Distribution of Rooted Aquatic Plants and Filamentous Algae in the Klamath River, CA

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For the Klamath Tribal Water Quality Consortium

26 October 2020

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Summary

The middle and lower reaches of the Klamath River flow 190 miles from Iron Gate Dam to the Pacific Ocean. The river is subject to seasonally high nutrient concentrations, warm water temperatures, and hydrologic alteration from dams, resulting in extensive growth of rooted aquatic plants and filamentous algae. Despite acknowledgement that prolific algal and plant growth degrades water quality, fish habitat, and native fishing practices, no previous studies have quantified rooted aquatic plant and filamentous algae distribution in the Klamath River below Iron Gate Dam. Documenting patterns of algae and aquatic plant growth can lead to mechanistic understanding of how physical and chemical factors influence biological structure in the river, and will help inform expectations of how aquatic vegetation will change following dam removal.

In June and July of 2019 and 2020, we conducted wading and snorkeling surveys of rooted aquatic plants and filamentous algae at 11 and 10 reaches (2019 and 2020, respectively) in the Klamath River. At each reach, we surveyed six transects in variable habitats. At each transect, we surveyed the river cross section at 11 evenly divided points where we estimated the percent cover of filamentous algae and rooted aquatic plants, as well as water depth, substrate type, and plant and algae characteristics.

Rooted aquatic plants in the Klamath River displayed a longitudinal pattern below Iron Gate Dam, while patterns in filamentous algae were more complex. Highest coverage of rooted aquatic plants were observed at sites closest to Iron Gate Dam in both years, and decreased with distance downstream from the dam. Percent cover of filamentous algae did not follow a distinct longitudinal pattern, although dominant algal taxa shifted, with *Ulothrix* dominant at sites closer to Iron Gate Dam and *Cladophora* dominant at sites below the Scott River.

Differences in river flows between 2019 and 2020 likely influenced algal and rooted aquatic plant cover between years. 2019 was a wet year in the Klamath Basin, with multiple winter and spring floods and later onset of summer low-flow conditions, while 2020 had very few winter and spring high flow events and earlier onset of summer low-flows. The coverage of rooted aquatic plants was higher in 2020 at all sites, with increased coverage attributed primarily to a single species of rooted aquatic plant. Similar patters of filamentous algal coverage were present between years, but coverage of *Cladophora* was lower in 2020 surveys, likely due to the surveys being conducted after *Cladophora* peak biomass. Flows are likely a major driver of primary producer biomass and composition, with both the

timing and magnitude of winter flushing flows and the timing and magnitude of summer low-flow onset influencing the community composition, spatial distribution, and seasonal timing of primary producer assemblages in the Klamath River.

Further research documenting the spatial and temporal patterns of primary producer assemblages will help explain patterns of ecosystem scale productivity and water quality dynamics in the Klamath River. Documenting primary producer assemblages under a range of water-year conditions prior to dam removal will provide baseline data on the range of conditions that exist on the Klamath River with dams in place.

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1 Introduction

Algae and aquatic plants are essential parts of river ecosystems. The growth of algae and aquatic plants provides an important basis for aquatic food webs, influences water quality, provides habitat for fish, and controls carbon cycling (Hall et al., 2001; Vadeboncoeur and Power, 2017; Genzoli and Hall, 2016; Nichols et al., 2020). Land use and direct alterations to rivers are associated with widespread increases in algae growth rates and biomass (Griffiths et al., 2013; Davis et al., 2012; Sabater et al., 2018). This increase in primary productivity and biomass of algae and aquatic plants, termed eutrophication, is a growing problem to freshwater ecosystems (Smith et al., 2006; Sinha et al., 2017). Eutrophication can degrade water quality and fisheries health by causing large daily fluctuations in pH and dissolved oxygen, promoting toxin-producing species, and altering aquatic food webs (Genzoli and Hall, 2016; Paerl et al., 2018; Power et al., 2015).

The middle and lower Klamath River, flowing 190 miles from the outflow of Iron Gate Dam to the Pacific Ocean, is subject to high nutrient concentrations, warm water temperatures, and hydrologic alteration from dams (Oliver et al., 2014; David et al., 2018), resulting in extensive growth of rooted aquatic plants and filamentous algae. Despite acknowledgement that prolific algal and plant growth can degrade water quality, promote salmon parasites, and disrupt indigenous fishing practices (Malakauskas et al., 2013; Genzoli and Hall, 2016), no previous studies have described patterns of rooted aquatic plants or filamentous algae growth in the Klamath River below Iron Gate Dam.

