Water Quality and Periphyton

in the Lower Deschutes River: Summer 2019

Report prepared for

Portland General Electric

&

The Confederated Tribes of the Warm Springs Reservation of Oregon

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Table of Contents

List of Figures

List of Tables

Summary

Portland General Electric (PGE) staff sampled seven sites in the Lower Deschutes River (LDR) for nutrient chemistry and periphyton in July through September 2019. The purpose of the brief study was to evaluate the effects of a naturally caused high-flow event on the LDR. The high flows occurred on April 8–10, 2019, and at its peak resulted in a discharge at the Reregulating Dam tailrace of 11,600 cubic feet per second (cfs) and a flow of 25,100 cfs at the mouth of the river. Nutrient chemistry in the river was similar to samples collected previously from 2015–2017. Concentrations of total phosphorus and total nitrogen changed only slightly from the ReReg tailrace (RM 100.1) to the River Mouth (RM 3.5). Concentrations of soluble reactive phosphorus (SRP) declined by 0.01 mg/L in July, the month exhibiting the largest changes in water chemistry. Concentrations of nitrate declined by 0.15 mg/L in July from the ReReg tailrace to River Mouth, which was similar to the spatial pattern exhibited in the summer of months of 2015–2017. The periphyton community exhibited a total biomass similar to previous years, however, there was a major change in the dominant periphyton taxa. The most abundant taxon in the 2019 samples was *Homoeothrix*, a non-heterocystous cyanobacteria. *Homoeothrix* represented over 70% of the periphyton biovolume present in the river during this period. *Cladophora*, which was abundant in 2015–2016, was largely absent in 2019. The biomass of diatoms remained low and comprised only a minor portion of the periphyton biovolume. The leading hypotheses for the change in periphyton community composition in 2019 is that high flows in spring 2019 dislodged the previous heterocystous periphyton. However, nutrient concentrations were not measured in the spring of 2019, so it is unknown if spring nitrate concentrations were high, which could have contributed to more favorable conditions for *Homoeothrix.*

Introduction

Periphyton growth in rivers has been linked to a variety of factors including light, nutrient concentrations, invertebrate grazing, substrate composition, current velocity and flood-flow interval. The Lower Deschutes River (LDR) is notable for having a relatively stable flow regime (O'Connor & Grant 2003), a feature which facilitates abundant periphyton biomass. Furthermore, the reoccurrence interval for flood flow has been notably low over the last two decades and may be a contributing factor to abundant periphyton in the LDR (Eilers & Vache 2021). During the study conducted form 2015–2017 there were no major flood events, although a high discharge event of 9,970 cfs was observed at the ReReg tailrace on March 20, 2017. A greater high-flow event occurred on April 9, 2019 when peak discharge from the Project reached 11,600 cfs and flows at the mouth reached 25,100 cfs. This event raised the question about whether flows had been sufficient to cause a change in periphyton community composition or biomass in the LDR. As a result, PGE staff conducted monthly periphyton and water quality sampling of selected sites in the lower river from July–September 2019. This report summarizes the nutrient chemistry and periphyton community observed in summer 2019.

The report was issued in February 2020 and included periphyton data for the LDR provided by a contract laboratory that was determined to be incorrect after the final report was published. The report has been revised to reflect the corrected periphyton data provided by the laboratory in 2020.

Methods

A subset of sites from the 2015–2017 Water Quality Study were sampled in 2019 using the same field and analytical methods (Eilers &Vache 2021) (Table 1). Water samples were sent to the CCAL Laboratory at Oregon State University and the periphyton samples were sent to Rhithron Associates, Inc. Three samples were collected in duplicate and three field blanks were collected. All quality assurance samples were within normal tolerances. Nutrient concentrations are expressed as milligrams per liter (mg/L), periphyton biovolume expressed as cubic microns per square centimeter ($\mu m^3/cm^2$), and nitrogen to phosphorous ratios are expressed as mass.

Table 1. Sample sites in the LDR selected for sampling in 2019.

Site	Site ID	River Mile	River Kilometer	Latitude	Longitude
Reregulating Dam	1	100.1	161.1	44.72565	-121.247542
South Junction	5	83.3	134.0	44.869411	-121.058139
Ferry	9	62.5	100.6	45.062264	-121.119781
Sandy Beach	12	45.5	73.2	45.24045	-121.048969
Wreck	14	36.2	58.2	45.32146	-120.982923
Rattlesnake	16	29.6	47.6	45.345698	-120.93894
River Mouth	21	3.5	5.6	45.595342	-120.897506

Results

Hydrology

The long-term flows in the LDR are highly stable for a river of its size (O'Connor & Grant 2003). This stability can be attributed, in part, to the construction of several dams in the basin, and the high percentage of groundwater contribution to total discharge. Two relatively notable flow events have occurred in the LDR over the last five years, one in spring 2017 and one in spring 2019 (Figure 1). The event in 2017 resulted in a peak discharge of 9,970 cfs on March 20, 2017. The 2017 high flows were generated largely by flows upstream of the Project; consequently, the flows at the mouth of the river remained modest, reaching a maximum discharge of 13,700 cfs on March 19, 2017. The high-flow event in April 2019 produced a peak discharge of 11,600 cfs at the Madras gage and a peak flow of 25,100 cfs at the Moody gage, both on April 9, 2019. Although the April 2019 event was brief, it corresponded to greater flows throughout the lower basin. This is apparent when examining the maximum flows from the Warm Springs River, which were less than 2,000 cfs in 2017, but more than double that in 2019.

River temperatures for the study period show that maximum water temperatures were observed in 2015, and the coolest summer temperatures were observed in 2019 (Figure 2). Temperature differences between the Moody and Madras gages were similar among years, although the smallest differences between gages occurred in 2019.

