Appendix E

Aquatic Vegetation in Selected Sites of the Lost River, OR and CA

By
J.M. Eilers
MaxDepth Aquatics, Inc.
Bend, OR

This Page Intentionally Left Blank

MaxDepth Aquatics, Inc.

Aquatic Vegetation in Selected Sites of the Lost River, OR and CA

Prepared for
Tetra Tech, Inc.
Fairfax, VA

By
J.M. Eilers
MaxDepth Aquatics, Inc.
Bend, OR

January, 2005

ABSTRACT

A survey was conducted at ten sites in the Lost River of Oregon and California in July 2004 to determine the nature of the aquatic plant communities in the river system. Sample sites were selected from throughout the river to represent a range of habitat types. A transect was selected at each site to characterize the plant community with respect to dominant taxa, percent cover, substrate type, stream velocity, and light extinction. Subsamples were collected at each site to verify species identification, plant biomass, and nutrient composition of the plants. The dominant taxa present in the river system based on these sites were *Ceratophyllum demersum* (coontail). *Lemna minor* (duckweed) was also common at many of the sites. Additional taxa included several species of pondweed (*Potamogeton pectinatus, P. crispus, and P. nodosus*), *Elodea canadensis*, and *Heteranthera dubia*. *Cladophora sp.*, a filamentous alga also common in nutrient-rich waters, was also present at a number of sites, commonly attached to the macrophytes present. All of these taxa found in the Lost River are tolerant of high turbidity and are common species found in eutrophic lakes and slow-moving waters. The chemical analysis of the plants showed that they were generally nitrogen deficient based on ratios of nitrogen to phosphorus in the plant tissue. The biomass and percent cover of aquatic plants ranged greatly from virtually absent to 15 kg/m^2 (wet weight). Factors affecting the type and abundance of aquatic plants at the study sites included stream velocity, substrate composition, depth, and light extinction. Attached macrophytes were uncommon below a depth of 1.5m, a depth at which light extinction would have been limiting at most sites. The chemical composition of the macrophytes showed strong trends in C:N and N:P ratios from the upstream sites to the downstream sites. The ratios of N:P for the upstream sites indicate possible N-limitation among the macrophytes.

INTRODUCTION

The Lost River is a system with headwaters in northern California at Clear Lake. The river enters into southern Oregon and courses back into California at Tule Lake. The Lost River is also connected to the Klamath River system through irrigation inputs from Upper Klamath Lake and return flows to the Klamath River from the Klamath Straits Drain. The flow in the Lost River is highly regulated with numerous withdrawals for irrigation, return-flows from irrigation, channelization, and impoundments. The Lost River currently does not meet water quality standards and is being studied to better understand the factors affecting water quality in the system.

Tetra Tech, Inc. was contracted by the States of Oregon and California to model spatial and temporal variations in water quality throughout the Lost River. The mathematical modeling requires that the key physical, chemical, and biological attributes of the system be represented to the extent possible. It was recognized that aquatic plants are abundant in portions of the Lost River and thus may play an important role in affecting nutrient fluxes and short-term changes in water quality parameters such as dissolved oxygen and pH. Consequently, Tetra Tech, Inc. contracted with MaxDepth Aquatics, Inc. to sample selected sites in the Lost River and characterize the aquatic plant community. This report describes the results of this study.

METHODS

Ten sites were selected for sampling in the Lost River (Figure 1). These sites were selected to represent portions of the Lost River throughout its course. Several impoundments in the system were also selected for sampling because of the enhanced opportunity for macrophyte growth in these areas. The final list of sample sites was reviewed by staff from the Oregon Department of Environmental Quality, the California Water Quality Control Board, and Tetra Tech, Inc. The site locations are depicted in Figure 1 and are listed in Table 1.

At each site, digital images were recorded to document the conditions at the time of sampling. A transect position was located to best represent conditions near the site with respect to macrophyte cover and within the constraints imposed by access conditions. A tape measure was extended and secured across the river to guide the field crew across the study site. A sampling interval was selected that would provide approximately 20 measurement intervals across the river with a spacing generally no greater than 3 m between measurements. At each interval, the depth at the site was measured and the current velocity was measured at mid-depth with a Marsh-McBirney Flo-Mate

3000 current meter. Light extinction was measured in an area without macrophytes by lowering an Onset light intensity meter oriented up and attached to a marked rod into the river. The meter was held in position for two minutes at each depth interval of 0.3 m up to a maximum depth of 1.2 m or when the river bottom was reached. Substrate texture was determined with a rake, aluminum probe, or visually where possible.