In the Klamath River, the series of hydroelectric dams that end at river mile 190 stabilize flow and substrate below these dams, with the river becoming less stable with distance downstream from the dams as the river receives inputs of water and sediments from many large, unregulated tributaries. The discontinuity associated with the dams and subsequent longitudinal changes, both due to dams and geographic conditions, provide a gradient of flow and bed stability that is expected to influence filamentous algae and rooted aquatic plant assemblages (Merz et al., 2008; Abati et al., 2016). Documenting the spatial distribution, interannual variability, and relative coverage of aquatic plants and filamentous algae provides a framework for further research aimed at understanding how high rates of growth influence water quality and fisheries health. Based on longitudinal gradients and observations from fisheries and water quality professionals, we predicted that rooted aquatic plants would cover large areas of streambed closer to Iron Gate Dam and that coverage would attenuate downstream with distance from the dam.

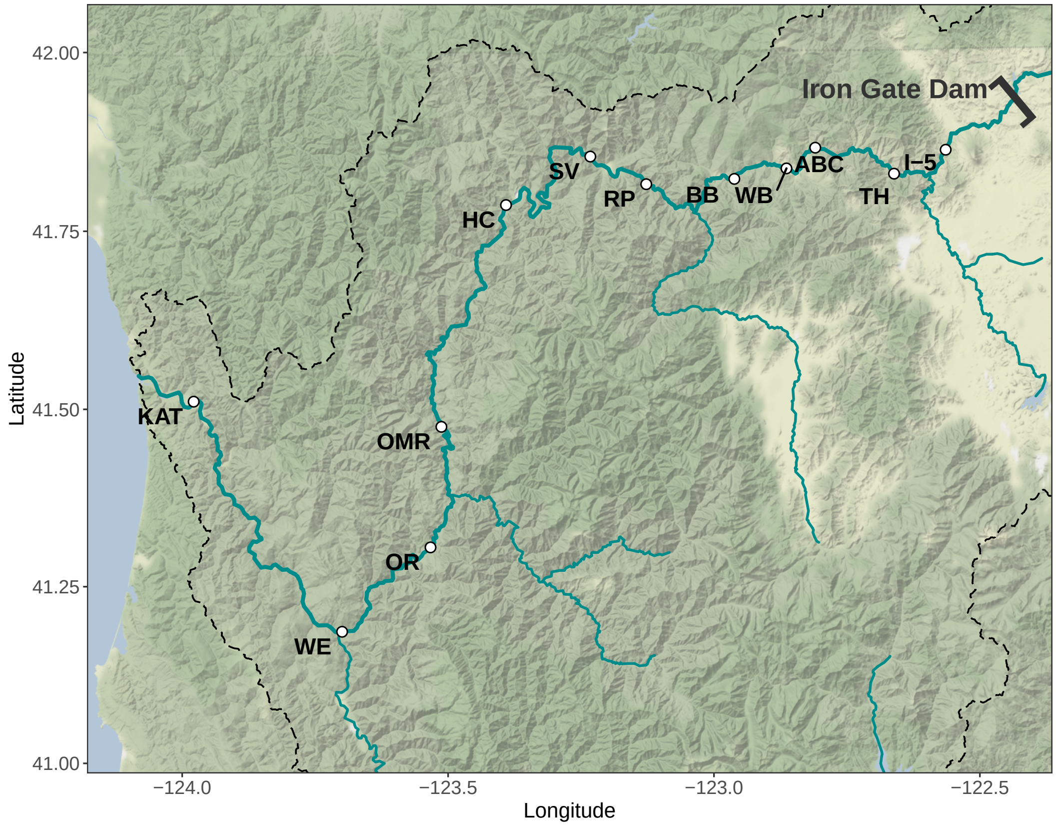


Figure 1. Map of filamentous algae and aquatic plant survey sites along the Klamath River, CA.