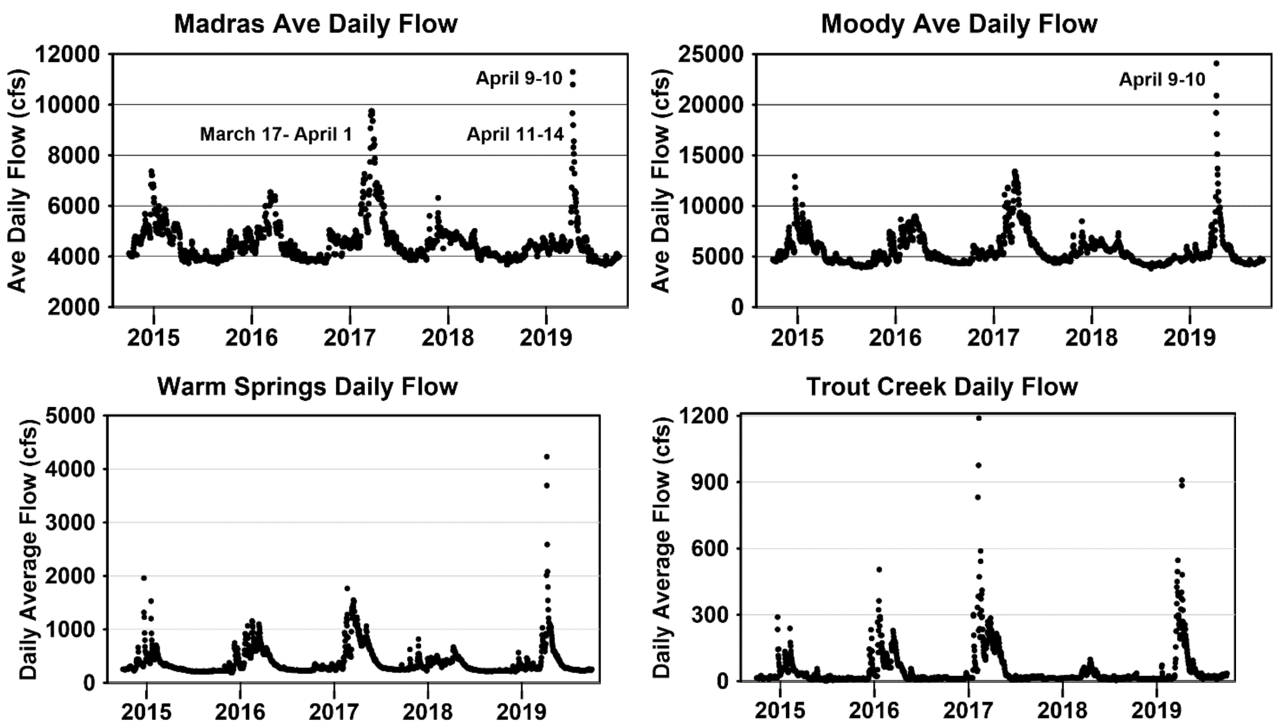

Figure 1. Daily average discharge measured at Madras (USGS #14092500), Moody (USGS #14103000), Warm Springs River (USGS #14097100) and Trout Creek (OWRD # 14095255) for WY 2015–2019.

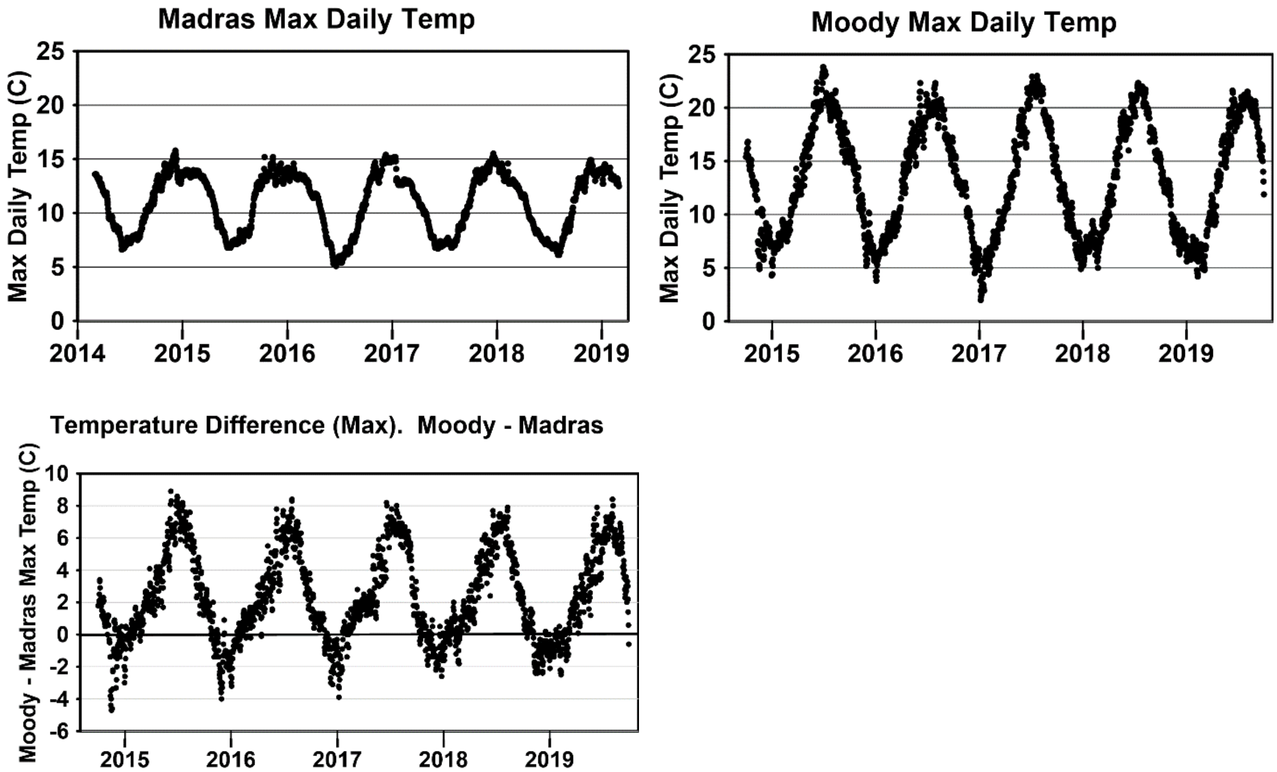

Figure 2. Maximum daily river temperature for Madras and Moody gages and the differences between measurements at Moody and Madras.

Water Chemistry

Concentrations of the major nutrients sampled in summer 2019 are presented in Table 2 and Figure 3. The results show substantial differences among the three summer months sampled with total phosphorus (TP), soluble reactive phosphorus (SRP) and nitrate (NO_3) exhibiting the greatest concentrations in September. Total nitrogen (TN) and ammonia (NH_3) showed the greatest concentrations in August. The general pattern of nutrients shows decreasing concentrations from the ReReg Dam to the mouth. This pattern is particularly evident for NO_3, which decreased up to 0.20 mg/L over the length of the river. The relatively high concentrations of phosphorus and more modest concentrations of nitrogen result in conditions where the entire river would be classified as N-limited based on N:P ratios shown in Figure 4. Mass ratio of total nitrogen (TN) to total phosphorus (TP) and soluble inorganic nitrogen (SIN) and soluble reactive phosphorus (SRP) for July, August and September 2019 in the LDR.

Early applications of N:P ratios in assessments of limiting nutrients employed total nitrogen and total phosphorus (Redfield et al. 1963). A better indicator of limiting nutrient concentrations for algal populations in freshwater is provided by comparing the more available forms of nitrogen and phosphorus: soluble forms of phosphorus (SRP) and soluble (also referred to as dissolved) inorganic nitrogen (SIN) (NO_3 + NH_3). The results of SIN:SRP show that values in 2019 are similar to those in other years (

Figure 5). The drought year of 2015 stands out as being most different from the results for the other three years.

The comparisons with results from other years by month show that the results measured in summer 2019 are similar to those measured in 2015–2017 (Figure 6 – Figure 10).

(a N:P ratio of 7.2 is considered the demarcation between N-limited and P-limited). Because nitrogen decreases more rapidly than does phosphorus, the N:P ratios also decrease downstream. The abundance of phosphorus in the LDR means that periphyton in the river is clearly not P-limited. However, that does not necessarily mean that it is inevitable that the river is therefore N-limited because other factors such as light limitation cannot be excluded as limiting periphyton growth.

Table 2. Nutrient chemistry from samples collected in 2019. Duplicate and blank sample results are not presented. All nutrient concentrations are expressed in mg/L.