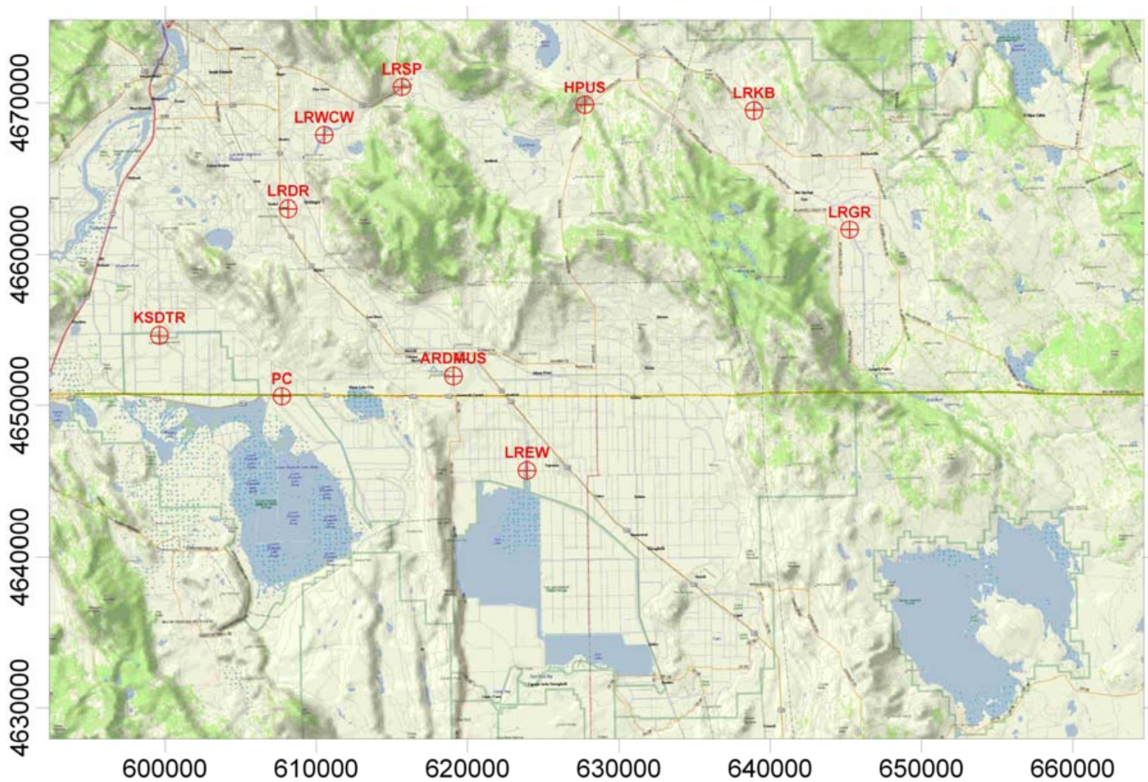


Figure 1. Lost River study sites shown in red. The yellow horizontal line represents the border between Oregon and California. The numbers on the axes represent UTM coordinates.

Table 1. Sample site locations for the Lost River Aquatic Plant Synoptic Survey.

Site ID	Site Name	Latitude	Longitude
LRGR	Lost River @ Gift Rd.	42 05.597	121 14.618
LRKB	Lost River @ Keller Bridge	42 09.918	121 19.084
HPUS	Harpold Dam, upstream	42 10.233	121 27.199
LRSP	Lost River @ Stevens Park	42 10.990	121 35.963
LRWCW	Wilson Reservoir @ Crystal Springs Rd.	42 09.317	121 39.736
LRDR	Lost River @ Dehlinger Rd.	42 06.700	121 41.514
ARDMUS	Anderson-Rose Dam, upstream	42 00.629	121 33.728
LREW	Lost River @ East-West Rd.	41 57.221	121 30.290
PC	P Canal	42 00.001	121 41.950
KSDTR	Klamath Straits Drain @ Township Rd.	42 02.244	121 47.781

At each position, the percent macrophyte/algae coverage was recorded by placing a 0.25 m^2 quadrat over the surface and estimating the coverage in each of the 16 subdivisions within the quadrat. The percent coverage along a transect was expressed as the average of the percentage cover within each quadrat. Macrophyte samples were collected from two quadrats per site, where possible. At shallow sites, the samples were collected by wading and removing all of the vegetation from within the quadrat by hand. For deeper sites, a long-handled rake was used to remove macrophytes from the substrate within an area represented by placing the quadrat at the surface. The samples were taken to shore for processing. For sites with very abundant plant samples, the samples were spun in a mesh bag to remove excess water and were weighed in the field. In these cases, a subsample was placed in a WhilPac® bag and stored on ice prior to shipment to the laboratory. The relative abundance of various taxa was estimated by sorting through the plants and comparing the amounts of each taxon. Field identification of plant specimens was based on Fassett (1957). Samples of single species of plants were collected for chemical analyses and to verify taxonomy. Samples for taxonomic verification were dried and pressed and shipped to Portland State University. Samples intended for chemical analysis were kept on ice and generally shipped the same day for overnight delivery to the Central Analytical Laboratory, Crop and Soil Science Department, Oregon State University, Corvallis.

Water samples were collected at each site and preserved with magnesium bicarbonate and stored on ice for analysis of chlorophyll *a*. A separate sample was preserved in Lugol's solution for analysis of phytoplankton community composition. Both of these samples were shipped overnight to Aquatic Analysts, White River, Washington. Chlorophyll *a* was analyzed using a spectrophotometer and phytoplankton community composition was determined by light microscopy.

Samples retained for chemical analysis were dried at 65 °C, 105 °C, and 500 °C. The samples were analyzed for carbon and nitrogen on a Leco Analyzer. The plant tissue was also analyzed for phosphorus using a total Kjeldahl digestion followed by spectrophometric measurement of phosphorus. Details of all field and analytical methods are presented in the quality assurance project plan (Tetra Tech, Inc. 2004).

RESULTS

The physical characteristics of the sample sites are summarized in Table 2 and Figure 2. Photo-documentation of the sites is provided in Appendix A (Attached CD). The sites ranged from areas averaging less than 1m in depth to the impoundment upstream of Anderson-Rose Dam (ARDMUS) with a maximum depth of 5 m. Current velocity at the sites ranged from no detectable current at Wilson Reservoir (LRWCW) to a maximum of 0.71 m/s in the thalweg at Dehlinger Road (LRDR). Most sites had a majority of mud substrate, although sand and gravel was occasionally encountered. Light extinction at a depth of 0.9 m averaged 97.0 percent reduction from the incident light at the surface. The light reduction values are reported at 0.9 m for all sites to allow a standard basis for comparison of transparency among sites. The greatest rate of light attenuation occurred at Gift Road (LRGR), followed closely by the values measured at Dehlinger Road (LRDR). The clearest water was measured at East-West Road (LREW) where light extended to the substrate at all points along the transect.

Table 2. Physical characteristics of site transects.

Site	Ave Depth (m)	Max Depth (m)	Ave Velocity (m/s)	Discharge (m^3/s)	% Mud	% Sand	% Gravel	% Rock	% Light Reduction @ 0.9 m
LRGR	1.05	1.4	0.03	0.48	82		13	5	99.6
LRKB	1.06	1.2	0.12	2.05	100				98.0
HPUS	1.62	2.2	ND	ND	54	2	22	22	98.7
LRSP	1.94	2.7	0.01	0.88	89		11		96.0
LRWCW	2.59	4.0	ND	ND	100				96.0
LRDR	1.45	2.1	0.39	13.08	46	39	15		99.0
ARDMUS	2.6	5.0	0.07	13.16	100				97.2
LREW	0.89	1.2	0.05	1.96	100				90.0
PC	0.83	1.2	0.07	0.78	100				96.8
KSDTR	1.7	2.1	-0.002	-0.09	93			7	98.7

