ultimately, irradiance measures were deemed to be of little use.

The inverted microscope method was utilized to identify and enumerate algae (Margalef 1969). This method involves placing an aliquot of defined volume from the algal sample in a sedimentation chamber so that cells and colonies sink to the bottom, which consists of a thin glass plate that can be viewed with an inverted microscope.

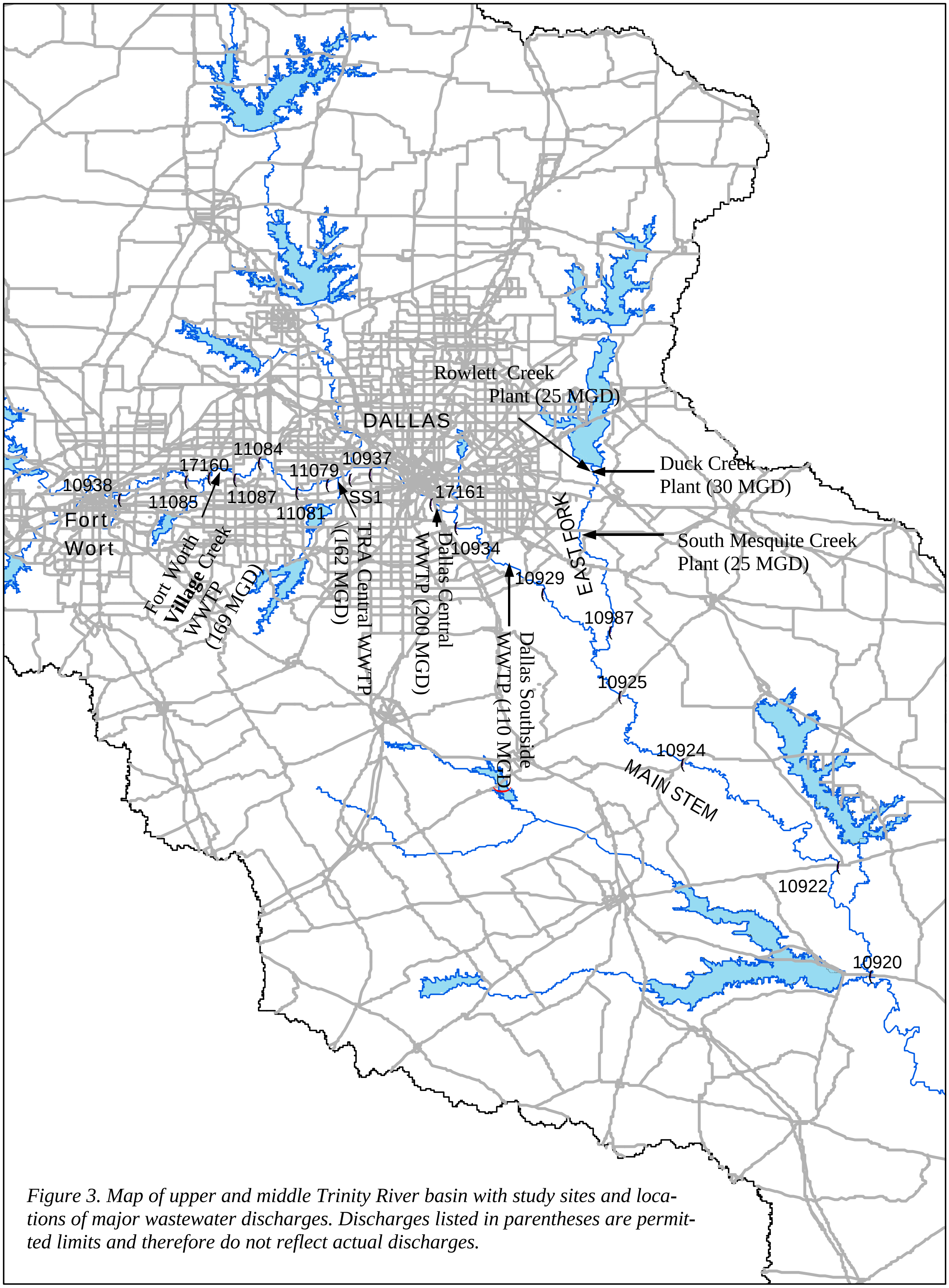

Figure 3. Map of upper and middle Trinity River basin with study sites and locations of major wastewater discharges. Discharges listed in parentheses are permitted limits and therefore do not reflect actual discharges.

Table 2. Study Sites, Phases, Distances, Travel Times, Dates Sampled and Hydrologic Order

SITE DESCRIPTION	SITE ID	PHASES SAMPLED	CUMULATIVE DISTANCE (mi)	CUMULATIVE TRAVEL TIME (hrs—estimated)	DATES SAMPLED	HYDO ORDER
Immediately Below Beach Street Impoundment on West Fork in Fort Worth	10938	I	0	0	7/29/02	1
Precinct Line Road	11085	I	12	180	7/29/02	2
Bedford Arlington Road	17160	I and II	15.1	236	7/29/02 9/5/02 9/26/02 10/1/02	3
FM 157	11087	I	19.5	242.5	7/29/02	4
HWY 360	11084	I and II	24.5	251.1	7/29/02 9/5/02 9/26/02 10/1/02	5
Belt Line Road	11081	I	31	260.6	7/29/02	6
Immediately upstream of TRA Central WWTP Outfall	11079	I and II	36.75	267.3	7/29/02 9/5/02 9/26/02 10/1/02	7
Main Stem below Singleton BLVD at location of Old Singleton Road bridge	SS1	I	38.25	269.3	7/29/02	8
Mockingbird	10937	I	41.25	273.3	7/29/02	9
Immediately upstream of Dallas Central WWTP Outfall	17161	I	50.25	285.3	7/29/02	10
South Loop 12	10934	I	54.5	289.6	7/3002	11
Malloy Bridge	10929	I and II	71.5	311.6	7/30/02 9/5/02 9/26/02 10/1/02	12
HWY 34 near Rosser	10925	I and II	93.5	340.6	7/30/02 9/5/02 9/26/02 10/1/02	13
HWY 85	10924	I	112.5	371	7/3002	14
HWY 31 near Trinidad	10922	I and II	152.1	427.1	7/3002 9/5/02 9/26/02 10/1/02	15
HWY 287 near Cayuga	10920	I	170.1	455.1	7/3002	16
HWY 79 near Oakwood	10919	I	229.6	538.6	7/3002	17
HWY 7	10918	I	276.6	607.5	7/3002	18
East Fork at Valley Ranch	10987	I and II	NA	NA	7/31/02	NA

Fields or transects of known area on the bottom plate are then examined, with all algal specimens identified and enumerated. In this method, the volume of aliquot thus sedimented is adjusted based on total density of algae. Experience in Texas reservoirs suggested that 20 ml represented a reasonable volume for initial counts, and this volume was thus utilized.