Site Name	Site ID	River Mile	Sample Date	TP	SRP	NH_3	NO_3	TN
ReReg Dam	LDR01	100.1	7/18/2019	0.073	0.041	0.022	0.200	0.37
			8/12/2019	0.081	0.051	0.037	0.248	0.49
			9/23/2019	0.091	0.076	0.026	0.265	0.41
South Junction	LDR05	83.3	7/18/2019	0.061	0.033	0.019	0.129	0.33
			8/12/2019	0.075	0.051	0.022	0.216	0.40
			9/23/2019	0.085	0.071	0.017	0.239	0.38
Ferry	LDR09	62.5	7/15/2019	0.066	0.040	0.018	0.154	0.37
			8/13/2019	0.070	0.045	0.018	0.198	0.41
			9/24/2019	0.084	0.043	0.015	0.079	0.38
Sandy Beach	LDR12	45.5	7/16/2019	0.065	0.038	0.020	0.110	0.32
			8/15/2019	0.075	0.051	0.025	0.186	0.40
			9/25/2019	0.089	0.071	0.019	0.227	0.38
Wreck	LDR14	36.2	7/15/2019	0.063	0.036	0.014	0.096	0.31
			8/13/2019	0.079	0.056	0.017	0.187	0.40
			9/24/2019	0.098	0.070	0.015	0.202	0.35

Rattlesnake	LDR16	29.6	7/15/2019	0.065	0.035	0.013	0.084	0.32
			8/13/2019	0.078	0.058	0.018	0.191	0.39
			9/24/2019	0.092	0.071	0.016	0.204	0.35
River Mouth	LDR21	3.5	7/16/2019	0.058	0.028	0.014	0.048	0.28
			8/15/2019	0.075	0.054	0.020	0.143	0.33
			9/25/2019	0.085	0.068	0.017	0.172	0.34

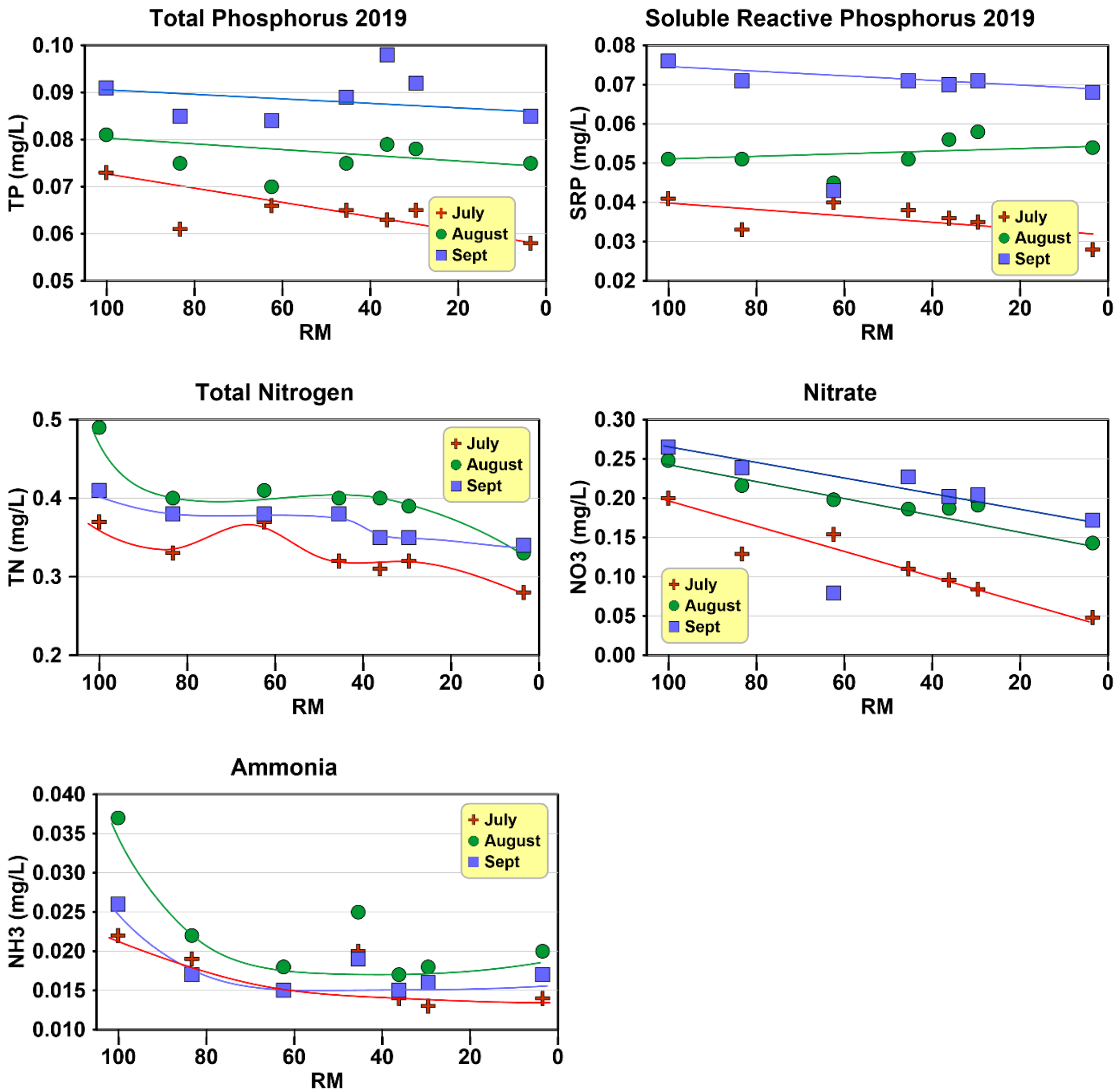

Figure 3. Nutrient concentrations measured at seven stations in the LDR during July, August and September 2019.

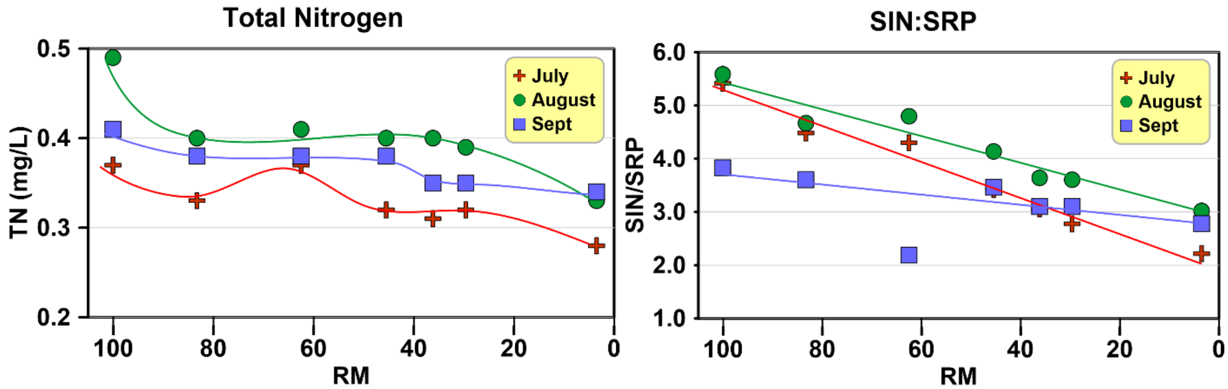

Figure 4. Mass ratio of total nitrogen (TN) to total phosphorus (TP) and soluble inorganic nitrogen (SIN) and soluble reactive phosphorus (SRP) for July, August and September 2019 in the LDR.