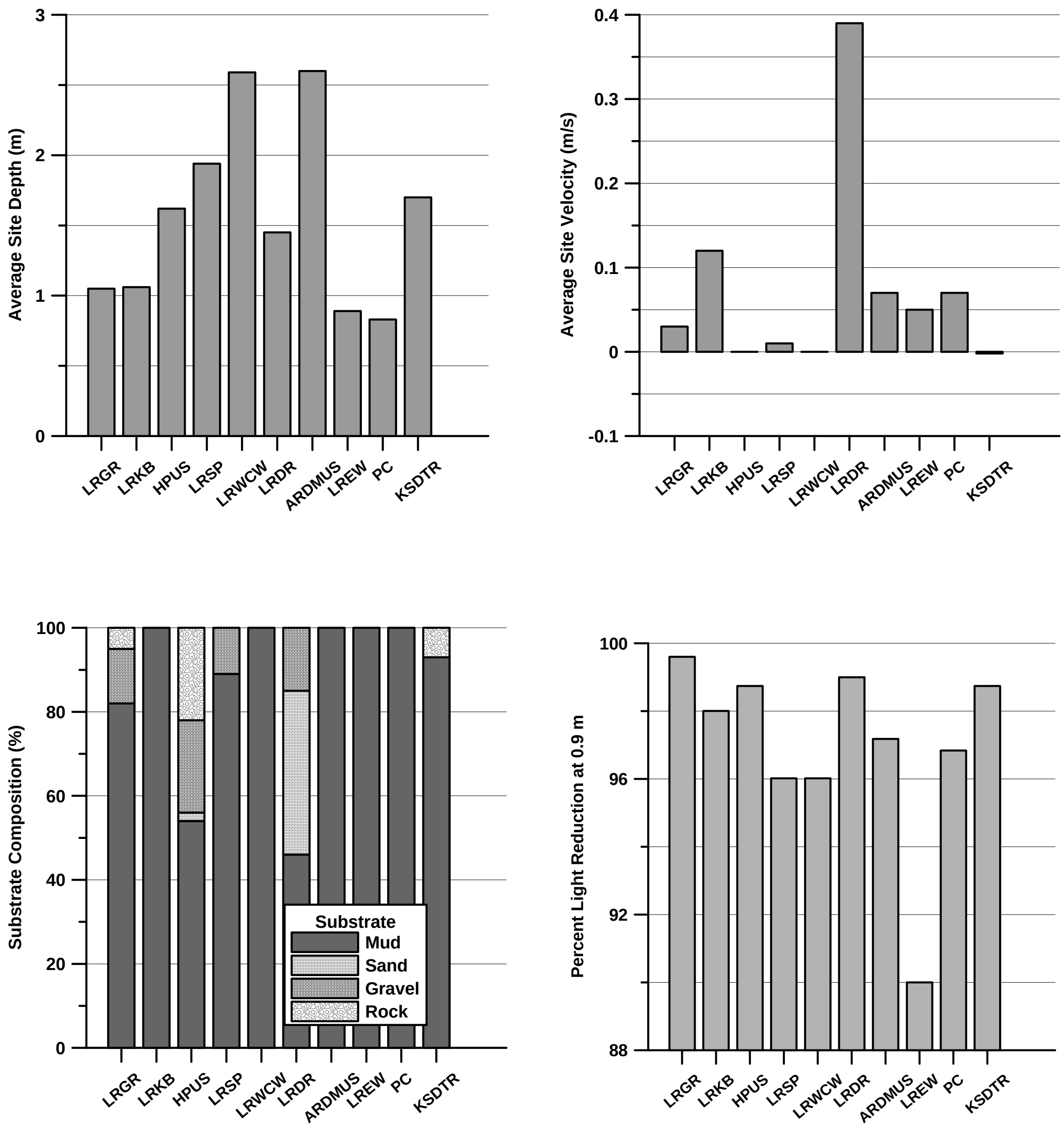


Figure 2. Physical attributes of Lost River sampling sites.

Some sites such as Kellar Bridge (LRKB) and Dehlinger Road (LRDR) had available habitat that was apparently limited by factors other than substrate or depth. While sample LRDR, we observed high flows and a considerable amount of dislodged macrophytes being transported downstream. The flow velocity at this site was sufficient to prevent macrophytes from occupying much of the channel. The Klamath Straits Drain site (KSDTR) has very steep-sided banks dominated by rock substrate. The vast majority of the channel bottom was mud, but most of this was probably light-limited given the information on light extinction. The KSDTR site showed a slight flow reversal during the sampling.

Macrophyte coverage ranged from about one percent at the Klamath Straits Drain (KSDTR) to almost 90 percent at Gift Road (LRGR) (Table 3). Macrophyte coverage typically was most abundant adjacent to the river banks and extended out into the channel to the extent possible given the constraints imposed by current velocity, substrate, and light availability. The greatest density in macrophyte abundance was measured at Gift Road (LRGR), which also had the greatest macrophyte coverage on a percentage basis. However, the greatest overall coverage occurred in Wilson Reservoir (LRWCW) where macrophyte coverage extended for a total distance of nearly 94 m. The cross-sectional profiles for the sample sites and a representation of the dominant macrophyte coverage are illustrated in Figure 3.

Table 3. Macrophyte coverage and mass in the Lost River.

Site	Ave Plant Cover per transect (%)	Plant Mass (Wet wt, g/m^2)	Plant Mass (Dry Wt @ 105° C, g/m^2)	Plant Mass (Dry Wt @ 500° C, g/m^2)	Transect length (m)	Plant Mass Per Transect (Wet Wt., kg)
LRGR	87.5	14964	321.3	77.5	18.3	178.8
LRKB	5.3	144	2.4	0.7	17.4	0.1
HPUS	57.8	946	19.5	4.4	80.8	44.2
LRSP	39.8	1213	21.8	8.0	29.9	21.8
LRWCW	54	459	8.0	1.3	173.7	43.1
LRDR	9.5	140	3.0	1.1	21	0.3
ARDMUS	21	663	18.1	4.7	59.4	8.3
LREW	14.8	1052	20.7	5.1	39	19.0
PC	40.8	689	21.8	5.4	11.6	3.3
KSDTR	1.4	260	4.3	1.6	21.3	0.3