Table 2. Water quality variables analyzed.

PARAMETER	UNITS
Dissolved Oxygen	mg/L
pH	Standard Units
Water Temperature	Degrees C
Air Temperature	Degrees C
Specific Conductivity	Micro siemen
NO2/NO3	mg/L
TKN	mg/L
NH3	mg/L
OP-O4	mg/L
NO3	mg/L
Total Phosphorus	mg/L
Chlorophyll a	ug/L
E. coli	MPN
Total Suspended Solids	mg/L

For this study, the “natural units” method was followed, meaning that an individual unit of algae was the cell for unicellular organisms and the colony for colonial organisms. Count data were entered into Excel spreadsheets for conversion to volumetric density, and for data summary and statistical analysis.

A complete identification to species level was not attempted. Instead, coarse categories based on higher taxonomy (algal divisions), size, and morphology were enumerated. This resolution was sufficient to detect major successional changes in algae.

Because the algal units counted cover a very wide range of size, counts at three magnifications was necessary. At each magnification, sufficient fields or transects were examined to count 200-400 units in the dominant category.

RESULTS

Water Quality Variables

Examination of the measured water quality parameters indicates a strong, incremental influence on certain variables by the four major wastewater dischargers. This phenomenon is clearly displayed in figures 5 and 8, which show concentrations of the dissolved nutrients otrhophosphate and nitrate plus nitrite. Concentrations of these parameter increase dramatically after each input of reclaimed water and then slowly decrease before the next point source. Although not shown, total phoshporus followed a similar pattern.

Concentrations of chlorophyll a steadily increased downstream, peaking at Highway 287 near Cayuga before dropping sharply. An exception to this trend was seen at the two uppermost sites, 17160 and 11084. These sites, sampled only during phase one in July of 2002, had relatively high concentrations of chlorophyll a and by extension algae.

Total suspended solids showed a pattern of increasing concentrations downstream. Conversely to dissolve nutrients however, TSS concentrations were seen to decrease with each input of reclaimed water, and slowly increase with distance from the point source.

Dissolved oxygen concentrations, while highly variable at the FM 157 site, were otherwise fairly consistent, increasing slightly in a downstream manner. It should be noted however that samples further downstream were collected later in the day. It is

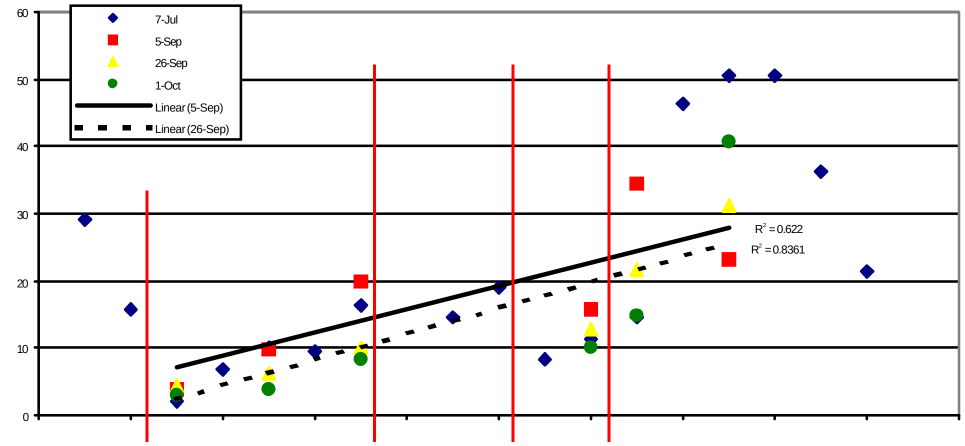

Figure 4. Chlorophyll a concentrations in the Main Stem.

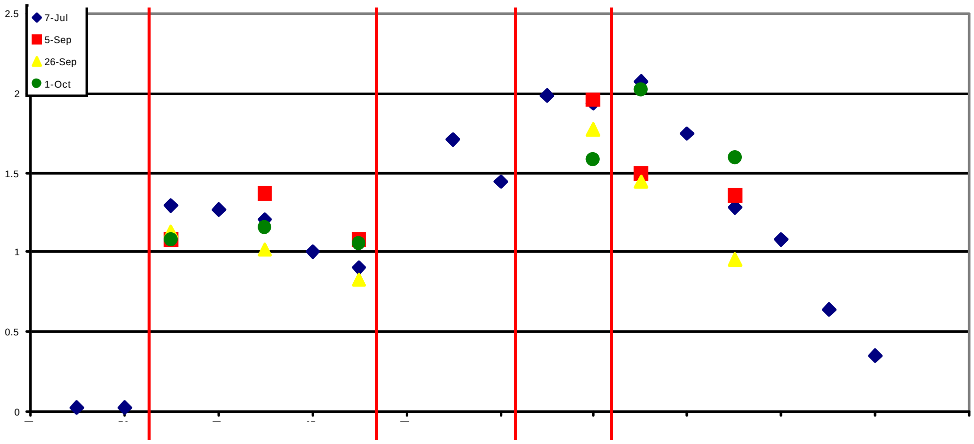

Figure 5. Orthophosphate concentrations in the Main Stem.