Early applications of N:P ratios in assessments of limiting nutrients employed total nitrogen and total phosphorus (Redfield et al. 1963). A better indicator of limiting nutrient concentrations for algal populations in freshwater is provided by comparing the more available forms of nitrogen and phosphorus: soluble forms of phosphorus (SRP) and soluble (also referred to as dissolved) inorganic nitrogen (SIN) (NO_3 + NH_3). The results of SIN:SRP show that values in 2019 are similar to those in other years (

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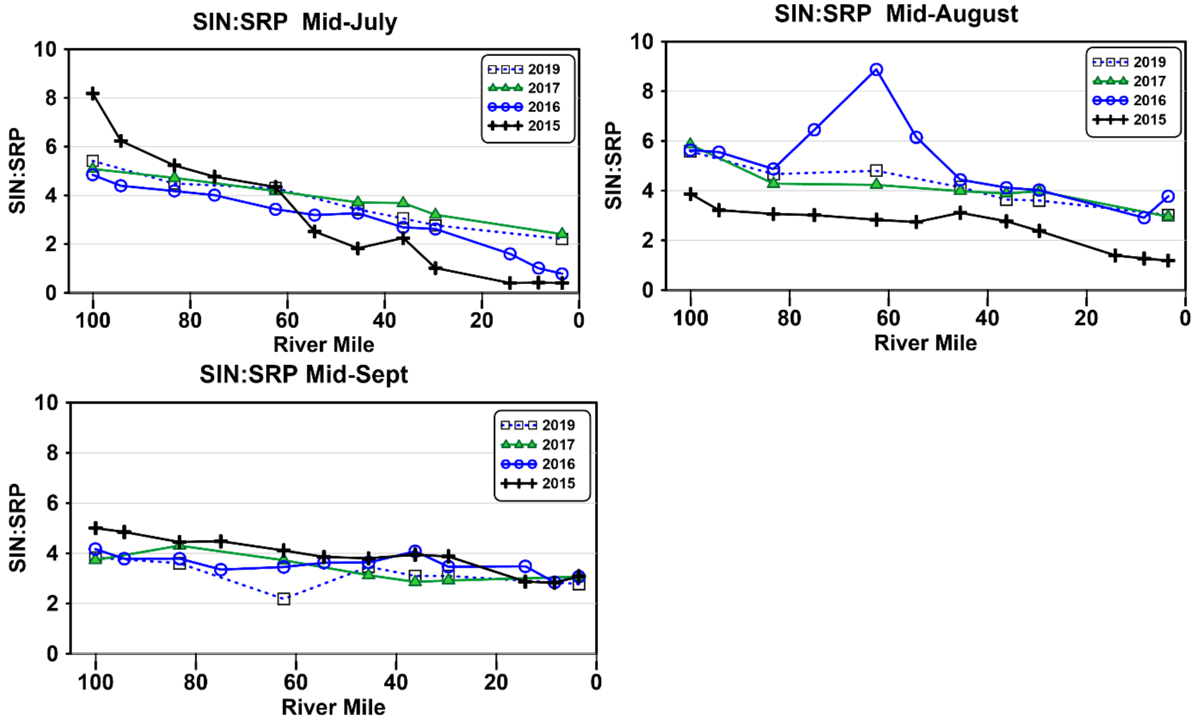

Figure 5. Mass ratio of soluble inorganic nitrogen and soluble reactive phosphorus for July, August and September 2019 for the LDR.

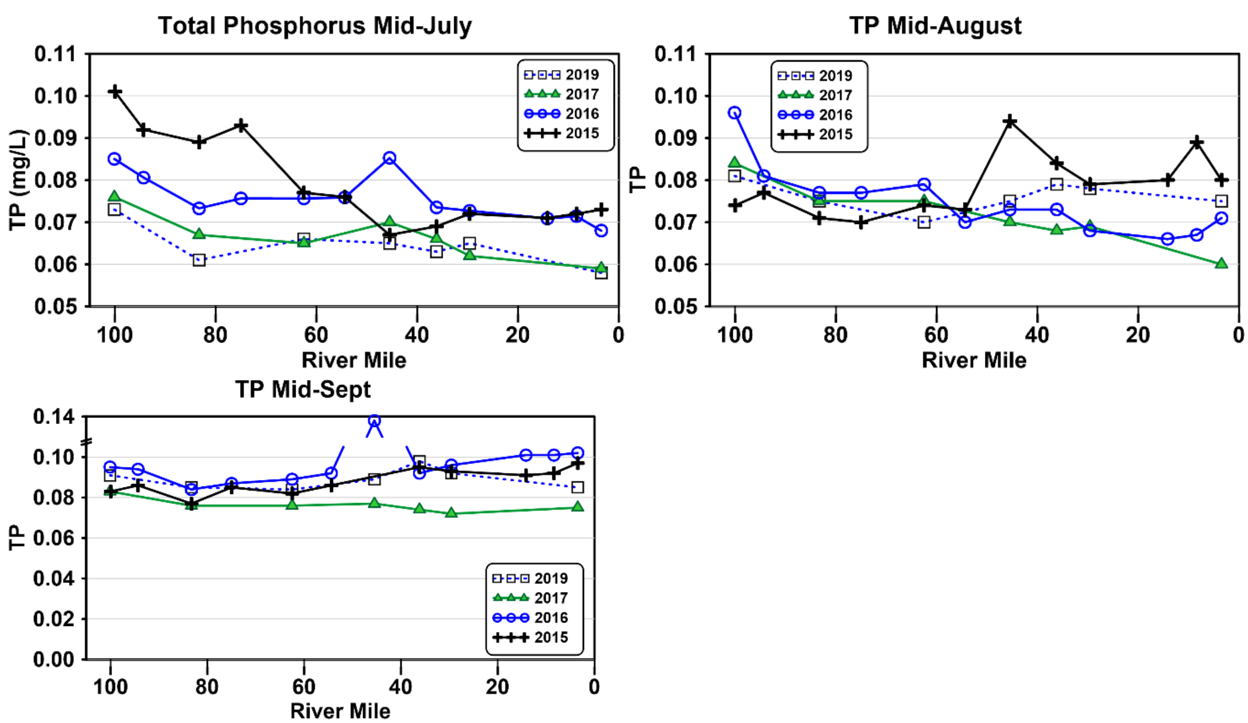

Figure 6. Concentrations of total phosphorus (mg/L) for July, August and September for 2015–2017 and 2019 in the LDR.