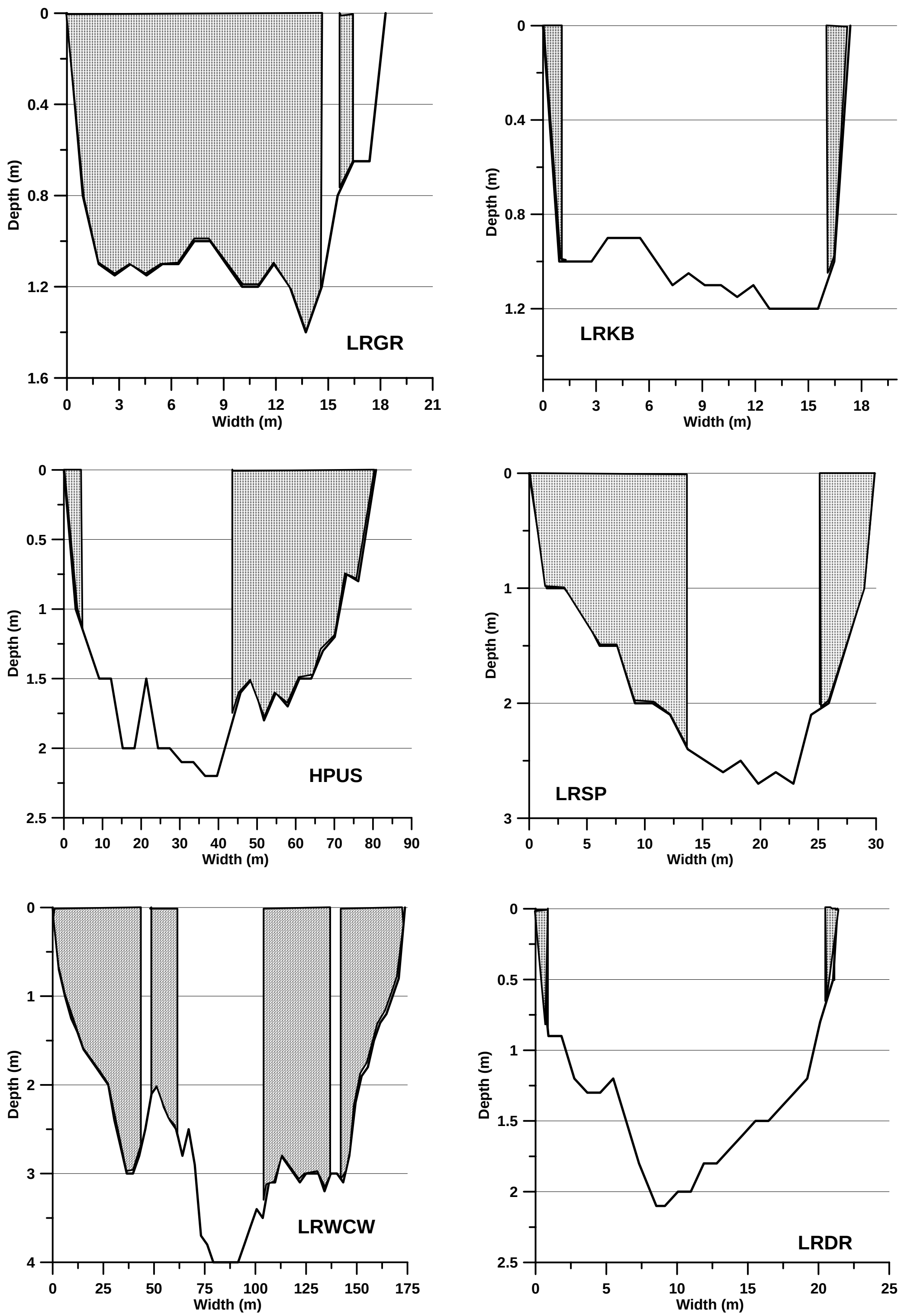


Figure 3. Cross sections of macrophyte sampling transects in the Lost River system. Scales of axes are adjusted to accommodate the varying dimensions of the sites.