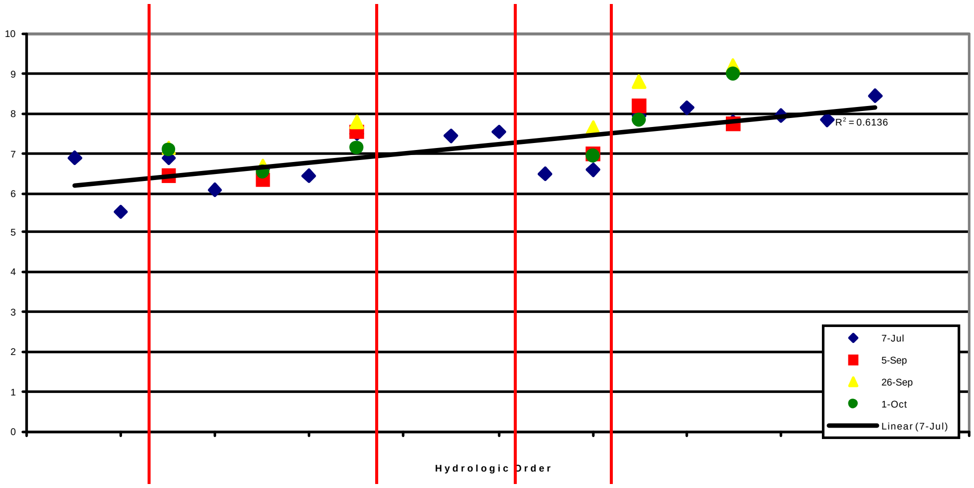

Figure 6. Dissolved oxygen concentrations in the Main Stem.

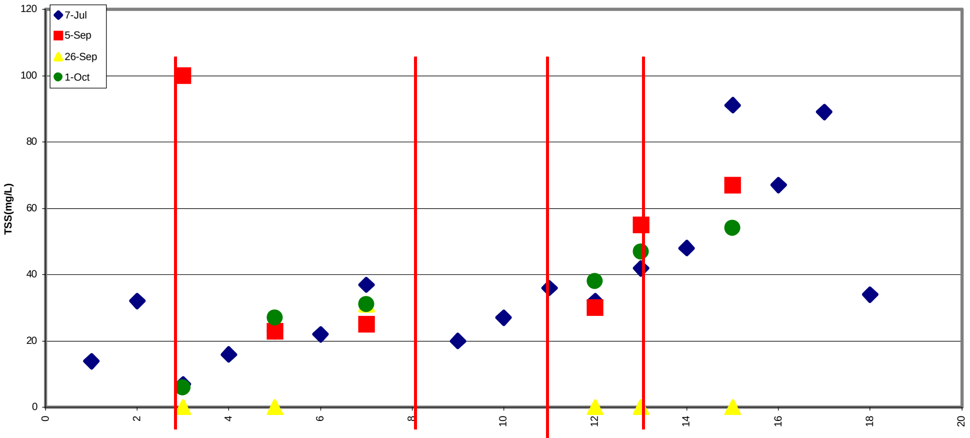

Figure 7. Total suspended sediment concentrations in the Main Stem.

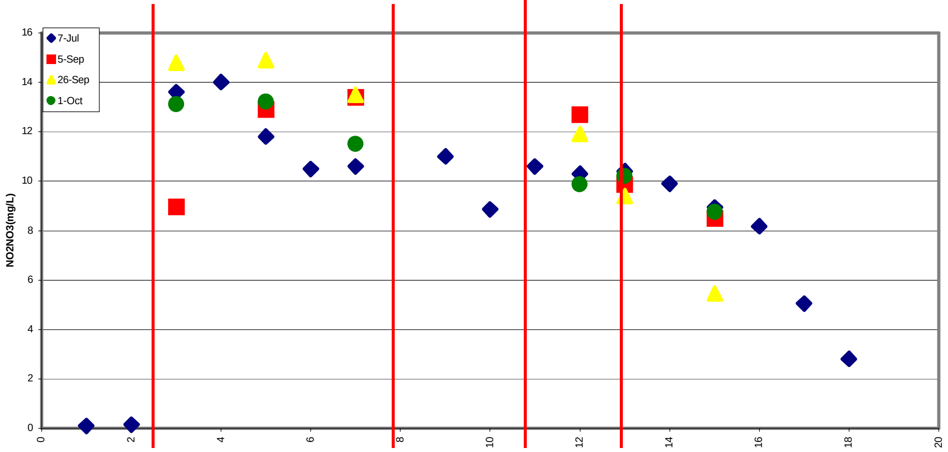

Figure 8. Nitrate plus nitrite concentrations in the Main Stem.

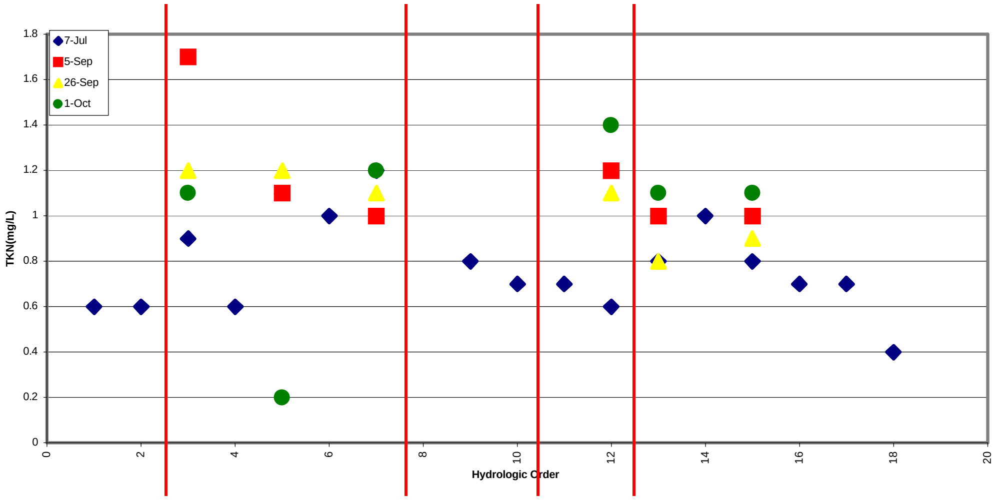

Figure 9. Total Kjeldahl nitrogen concentrations in the Main Stem.

therefore likely that the observed increase in dissolved oxygen concentrations is a function of sample times and corresponding levels of photosynthetic activities.

Analysis of East Fork data in terms of hydrologic order was not performed, as there was only one sample station in that reach. Like the Main Stem, the East Fork is effluent dominated, and demonstrated water quality characteristics consistent with this fact. Key variables are summarized in table 3.

Table 3. Average, minimum and maximum concentrations of key water quality variables at the East Fork site.