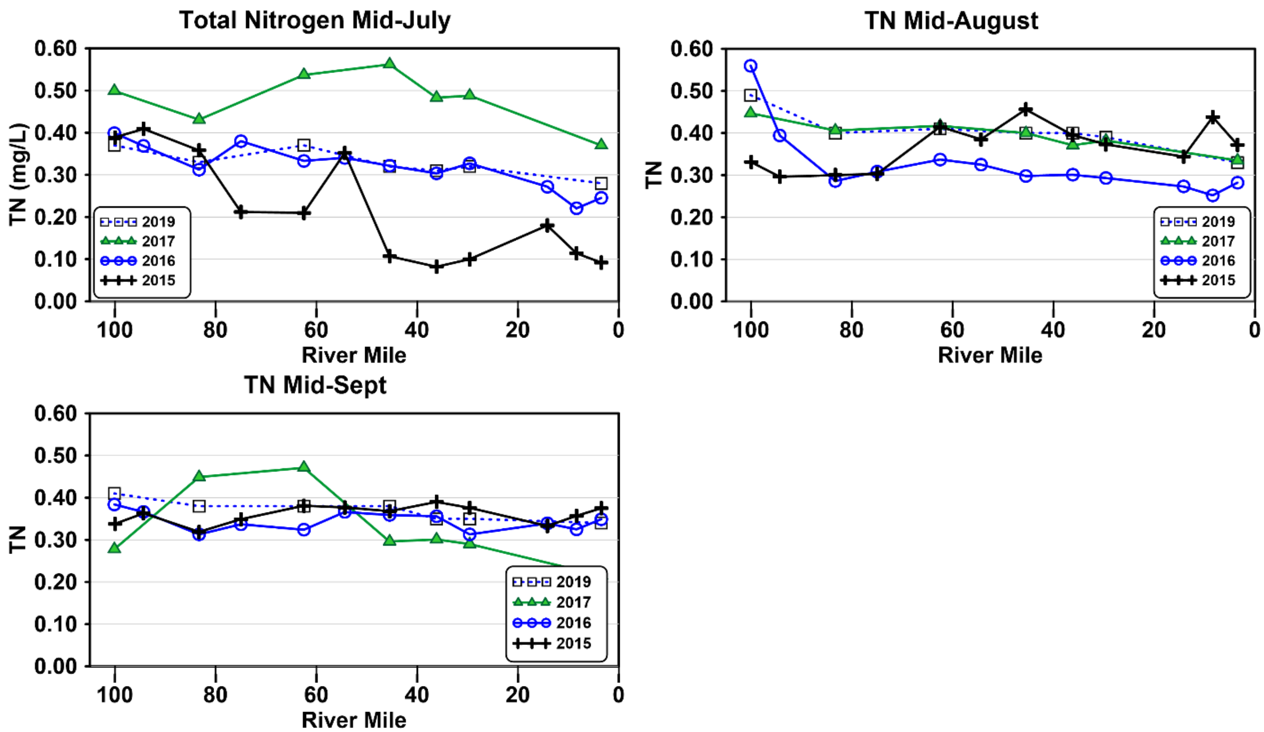

Figure 7. Concentrations of total nitrogen (mg/L) for July, August and September for 2015–2017 and 2019 in the LDR.

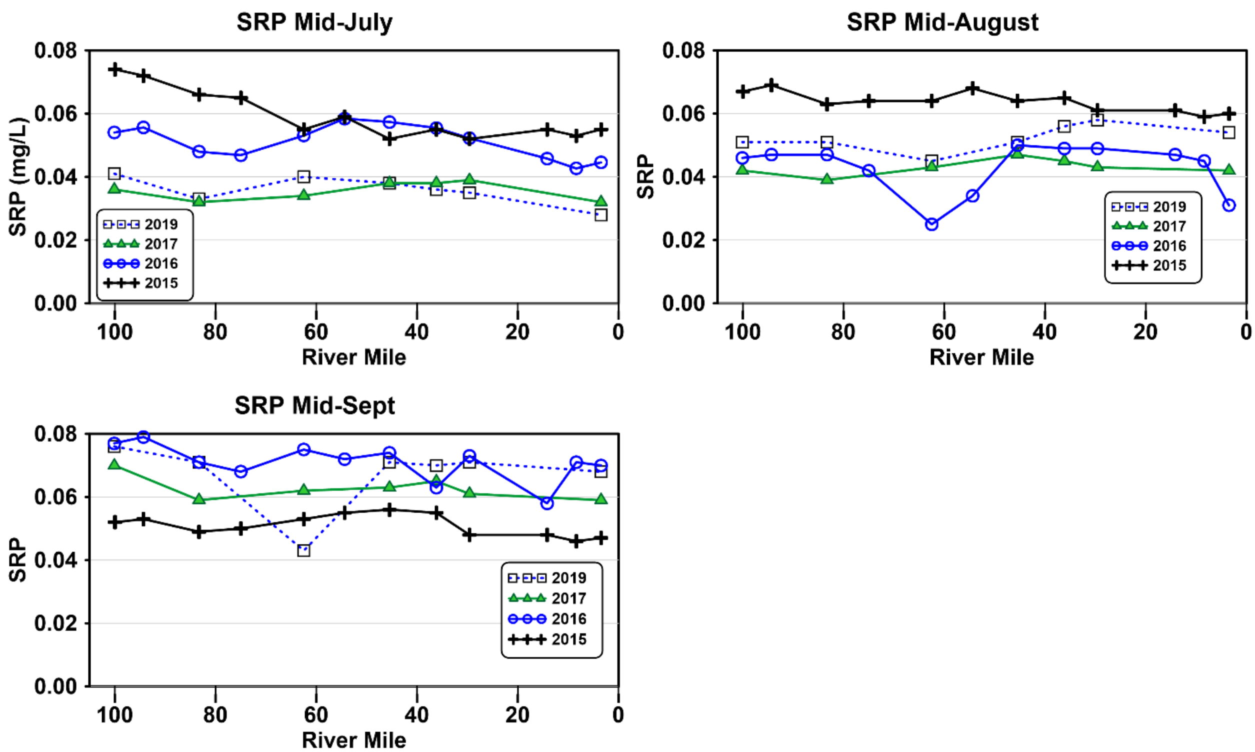

Figure 8. Concentrations of soluble reactive phosphorus (mg/L) for July, August and September for 2015–2017 and 2019 in the LDR.

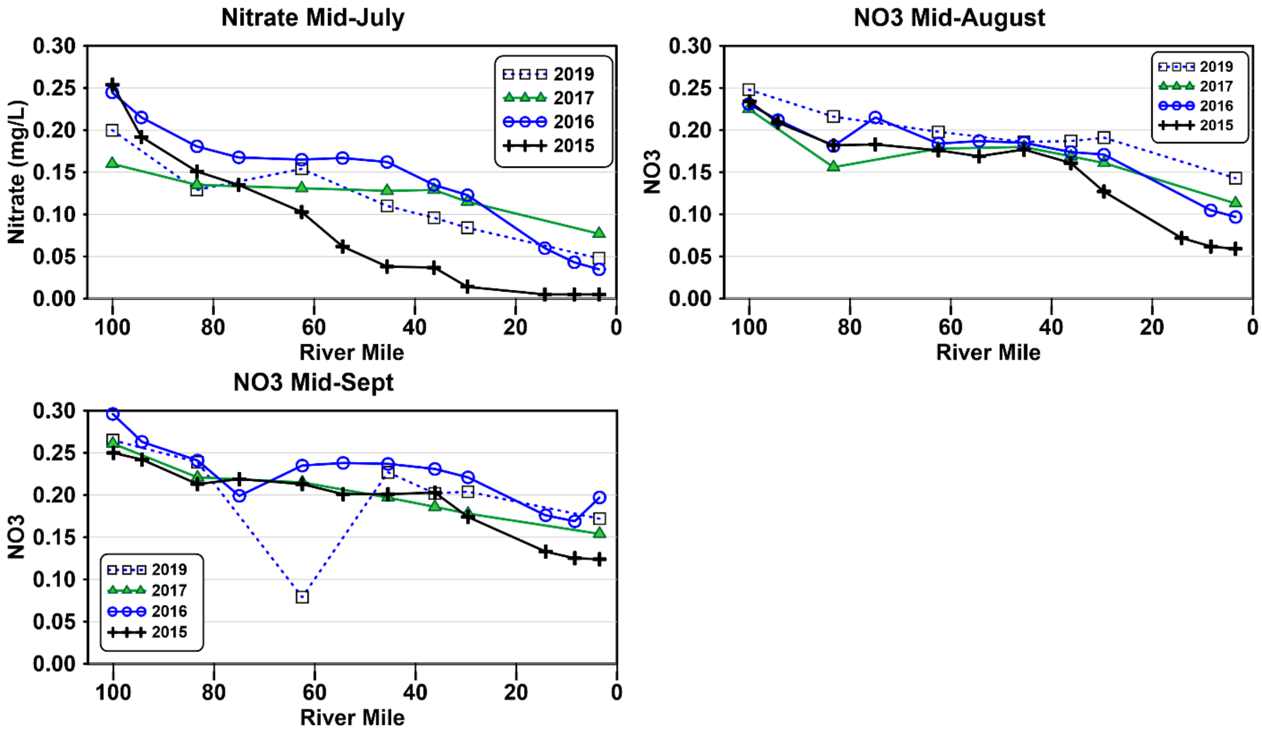

Figure 9. Concentrations of nitrate (mg/L) for July, August and September for 2015–2017 and 2019 in the LDR.