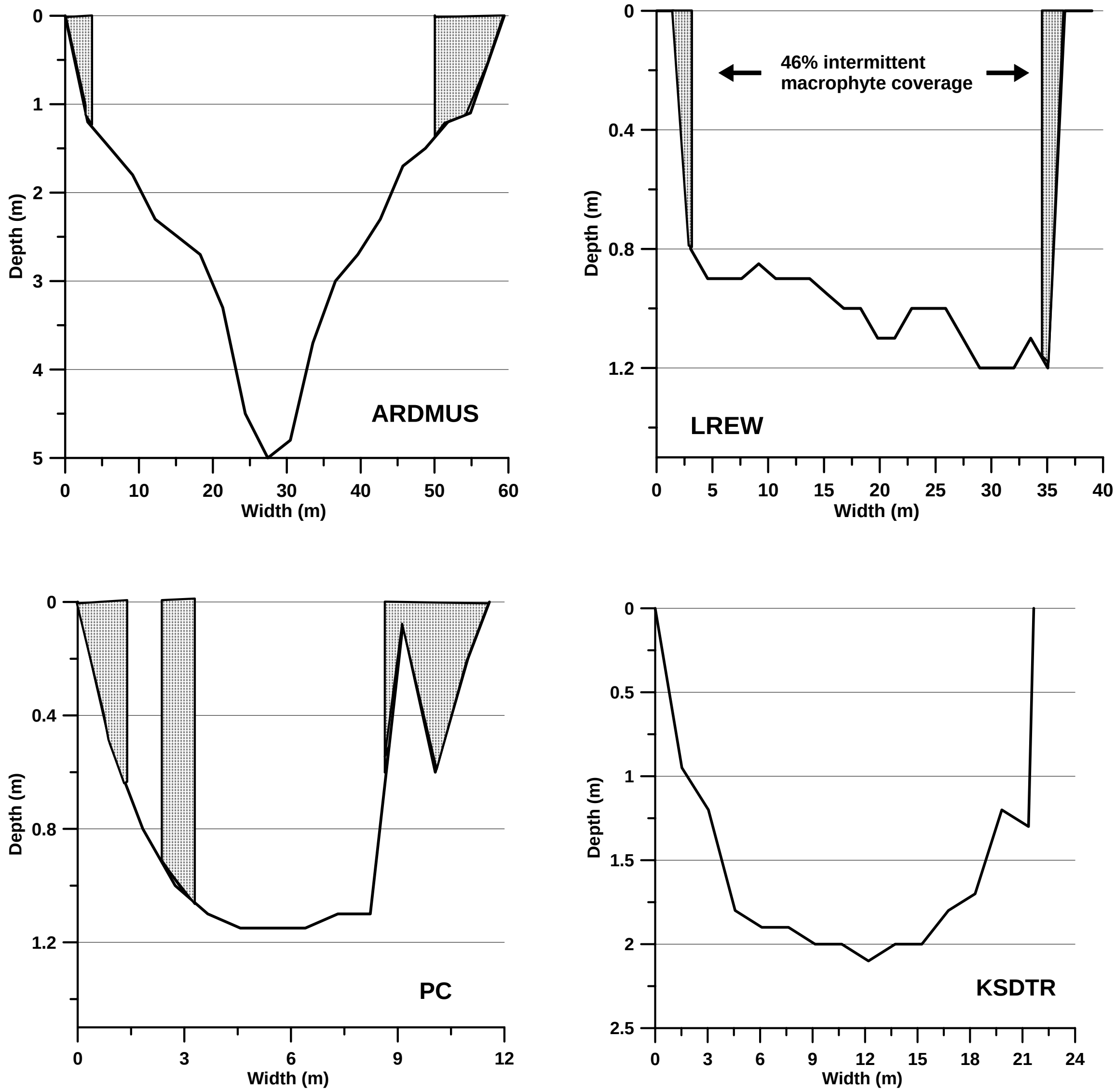


Figure 3 – continued. Cross sections of macrophyte sampling transects in the Lost River system. Scales of axes are adjusted to accommodate the varying dimensions of the sites.

The dominant macrophyte taxon present in the Lost River sample sites was *Ceratophyllum demersum* (coontail), which was present at eight sites and dominant (based on weight) at six of the sites (Table 4, Figure 4). Usually, there were multiple species present at a given site, often in a two-story structure. *C. demersum* would usually serve as the dominant rooted macrophyte. Where it was extremely dense, the overlying water velocity would be greatly reduced, thus providing habitat for an overstory of *Lemna minor* (duckweed). In some cases, the rooted macrophytes would also provide substrate for the filamentous alga, *Cladophora*. Several pondweed taxa were present (*Potamogeton pectinatus, P. crispus, and P. nodosus*) and one site contained moderate amounts of *Heteranthera dubia*. All taxa encountered in the Lost River are species that tolerate high turbidity (Nichols 1999) and are species common to lakes and slow-moving waters with high concentrations of nutrients.

Table 4. Relative dominance of macrophytes and filamentous algae at the Lost River sampling sites.

Site	Dominant Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6
LRGR	*Ceratophyllum*	*Heteranthera*	*P. pectinatus*	*P. nodosus*	*P. crispus*	
LRKB	*Lemna minor*	*P. pectinatus*				
HPUS	*P. crispus*	*Ceratophyllum*	*Cladophora*	*Lemna minor*	*P. pectinatus*	*Elodea*
LRSP	*Ceratophyllum*	*Lemna minor*	*Elodea*			
LRWCW	*Lemna minor*	*Ceratophyllum*	*Elodea*	*P. crispus*		
LRDR	*Ceratophyllum*	*Elodea*				
ARDMUS	*Ceratophyllum*	*Lemna minor*	*Cladophora*	*Elodea*		
LREW	*Ceratophyllum*	*Heteranthera*	*Cladophora*			
PC	*P. pectinatus*	*Cladophora*				
KSDTR	*Ceratophyllum* (floating)					

The chemical analysis of the plants showed that the vast majority of the samples showed that stoichiometry of the plant tissues varied widely among sites (Figure 5). These variations in carbon, nitrogen, and phosphorus content of the plants can be attributed, in part, to the variations in retention of nutrients among different taxa (Sterner and Elser 2002). However, there are some patterns that are strongly suggestive of systematic changes in the availability or usage of nutrients in the Lost River. Both the C:N and N:P ratios illustrate highly significant spatial patterns (Figure 6). The N:P ratio suggest that the upstream sites in the Lost River have macrophyte communities with a net deficiency of nitrogen, whereas the sites further downstream have N:P ratios near the expected values for plants (Figure 6).