PARAMETER	AVERAGE CONCENTRATION	MINIMUM	MAXIMUM
Orthophosphate	2.6 (mg/L)	2.1	4.4
Nitrate/Nitrite	10.3 (mg/L)	9.0	11.8
TKN	1.0 (mg/L)	0.7	1.5
Chlorophyll a	30.6 (ug/L)	8.7	51.7
Dissolved Oxygen	10.2 (mg/L)	8.7	11.5
TSS	88.3 (mg/L)	65	103

Water quality variables from all sites were examined statistically to determine relationships between variables, including hydrologic order (figure 10)

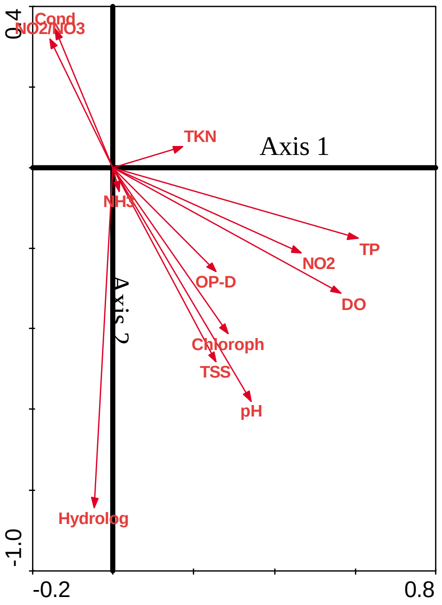

Figure 10. Relationships of quality variables and hydrologic order are shown in relation to two axes.

Algal Community Structure

Appendix A contains results of algae identification and enumeration. These data were analyzed by genera to determine potential relationships between water quality variables and presence of genera. Through this analysis of genera, several relationships were identified as seen in figure 11 and as described below:

A phylogenetically diverse group of genera were found to be associated with high TP, DO, & NO2. These genera included Aulacoseira, Chlamydomonas, Chlorogonium, Eudorina, Pandorina, Lagerheimia, Pediastrium, Cryptomonas, Rhodomonas, Euglena and Phacus.

Conversely, two genera of green algal, Ankistrodesmus and Crucigenia, were associated with lower concentrations of TP, DO, & NO2.

Genera associated with low hydrological order, high conductivity and high nitrite plus nitrate include the cyanobacteria Aphanocapsa, Cylindrospermum, “Oscillatoria”, Planktolyngbya, Raphidiopsis and Spirulina. Others genera found to be associated with lower hydrologic order were Dinobryon, Cymbella and Navicula. The latter two are pennate diatoms commonly living in benthic habitats. There association with low order is not surprising. It is also plausible that some of the filamentous cyanobacteria, including Oscillatoria and Planktolyngbya originate from benthic habitats, however most of the other genera in this group are believed to be considered planktonic.

Genera associated with high hydrological order, low conductivity, and low nitrite plus nitrate are mostly green algae common to reservoirs. These include Chlamydomonas, Chlorella, Coelastrum, Crucigenia, Oocystis and Selenastrum. Unicellular centric diatoms (Cyclotella, Stephanodiscus) also common in reservoirs, were likewise included in this group .

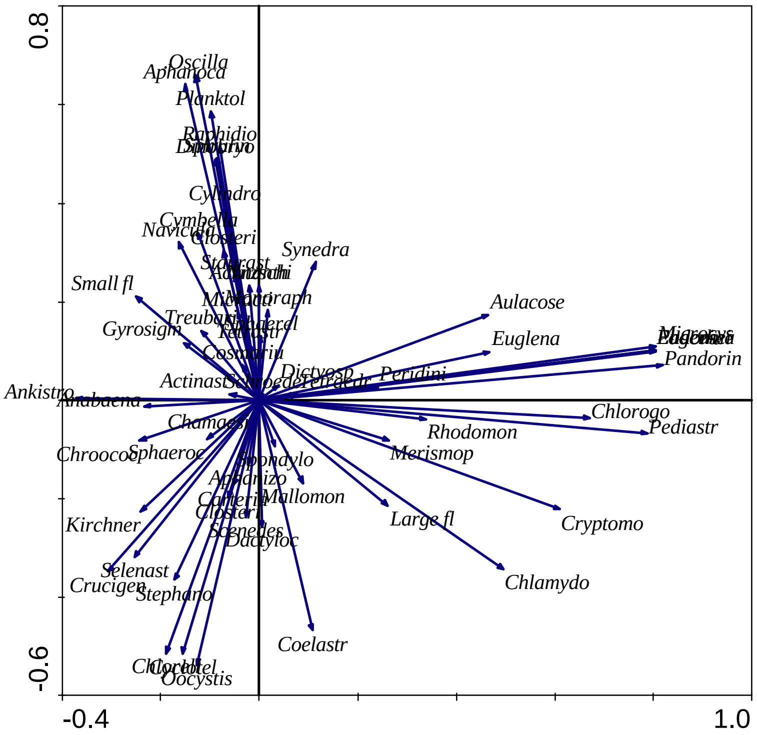

Figure 11. Algal genera relationships are shown in relation to axes. Figure 10 defines the relationship of the axes to the water quality variables. Axis one (horizontal) was found to be associated most closely with the parameter group of TP, DO and NO2. Axis two (vertical) is most closely associated with hydrologic order.

To summarize the patterns in algae, three potential assemblages were identified:

1. "High TP assemblage" consisting of diverse taxa associated with high TP.
2. "Blue-green & benthic assemblage" consisting of benthic pennate diatoms and cyanobacteria, associated with lower order reaches that tend to have higher nitrite and low conductivity.
3. "Reservoir assemblage" consisting of primarily green algae and diatoms that are also common in reservoirs and are associated with higher order reaches.

High TP Assemblage

The "high TP assemblage" characterizes only two samples, both of which were from the East Fork Valley Ranch site near Crandall, and both were collected in autumn. Thus the high TP assemblage was found only rarely. This assemblage appears to be problematic, and is highly influenced by a single sample. That sample had a concentration of 4.37mg/L which was the highest TP recorded during the course of the study by a factor of two.

Five genera were identified in five or fewer samples. For these, their relative abundance in the high TP sample was high, generating a strong correlation driven by a single influential point. Figure 12, a plot of Pandorina vs. TP illustrates this problem.