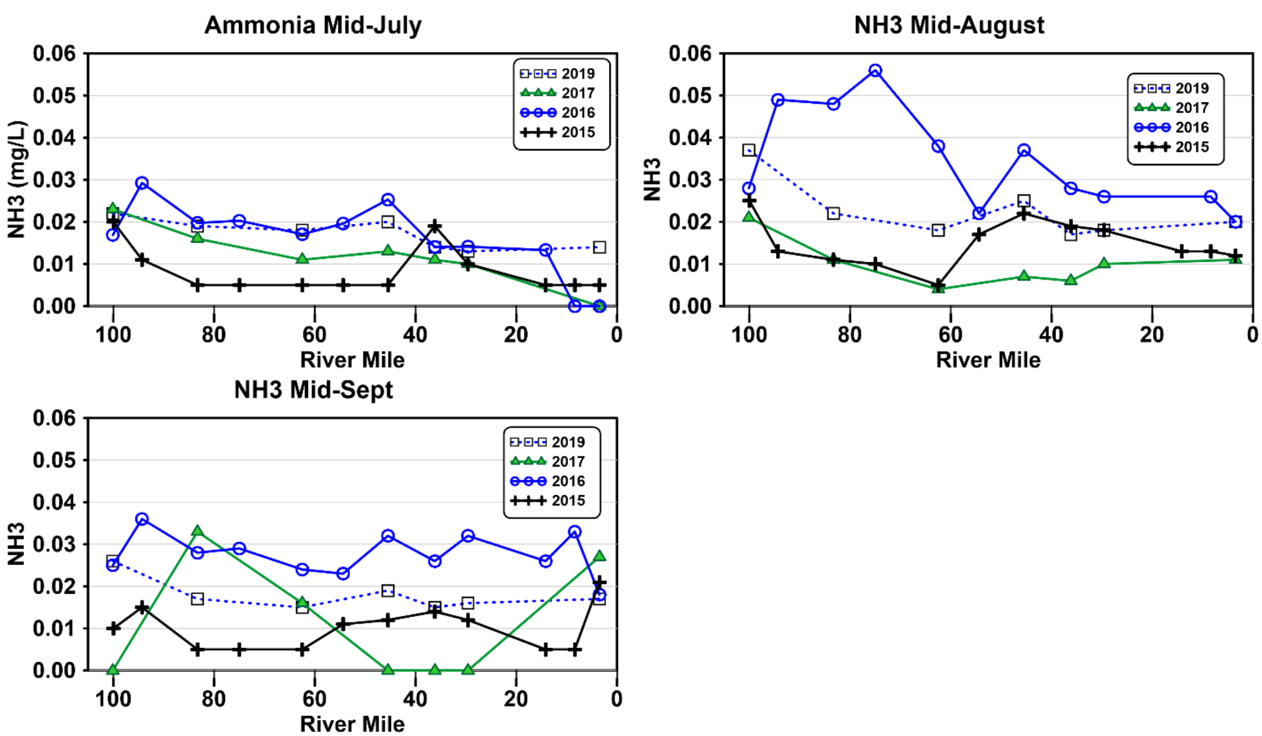

Figure 10. Concentrations of ammonia (mg/L) for July, August and September for 2015–2017 and 2019 in the LDR.

Periphyton

The dominant periphyton genera in the LDR during 2019 (i.e., those taxa with biovolumes greater than 1% of the total biovolume) are represented by seven taxa (Table 3). All other taxa comprised less than 1% of the total periphyton abundance. The most dominant taxon was the cyanophyte *Homoeothrix*, which represented over 70% of the total biovolume in the periphyton community (Figure 11). This represents a major change in dominant taxa from 2015 and 2016 in which *Cladophora* was the overwhelming dominant alga. *Homoeothrix* is a non-heterocystous taxon, whereas the next abundant cyanophyte, *Calothrix*, is heterocystous. Three diatom taxa were among the more abundant taxa present in the periphyton: *Gomphoneis*, *Cymbella* and *Nitzschia*. These are common genera and are best characterized at the species level regarding their habitat preferences. Only one green alga, *Stigeoclonium*, represented more than 1% of total periphyton biovolume. *Stigeoclonium* is a filamentous chlorophyte, and it seldom becomes as dominant as *Cladophora*. *Stephanodiscus niagarae*, a dominant centric diatom in the phytoplankton of Lake Billy Chinook, continued to be attached to the periphyton community in notable quantities, with a total biovolume of 2.73x10 $\mu m^3/cm^2$ and was the 13th most abundant genera in the periphyton in spite of its planktonic origins.

Table 3. Dominant periphyton genera in the LDR in summer 2019.

Genus	Group	Total Biovolume ($\mu m^3/cm^2$)	Percent of Total
Homoeothrix	Cyanophyta	3.44x10	70.6
Gomphoneis[a]	Diatom	3.53x9	7.2
Calothrix	Cyanophyta	2.52x9	5.2
Cymbella[b]	Diatom	1.77x9	3.6
Nitzschia	Diatom	1.32x9	2.7
Stigeoclonium	Chlorophyta	9.76x8	2.0
Phormidium	Cyanophyta	9.41x8	1.9

[a] Dominant species included *Gomphoneis eriense, Gomphoneis mammilla, Gomphoneis minuta, Gomphoneis olivaceum*

[b] Dominant species included *Cymbella affinis, Cymbella compacta, Cymbella janischii, Cymbella mexicana, Cymbella neocistula, Cymbella perfossilis, Cymbella subturgidula*

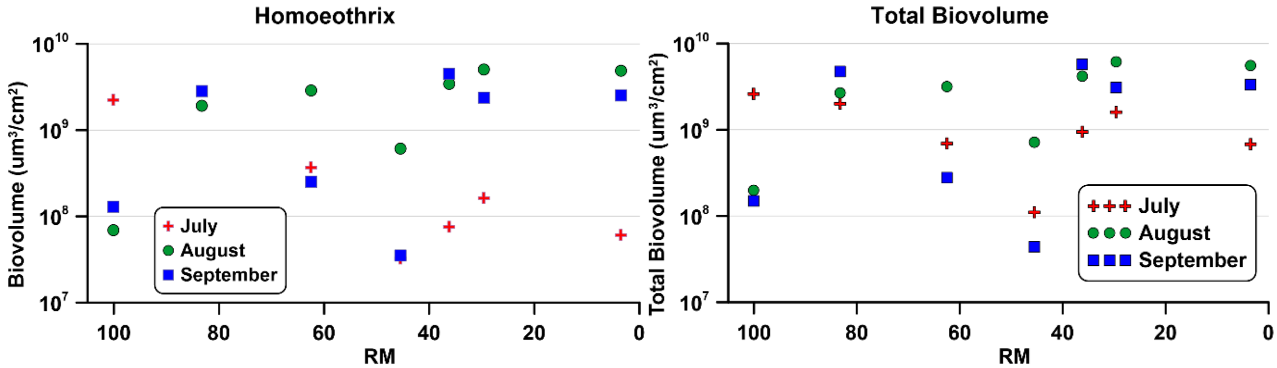

Figure 11. Total biovolume of *Homoeothrix* (*left*) compared with total periphyton biovolume (*right*) in the LDR in 2019.