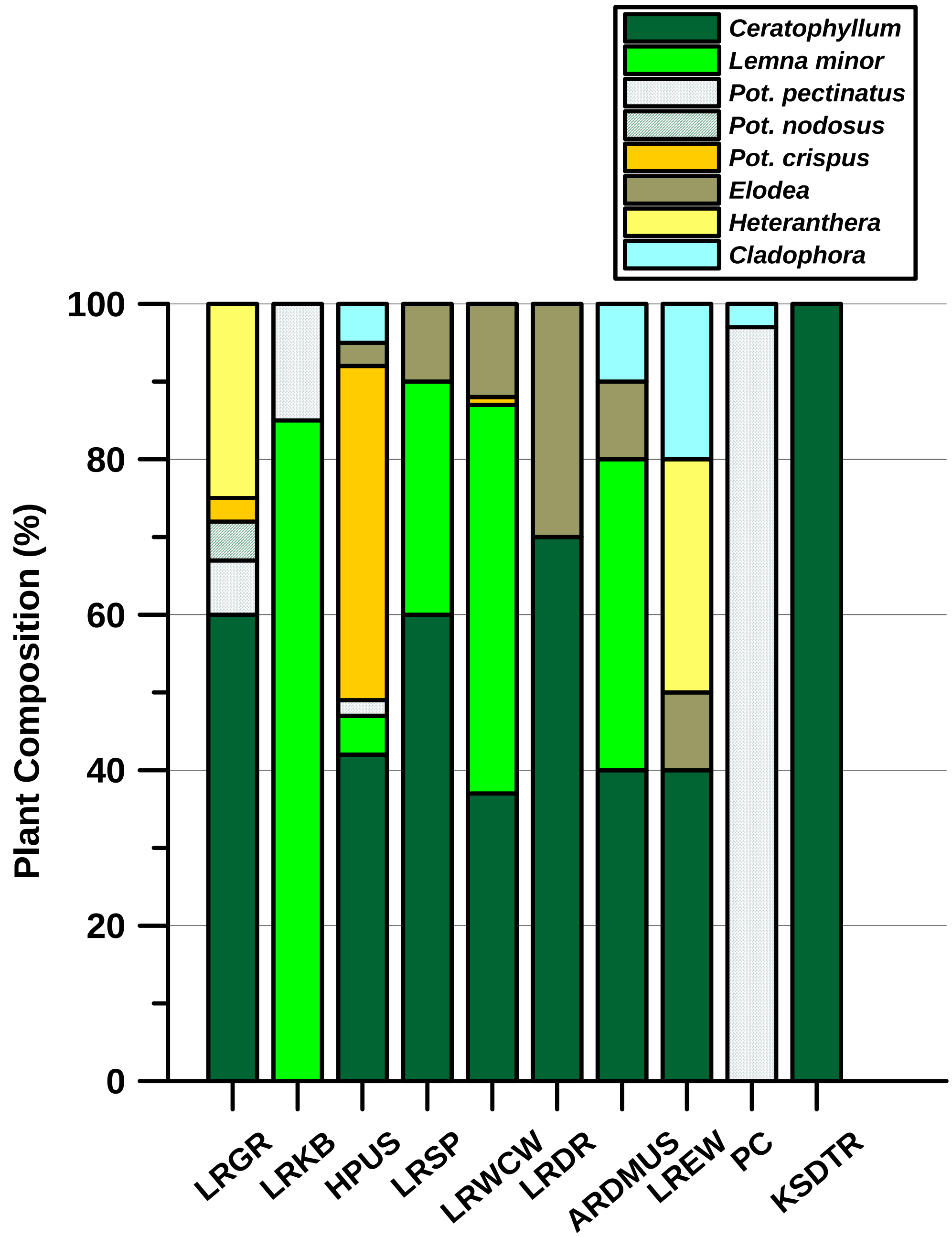


Figure 4. Relative abundance of aquatic plant taxa at the ten sampling sites in the Lost River. Abundance is based on relative mass.

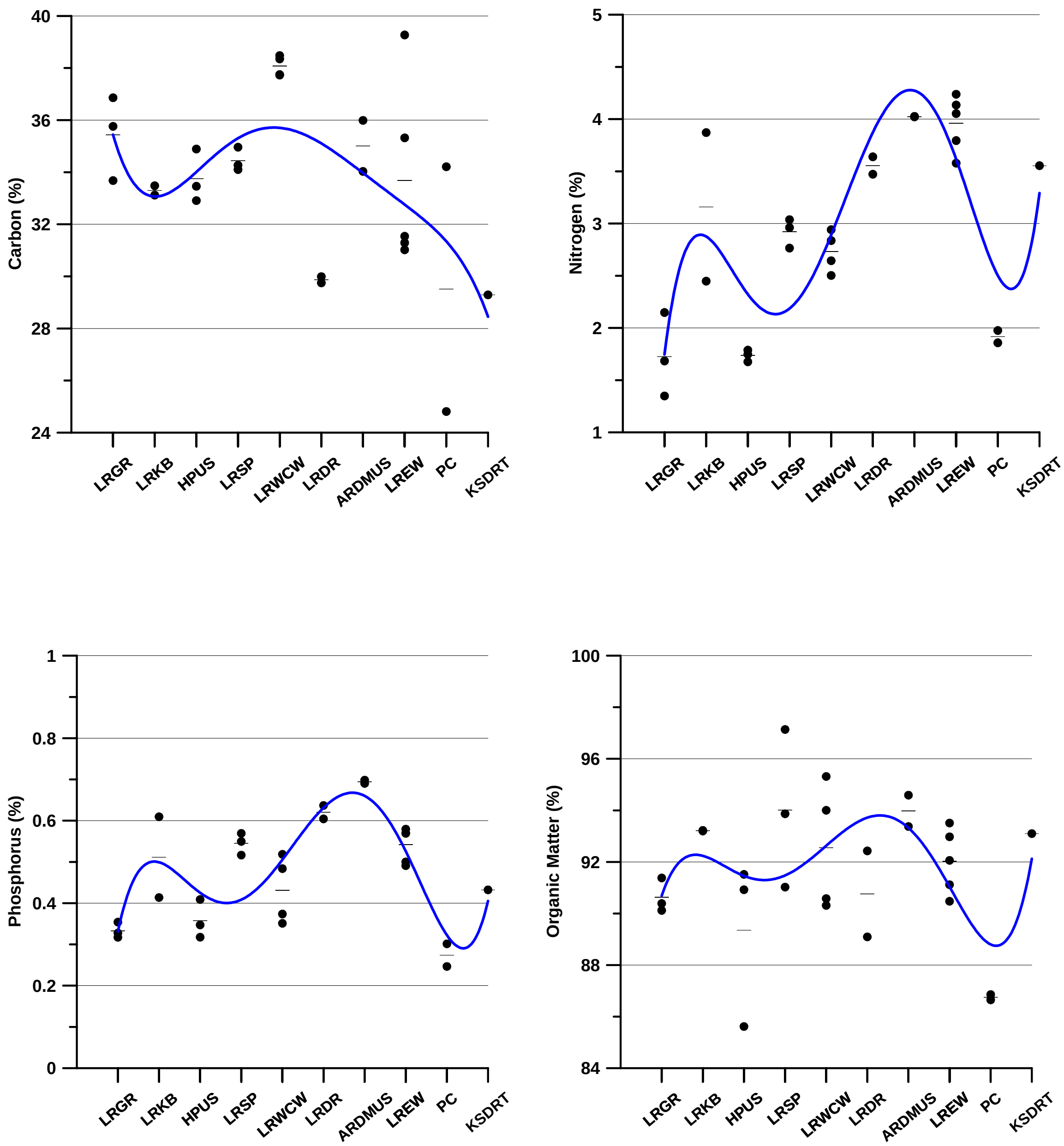
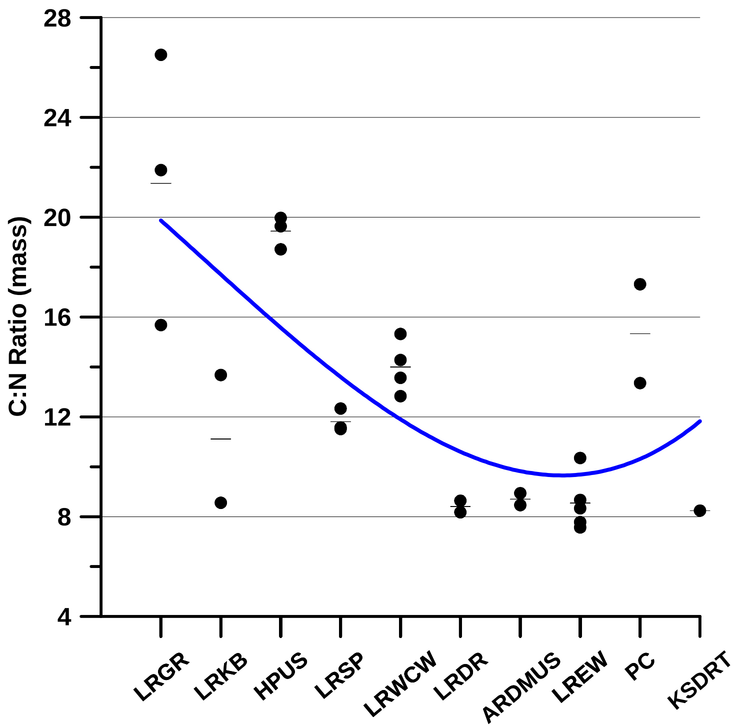