Six other genera, Pandorina, Chlorogonium, Eudorina, Lagerheimia, and Phacus, were included in the TP assemblage based on similar abundance patterns. Given the relative rarity of these genera, confidence in their identification as species associated with high TP conditions is low.

The remaining genera associated with high TP concentrations occur in 16 to 37 samples, however their association with TP is weak (correlations from -0.02 to 0.43), and again is a result of the single high TP sample. Figure 13 is a plot of Pediastrum, which had

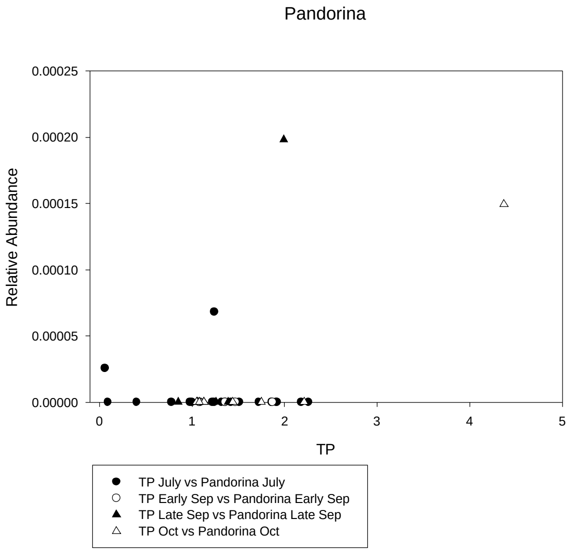

Figure 12. Pandorina abundance vs. TP concentrations.

the strongest correlation to TP (0.43). The remaining genera in the high TP assemblage have similar patterns, in that they reach a fairly high relative abundance in the high TP sample, but have no obvious relationship with TP in the remaining samples.

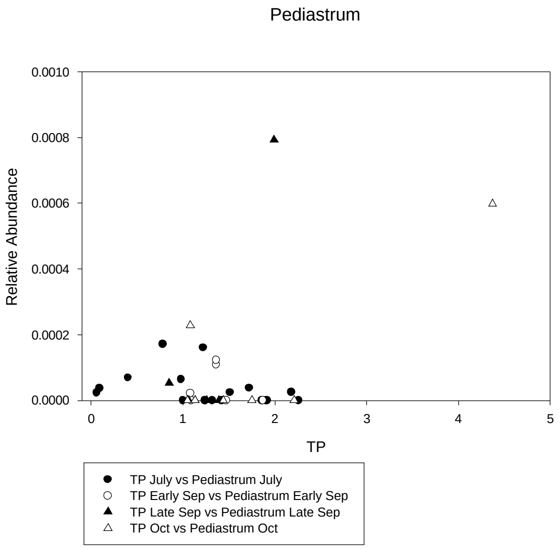

Figure 13. Pediastrum abundance vs. TP concentrations.

Additional statistical analyses were then performed, focusing on inter-species correlations (i.e. group analysis). Figure 14 shows the results of this analysis using a vector graph.

The group analysis again suggested a high TP assemblage. These groups, closely and positively correlated to axis one, consists of dinoflagelates, filamentous centric diatoms (Aulacoseria), euglenoids, large motile green colonies and Microcystis. Of these, large motile green colonies had the most convincing correlation (figure 15). Two of the genera included in this group, (dinoflagelates and filamentous centric diatoms) disagreed with the previously established positive relationship between TP and abundance, showing a negative relationship to that parameter. Figure 16 shows this negatively relationship for dinoflagelates.

Comparing the relative abundance of high TP groups identified during the group analysis again demonstrated the influence of the single exceptionally high TP sample were obvious. This fact ultimately calls into question the validity of the high TP assemblage, which could be nothing more than an artifact created by the single aberrant sample.

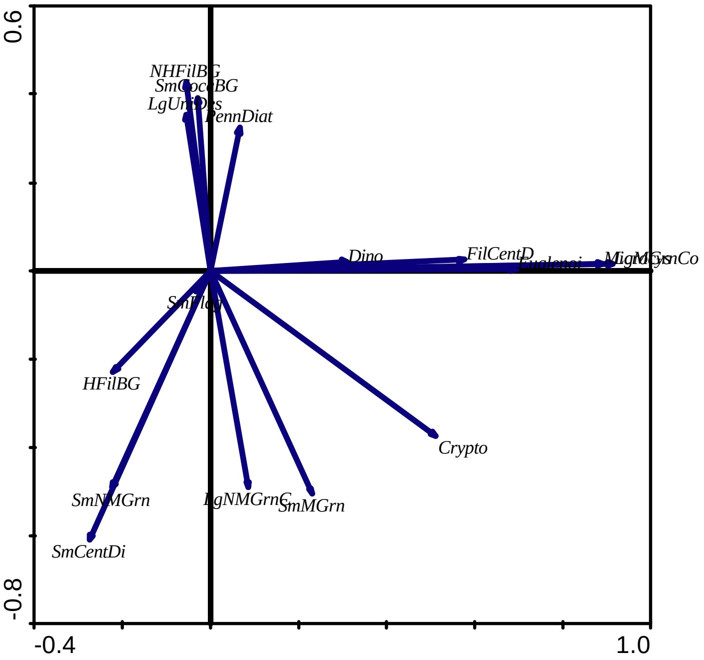

Figure 14. Vector graph of group correlations.

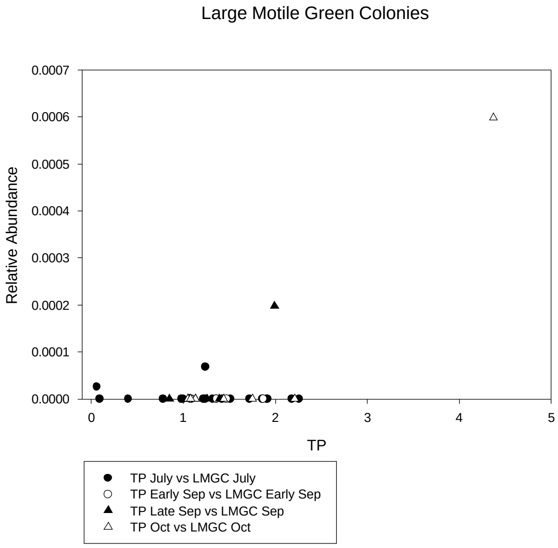

Figure 15. Abundance of large motile green colonies vs. TP.