Comparison of the total periphyton biovolume from 2019 with results from 2015–2017 shows that the 2019 results are similar to those previously measured (Figure 12). Although though there is considerable variability in periphyton biovolume at individual sites, a typical value of about 10^9 $\mu m^3/cm^2$ is a reasonable biovolume estimate for what is generally observed in the LDR.

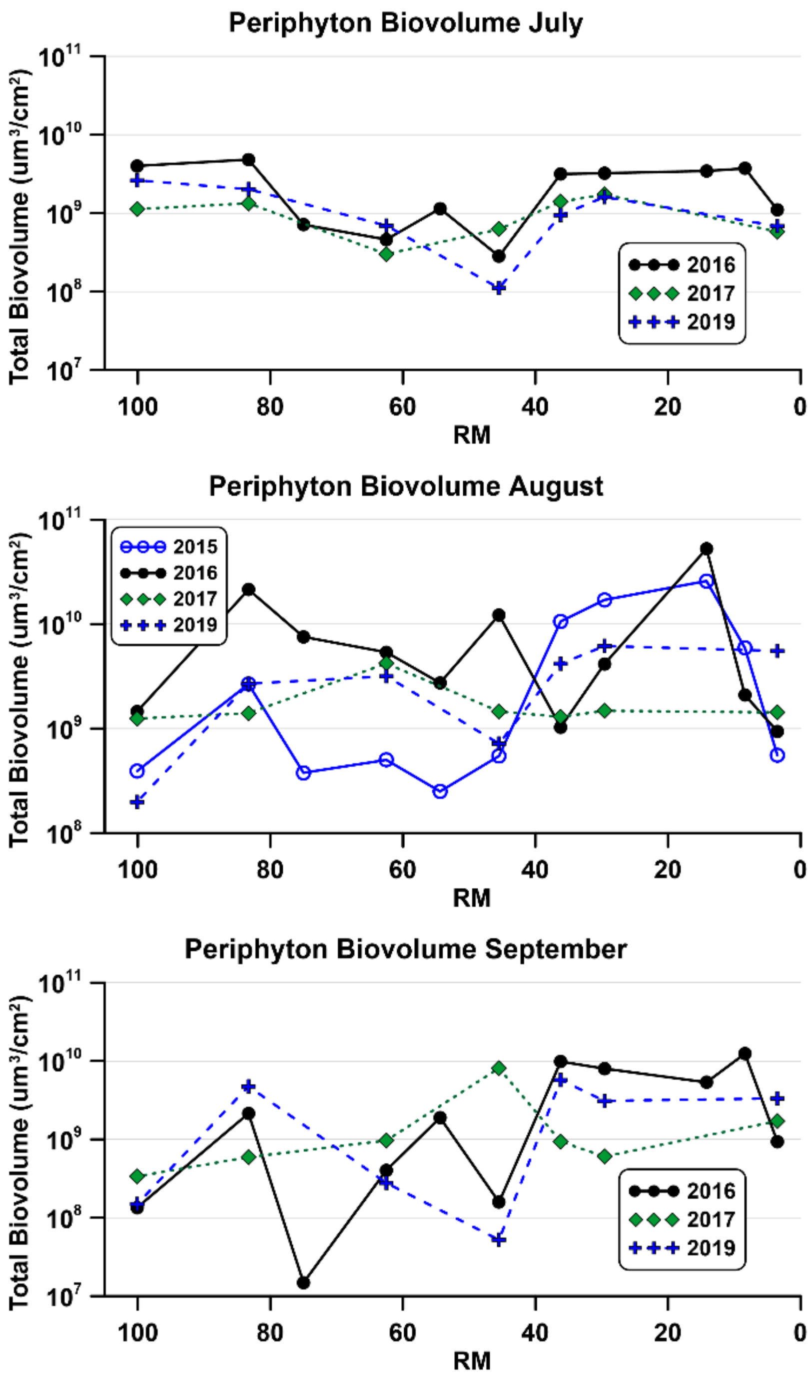

Figure 12. Total periphyton biovolume ($\mu m^3/cm^2$) for available years in July, August and September in the LDR.

Discussion

The results of the 2019 water quality sampling showed that nutrient concentrations were similar in summer 2019 and the three previous summers. However, we do not know how nutrient concentrations may have changed in the spring of 2017 and 2019. Despite the lack of change in summer water chemistry, there was a major shift in periphyton taxa between the two periods. The periphyton community from 2015–2016 was dominated by the filamentous green algae, *Cladophora*, whereas in 2019 the overwhelmingly dominant taxon was the cyanophyte *Homoeothrix*, a non-heterocystous taxon. Non-heterocystous taxa cannot fix nitrogen from the atmosphere and therefore they must acquire nitrogen from the water. The dominance of non-heterocystous taxa in 2019 suggests that inorganic nitrogen in the spring was present in sufficient concentrations to allow non-heterocystous taxa to become dominant. Grimm & Fisher (1986) concluded that inorganic nitrogen became limiting at nitrate concentrations less than 0.055 mg/L in a Sonoran Desert stream. Gillett et al. (2016) also noted that the fraction of N-fixing periphyton increased greatly when the concentration of nitrate was less than 0.06 mg/L in the Klamath River, a strong indication of N-limitation. Concentrations of nitrate in the LDR reached a minimum of 0.048 mg/L in the summer of 2019, but the minimum soluble inorganic nitrogen was 0.062 mg/L. These results suggest that nitrogen was seldom limiting to the periphyton community in summer 2019; however, it is unknown if concentrations of inorganic nitrogen were low in spring 2019 or if the periphyton community composition changed greatly from spring to summer of 2019.

The data from 2015–2016 showed that nitrate concentrations reached low levels in April through June of each year and rebounded in summer (Eilers and Vache 2021) (Figure 13). Concentrations measured in the spring below RM 40 exhibited particularly low values, either equal to or less than the critical minimum values reported by Grimm & Fisher (1988) and Gillett et al (2016) as N-limiting. If this pattern is representative of other years, then it is essential that spring nitrate concentrations be measured to assess the degree to which the LDR is N-limited. Therefore, the leading hypothesis for the change in periphyton community composition in 2019 based on the available data is that high flows in spring 2019 dislodged the previous heterocystous periphyton. It is possible that the flows in spring 2019 had elevated concentrations of nitrogen (nitrate) which could have promoted favorable conditions for other non-heterocystous taxa (such as *Homoeothrix*) to become dominant. However, water quality samples were not collected in the spring of 2019, preventing evaluation of this alternative hypothesis.