Figure 5. Chemical composition of aquatic plant samples (expressed as percent of dry weight) from the Lost River. The filled circles represent individual analyses and the horizontal line represents the average value for the sample site. The blue line represents a polynomial fit to the observed data.



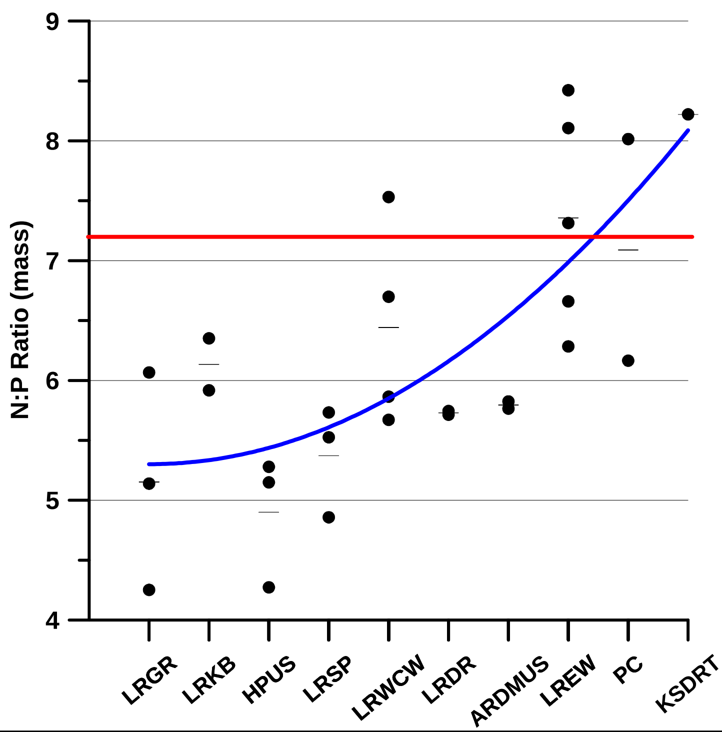


Figure 6. Ratios of C:N (top) and N:P (bottom) for aquatic plants in the Lost River system. The blue line represents a polynomial fit to the observed data. The red horizontal line in the bottom figure represents the expected ratio of N:P for plant tissue without limitations of N or P.

The Lost River has several impoundments that provide adequate habitat for the development of phytoplankton. Algal biovolume was lowest at the upstream sites and generally increased in the impoundments and downstream sites (Figure 7). Algal biovolume during the survey did not indicate bloom conditions at any of the sites. The algae samples from the Lost River showed a collection of taxa that indicate contributions from attached diatom species and true planktonic species (Figure 8). *Cryptomonas erosa* (Chlorophyceae) was the most common taxa among the sample sites, although it was not the most dominant organism at any one site. Epiphytic diatoms such as *Cocconeis* and *Nitzschia* were the most dominant algae present at several sites. All project results are provided in the attached Access® database (Appendix B).

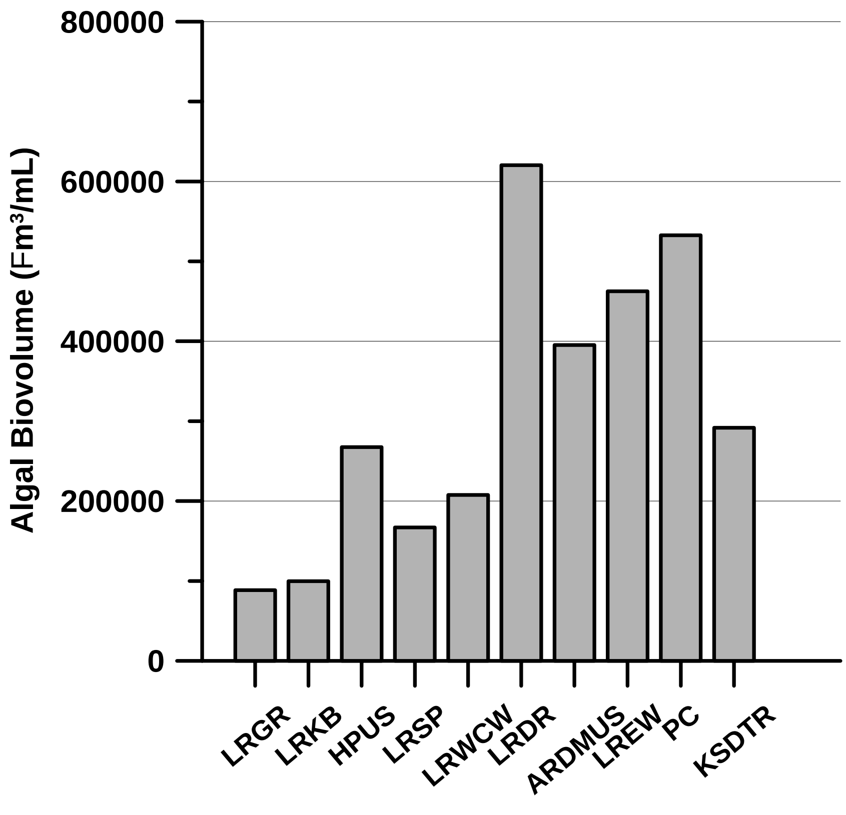


Figure 7. Algal biovolume present in water samples obtained from the ten sample sites in the Lost River system.