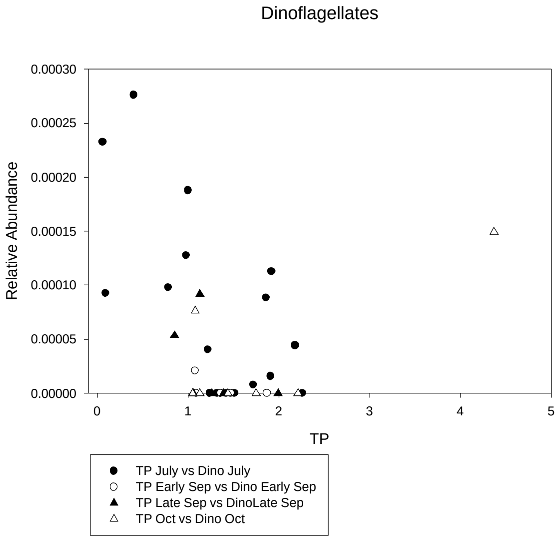

Figure 16. This graph of Dinoflagelate abundance vs. TP suggests dinoflagelates respond negatively to increasing concentrations of total phosphorus.

Blue-green And Benthic Assemblage

This assemblage consists primarily of blue-green and benthic algae, and was found to be associated with sites in the low order portion of the study reach. This is seen in the negative relationship these species demonstrated with axis 2, (figure 11) which was associated with decreasing hydrologic order (figure 10).

Two genera in particular, Aphanocapsa, a small-celled coccoid bluegreen algae and Navicula, a benthic pennate diatom, showed good correlations to hydrologic order (figures 17 and 18) in all sample runs. Five additional genera in this assemblage including Cylindrospermum, Raphidiopsis, Spirulina, Dinobryon and

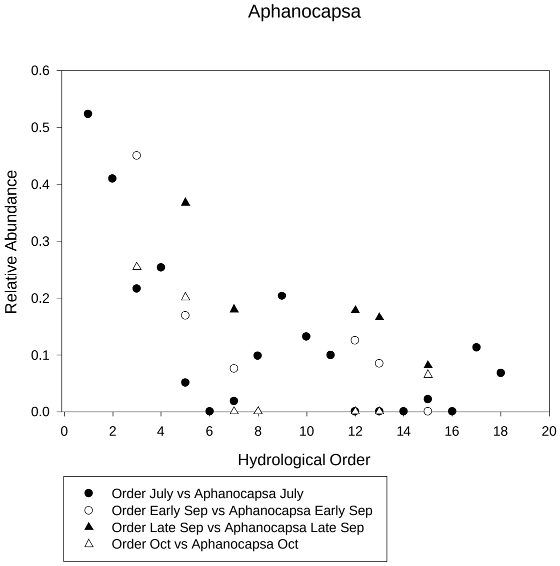

Figure 17. Aphanocapsa abundance in relation to hydrologic order

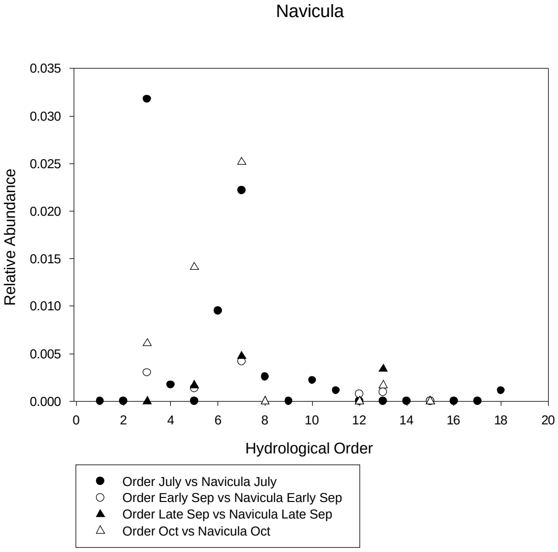

Figure 18. Navicula abundance in relation to hydrologic order

Cymbella occurred in 7 or fewer samples. However when present, these genera were found only in or upstream of Dallas. Nevertheless, the low frequency of occurrence of these genera gives low confidence to their identification as members of this assemblage.

Group analysis focusing on interspecies correlations identified small coccoid bluegreens, large unicellular desmids, non-heterocystous filamentous bluegreens and pennate diatoms as being included in this assemblage. The latter two are associated with benthic habitats, so it is possible that this “low order assemblage” is being influenced by benthic species suspended from the bottom. Large unicellular desmids and coccoid bluegreens are less clearly benthic in origin.

Table 4. Genera in High Order—Reservoir Assemblage and correlations to hydrologic order.

GENUS	NO. OCCURRENCES	CORRELATION WITH HYDRO ORDER
Chlamydomonas	37	0.26
Chlorella	38	0.48
Coelastrum	22	0.47
Crucigenia	28	0.42
Oocystis	37	0.48
Selenastrum	36	0.19
Cyclotella	38	0.58
Stephanodiscus	21	0.49

High Order—Reservoir Assemblage

Eight genera identified with this group had high frequency of occurrence and moderately strong correlations with hydrologic order (table 4). This assemblage contains many genera which are commonly found in north and east Texas reservoirs.

Group analysis of this assemblage found three algal groups with convincing relationships with hydrologic order. These include small centric diatoms, small non-motile greens and large non-motile green colonies. Figures 19-21 show these relationships.

Two other groups, heterocystous filamentous bluegreens and small motile greens also showed a relationship to flow, however this relationship is not as convincing as the other groups in this assemblage (figures 22 and 23).

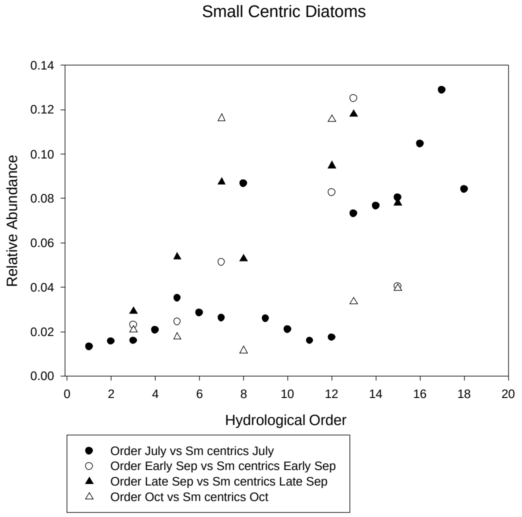

Figure 19. Relative abundance of small centric diatoms plotted against hydrologic order.