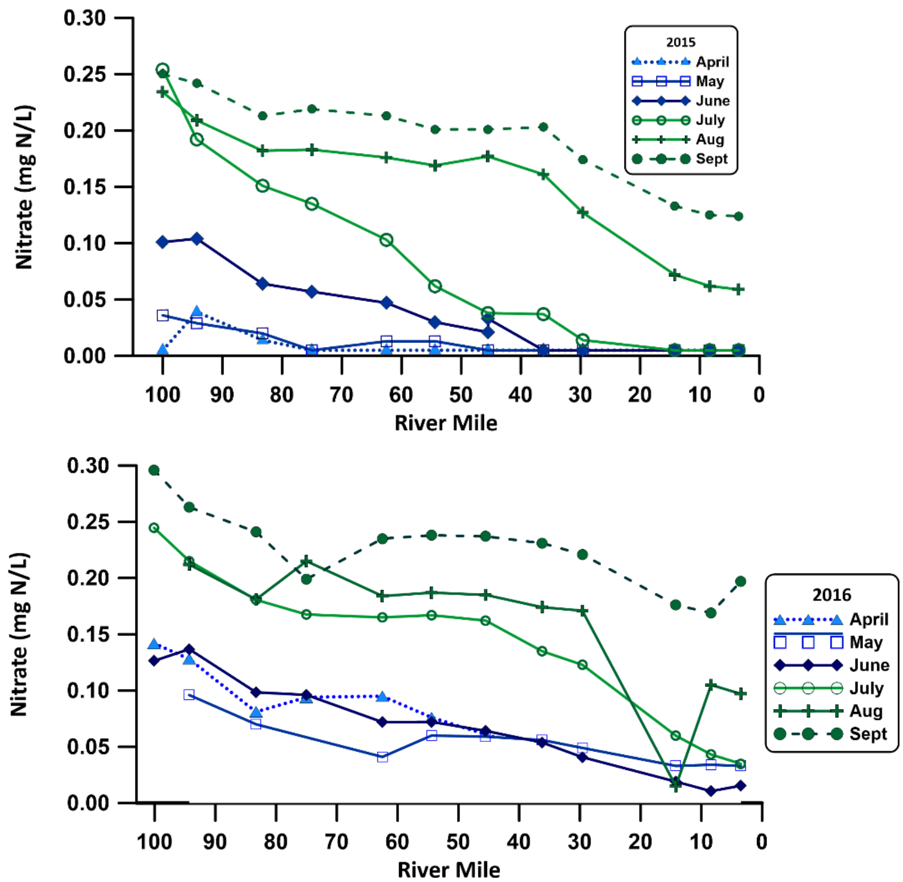

Figure 13. Concentrations of nitrate in the LDR during spring (blue) and summer (green) 2016.

The reason for the wholesale change in periphyton community composition in the LDR is not fully understood at this point. *Homoeothrix* appears to be relatively common in the United States (Potapova 2005) and it has been described in benthos from rapidly flowing “unpolluted”, mountain streams (Wehr et al. 2015). Potapova (2005) observed that *Homoeothrix* had relatively low optima for phosphorus, ammonia, and organic nitrogen, but moderately high optima for nitrate and TN based on the National Water-Quality Assessment (NAWQA) data set. The phosphorus preferences do not match the higher phosphorus concentrations in the LDR, but the preference for elevated nitrate is consistent with the higher nitrate concentrations in the LDR, especially in 2017 and 2019. *Homoeothrix* was found to be more prevalent in NAWQA sites with high channel gradients and large rocky substrate. Komárek and Anagnostidis (2005) indicated that *Homoeothrix janthina* is a lotic taxon with worldwide distribution. The cyanophytes *Calothrix* and *Phormidium* were among the more abundance taxa in the 2019 periphyton samples. The water quality preferences for *Calothrix* in the NAWQA data showed that *Calothrix* was present in relatively high quality waters, although those with elevated concentrations of nitrate (Potapova 2005). Other researchers have characterized *Calothrix* as an indicator of clean waters (Palmer 1959; Sládecek 1973). *Phormidium* on the other hand has been characterized as a pollution-tolerant taxon (Sládecek 1973). *Cladophora* was virtually absent in the 2019 samples, but another filamentous chlorophyte, *Stigeoclonium*, was present. *Stigeoclonium* is commonly listed as a pollution-tolerant alga (Palmer 1959; Sládecek 1973; Palmer 1975), although Biggs (1996) indicated that *Stigeoclonium* was characteristic of low-nutrient streams in New Zealand. The NAWQA sites indicated that *Stigeoclonium* preferred open channels and high current velocities (Potapova 2005), both features consistent with the physical habitat of the LDR.

One hypothesis for the reduction in *Cladophora* is that high spring flows in 2017 and 2019 increased shear stress to dislodge these algae (Figure 14). The data show a strong correlation of peak spring flow with reduction of *Cladophora* biovolume in the LDR. Whether this is the primary driver for the observed changes in *Cladophora* is uncertain, however, the increased river velocity corresponds with observations by others regarding the susceptibility of this alga to removal at high flows (Biggs 1996).

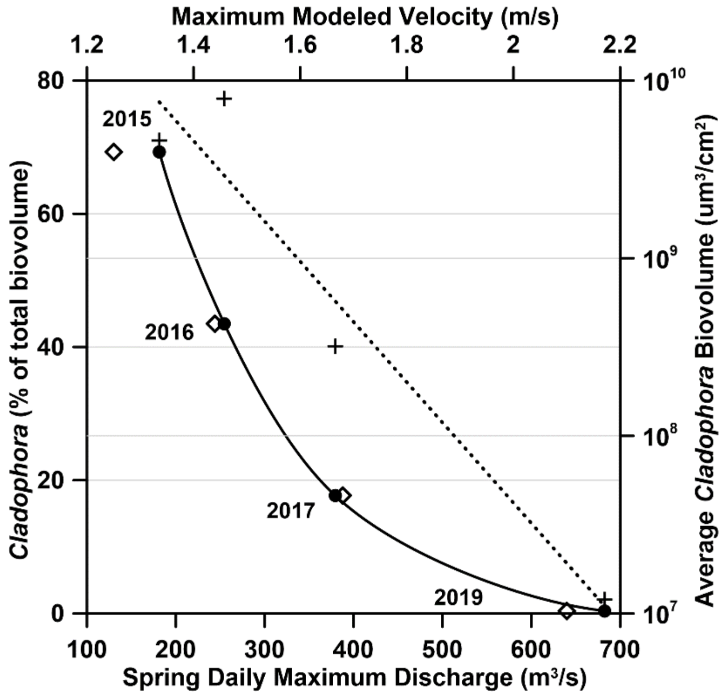

Figure 14. Spring daily maximum discharge (at Moody) versus percent of total biovolume of Cladophora (●) and modeled river velocity versus percent of total Cladophora biovolume (◇). Spring daily maximum discharge versus average annual biovolume of Cladophora (+) in the LDR from 2015 to 2019.

Conclusions

The nutrient chemistry in the LDR during summer 2019 was similar to concentrations observed during the summers of 2015–2017, however, it is unknown if there may have been differences in nitrate concentrations during the spring of 2019 compared to 2015–2017 previous years that could have contributed to differences in periphyton communities. The periphyton data from 2019 shows a major departure from the community observed in 2015–2016 in which *Cladophora* was dominant. The 2019 periphyton data shows *Homoeothrix* as the overwhelming dominant taxon, representing over 70% of the biovolume in the LDR. *Homoeothrix* has been associated with unpolluted sites. The biovolume of N-fixing periphyton taxa decreased considerably from 2015–2017 to 2019, yet there was no discernible change in nitrate or ammonia concentrations during summer between the two time periods. However, the high flow event in 2019 may have contributed to greater concentrations of nitrate in the LDR which favored *Homoeothrix* growth in the spring.

Although the study results document differences in periphyton community in the summer of 2019 with periphyton sampled in 2015–2017, the results do not allow for one to draw definitive conclusions regarding the immediate effect of the high spring discharge on the summer periphyton community. Assessing the effects of high discharge on the periphyton community requires the periphyton to be sampled shortly before and immediately after the high discharge. To measure the rate of periphyton regrowth, periphyton should be sampled at regular intervals following the event. Additionally, a future sampling study to examine possible changes in periphyton community composition should include sampling nutrients in the spring in addition to in the summer.

Acknowledgments

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