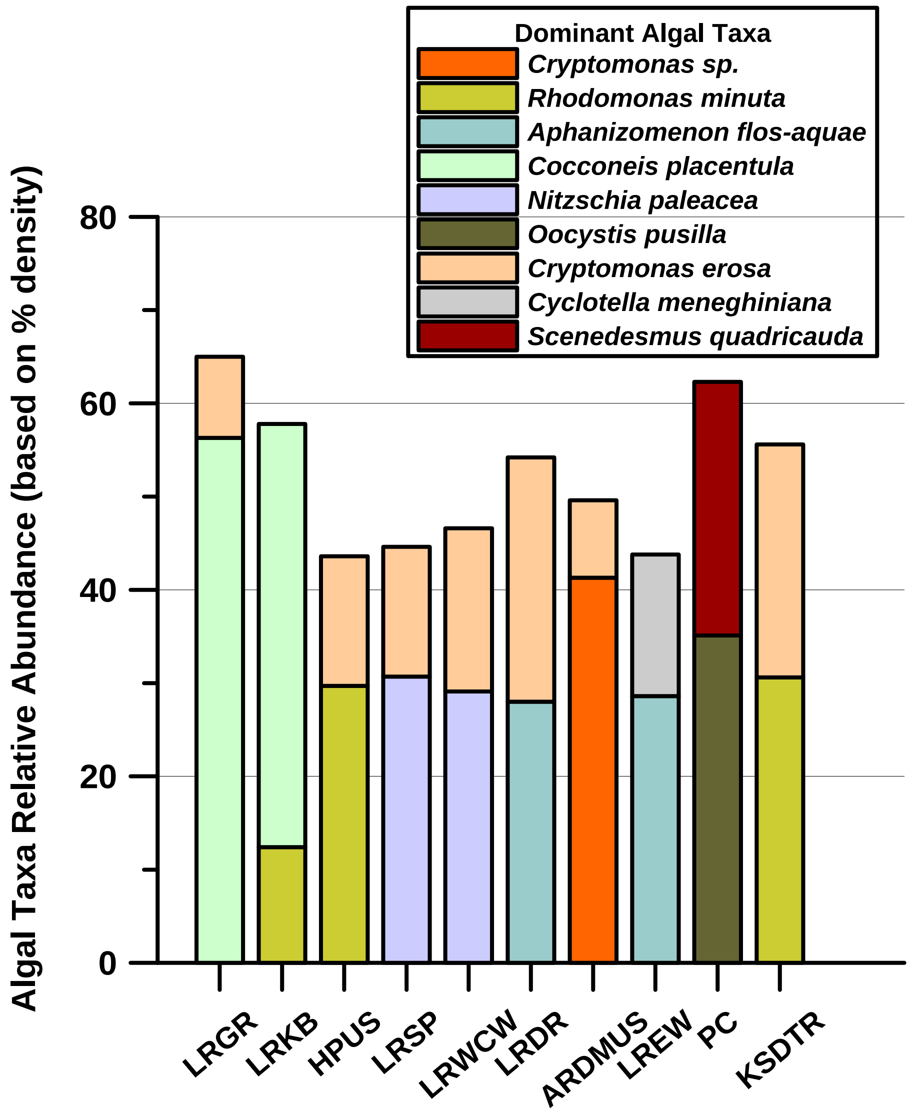


Figure 8. Relative abundance of the two dominant algal taxa within the ten Lost River sample sites.

DISCUSSION

The Lost River, as represented by the ten sites selected for sampling, contains abundant aquatic macrophytes at a number of sites. Physical habitat plays an important role in determining the abundance and species composition of the macrophyte community. Where current velocity is low, the typical macrophyte community consists of an understory of *C. demersum* with *L. minor* on the surface. Examples of such sites include LRSP, LRWCW, and ARDMUS. Other taxa such *Elodea* or *P. pectinatus* were often mixed in with the *Ceratophyllum*, but seldom were dominant. Where current velocity was moderate, macrophytes were generally limited closer to the banks. Examples of these types of habitats included LRDR and possibly LRKB, although we lack documentation for the later site. The last three sites sampled in the Lost River system, LREW, PC, and KSDTR, were among the least similar to the upstream sites and were very different from one another. The Lost River at East-West Road (LREW) was the site with the clearest water and also contained extensive beds of *Typha* extending from the banks on both sides of the channel. The sites contained a relatively diverse macrophyte community extending across much of the channel as wells as floating macrophytes, especially *Lemna*, derived from upstream. The P Canal (site PC) was dominated by *P. pectinatus*, with a minor amount of *Cladophora* attached to the macrophytes. The Klamath Straits Drain (KSDTR) had few attached macrophytes. Most of the plants appeared to be drifting in the canal. This site was notable for an algal sheen on the surface (Appendix A) and for relatively high light extinction.

The chemical composition of the macrophytes in the Lost River system varied considerably among sites, however the ratios of C:N and N:P exhibited discernable trends. The C:N ratio decreased from the upstream to downstream, whereas the N:P ratio increased in the same direction. The mass ratio of 7.2 is usually considered the point at which limitation of N or P can become an issue for the plants. Most of the sites upstream of ARDMUS appear to be N-limited, whereas the plants at sites downstream of ARDMUS approach the expected ratio for N:P. However, a variety of factors can affect nutrient content of plants that could not be addressed in this investigation (cf. Sterner and Elser 2002). As with a number of other aspects associated with this survey, conditions at other locations not sampled and during other times may greatly alter the results observed in this brief study.

LITERATURE CITED

Fassett, N.C. 1957. A Manual of Aquatic Plants. University of Wisconsin Press. Madison, WI. 405 pp.

Nichols, S.A. 1999. Distribution and habitat descriptions of Wisconsin lake plants. Bulletin 96. Wisconsin Geological and Natural History Survey. 266 pp.

Sterner, R.W. and J.J., Elser. 2002. Ecological Stoichiometry. Princeton University Press. Princeton, NJ. 439 pp.

Tetra Tech, Inc. 2004. Quality Assurance Project Plans. Lost River and Klamath River TMDL Studies. Fairfax, VA.

ACKNOWLEDGEMENTS

This project was funded through Contract #68-C-02-108, Task Order #31 from Tetra Tech, Inc. to MaxDepth Aquatics, Inc. The project officer for Tetra Tech was Andrew Parker. Field assistance was provided by Benn Eilers and Ian Gunter, MaxDepth Aquatics, Inc. I thank Dr. Mary Pfauth, Portland State University, for kindly confirming species identifications of voucher specimens.

APPENDICES

A. Digital images of sample sites.

B. Access database