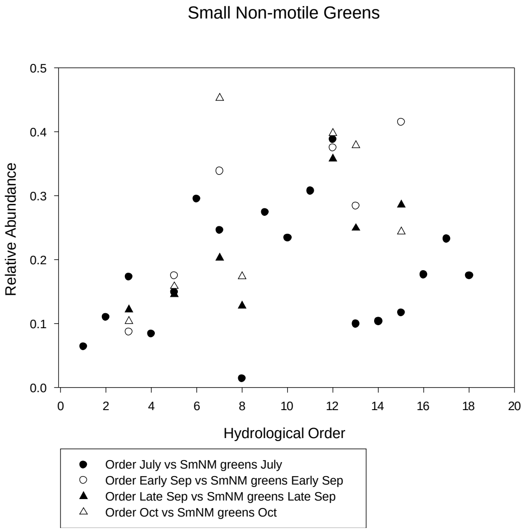

Figure 20. Relative abundance of small non-motile green algae plotted against hydrologic order.

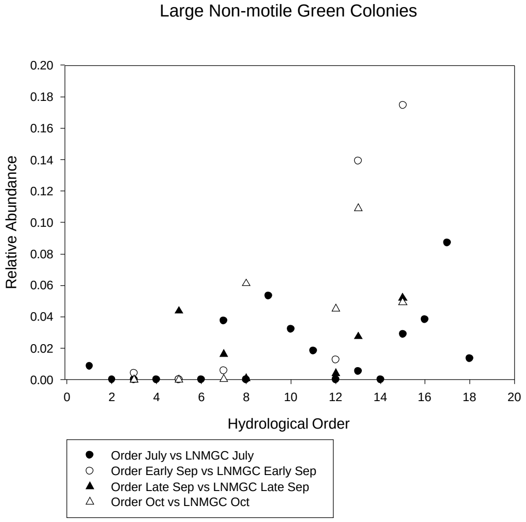
Large Non-motile Green Colonies

Figure 21. Relative abundance of large green algae colonies plotted against hydrologic order.

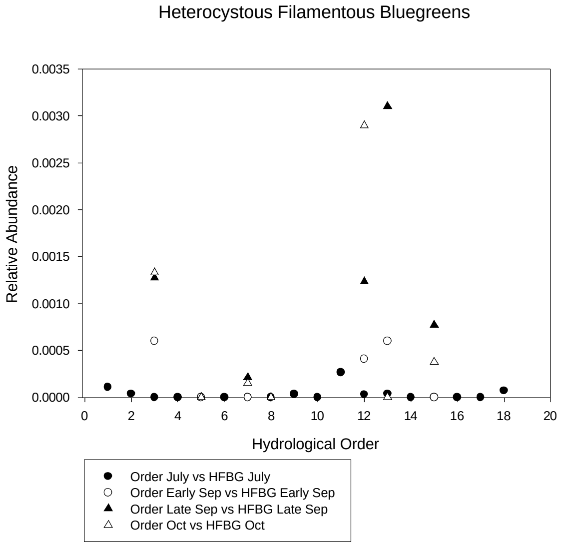
Heterocystous Filamentous Bluegreens

Figure 22. Relative abundance of heterocystous filamentous bluegreen algae to hydrologic order.

CONCLUSIONS

Both genera and group analyses yielded similar results, identifying three distinct algal assemblages. However only the two assemblages correlated with hydrological order, the “low order—bluegreen & benthic” and “high order—reservoir algae” assemblages are defined on the basis of multiple samples and genera with high frequencies of occurrence. As such, there is more confidence that hydrological order and some associated environmental variables (e.g. NO2/NO3 and conductivity) are related to changes in algal composition. Hydrological order appears to be the most important variable influencing many of the physical and chemical characteristics of the river.

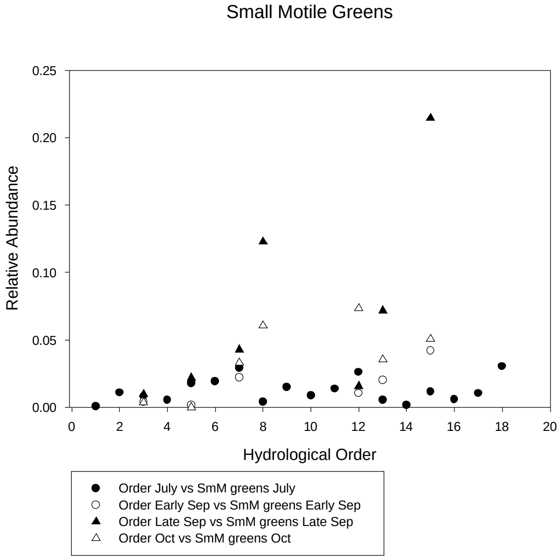
Small Motile Greens

Figure 23. Relative abundance of heterocystous filamentous bluegreen algae to hydrologic order.

Algal assemblage associated with high order sites contained many genera that are common in reservoirs in north and east Texas. Although the high order sites are deeper, they are substantially more turbid (figure 21). Accordingly, conditions at those sites do not necessarily resemble those in reservoirs making the selective mechanisms for this assemblage less intuitive.

In terms of abundance, small non-motile green algae dominated this assemblage. These algae are believed to be a good food source for planktavores. Large non-motile green colonies, although not predominant in terms of abundance, can due to their size constitute a majority of algal biomass. Unlike the small greens, these algae are believed to be a poor food source. Although the prevalence of this algal group was observed to be perhaps larger than noted in the literature, it is not believed to be unusually so and is therefore probably not problematic.

The small centric diatoms that were also closely associated with this assemblage represent a small percentage of algae in terms of relative abundance however like the large green colonial algae, their large size offsets this in terms of their contribution to the overall algal biomass. The prevalence of these algae is believed to represent a healthy situation and the increase of this group related to increasing hydrologic order is well supported by the literature.

Heterocystous filamentous bluegreens can be associated with taste and odor and toxicity issues. However their association with the high-order assemblage was weak, and their abundance sufficiently low to keep them from being a concern.

The algal assemblage associated with low order sites is less well supported by the data than that associated with high order sites, but is supported by the fact that it is biologically plausible. Many of the genera in this assemblage are pennate diatoms or filamentous bluegreens which are known to have representatives that live in benthic or periphytic habitats of streams and rivers. Since the river is both shallower and less turbid at lower order sites, it makes sense that this stretch is more likely to have more substantial benthic communities than the higher order sites.

Pennate diatoms were the most dominant algal type associated with this assemblage, representing what is believed to be a healthy situation. The increase in pennate diatoms downstream from the Village Creek Wastewater Treatment Plant could be evidence that the clear, nutrient rich water from that discharge is stimulating benthic algal growth.

Also associated with this assemblage are large unicellular green algae, which due to their size and protective coatings, are less suitable for food. These algae however represent a very small percentage of algal abundance in the low order reach. Also present were filamentous blue-greens, which are not favorable. These algae however were not overly abundant and are therefore not believed to be a concern.

There is much less confidence in the assemblage identified with high TP conditions. The analysis of environmental variables suggests that TP and some other nutrients vary somewhat independently of hydrological order, and it is plausible that some differentiation of algal composition could occur in response to this variation. Moreover, some of the genera in the “high TP” assemblage are large colonial forms known or suspected to have high nutrient requirements. Despite the plausibility of this assemblage, its support in the data is weak, and is based on a single sample with the highest TP and a somewhat unusual composition that includes several rare genera. Confirmation or refutation of this assemblage will require more samples with higher than usual TP.

The assemblages found during the course of this study represent what is believed to be a relatively healthy system. There was evidence that the numerous and significant municipal point sources discharging to the river are impacting algal biomass. Specifically, it is likely that the resultant increases in nutrient concentrations are allowing the river to support a larger algal population. However, no compelling evidence was found to suggest that the community composition would be significantly different in the absence of these point sources.

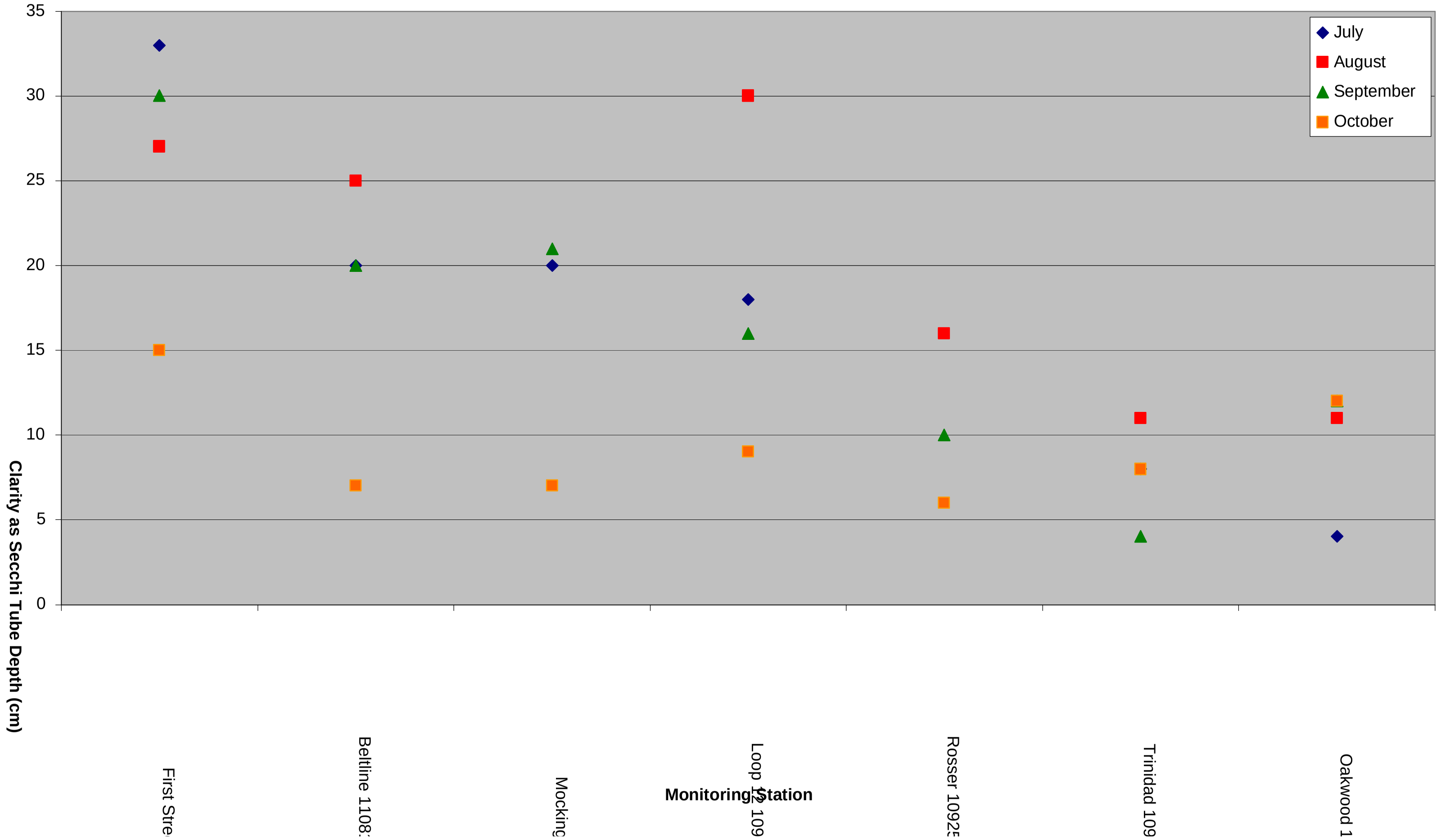

Figure 24. Turbidity in the Main Stem increases as one moves downstream. Although this pattern might be considered normal under high flow conditions, it is somewhat counterintuitive for low flow situations. Data for this figure were collected as part of TRA Clean Rivers Program routine monitoring during July, August September and October of 2002.

APPENDIX A

ALGAL ENUMERATION AND IDENTIFICATION DATA

JULY 29

SAMPLE RUN

SEPTEMBER 5

SAMPLE RUN

SEPTEMBER 26

SAMPLE RUN

OCTOBER 1

SAMPLE RUN