2 Methods

We conducted surveys for rooted aquatic plants and filamentous algae at 11 reaches (Figure 1, Table 1) in the Klamath River between Iron Gate Dam and the Klamath Estuary in 2019 and 2020. We conducted surveys between 26 June and 1 August 2019, and again between 1–17 of July, 2020. We surveyed reaches starting at the reach closest to Iron Gate Dam, and ending near the river mouth. In 2019, we surveyed the final reach (Klamath near Klamath Glen) two weeks after the other surveys because higher flows at this reach persisted through July, and would have made for challenging survey conditions. All reaches were surveyed in both years except the reach near Stanshaw Creek (OMR), which was only surveyed in 2019, and Above Beaver Creek (ABC, surveyed in 2019), which we moved to a reach below Beaver Creek, starting at the Klamath Community Center, and ending at Walker Bridge (WB, surveyed in 2020).

Table 1. Aquatic vegetation reach locations from 2019 and 2020 surveys. The latitude and longitude are reported for the downstream (6th) transect of each reach. River mile is approximate, and measured from the river mouth.

Site Name	Site Code	End Latitude	End Longitude	River Mile	Quadrants Surveyed	
					2019	**2020**
Above I5-Bridge	I-5	41.8642	122.56434	179	43	53
Tree of Heaven	TH	41.83071	122.66141	172	53	59
Above Beaver Cr	ABC	41.86707	122.80956	161	55	NA
Walker Bridge	WB	41.83807	122.8637	158	NA	64
Brown Bear	BB	41.82336	122.96172	150	56	65
Rocky Point	RP	41.81597	123.12736	136	53	63
Below Seiad Valley	SV	41.85465	123.23254	128	62	64
Happy Camp	HC	41.78677	123.39106	108	60	63
Stanshaw Creek	OMR	41.47537	123.51257	76	55	NA
Orleans	OR	41.30549	123.533	59	58	65
Weitchpec	WE	41.18631	123.69928	43	55	63
Klamath at Klamath Glen	KAT	41.5108	123.9784	6	62	60

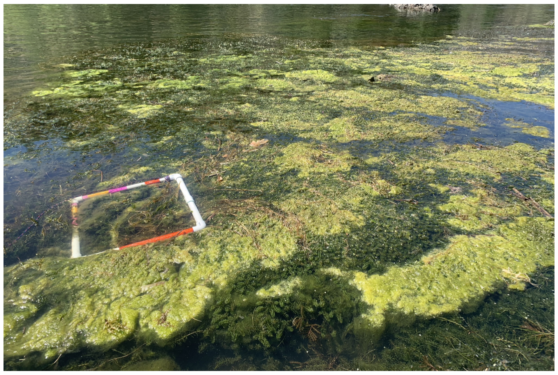
At each of the 11 reaches, we surveyed the riverbed to assess the coverage of aquatic vegetation. Reaches ranged from 1–8 km in length, based on river access points. We used kayaks to float the 11 reaches, surveying six transects in each reach, with transects randomly chosen among variable habitats represented in the reach. Each transect was a minimum of 100 m downstream from the previous transect, and attempts were made to survey transects with more pool-type and riffle-type characteristics. Areas of rapids and swift current were under represented in surveys due to safety concerns and general inability of a surveyor being able to access these swift sections. Along some transects, individual quadrants were not surveyed due to especially swift or deep points along a transect. At all transects, a minimum of seven quadrants were surveyed. We attempted to balance transect selection between what was possible to survey safely, and what was representative of the reach, and thus had to select transects in the field while conducting the first year of surveys. For the second year of surveys, we attempted to survey in the same river locations as the previous year, by navigating to the transect edge based on the latitude and longitude collected the previous year. No transects were fully wadeable across the river, confirming that the mixed survey method of wading and snorkeling was necessary. Each survey reach took one day to complete.

At each transect, we recorded longitude, latitude, and wetted width. We divided each transect into 11 evenly spaced quadrants based on river width, which we measured with laser range finders from the river's edge. When possible, the surveyor waded to the quadrant location, which was identified by a shore-based field technician using range finders to locate each quadrant based on the surveyor's distance from shore. When the river became too deep for wading (>1-1.4 m, depending on river velocity), the surveyor transitioned to snorkeling. At each quadrant, the surveyor dropped a 40×40 cm weighed PVC square to the riverbed. We measured water depth using a marked pole or a sonar depth finder (used at quadrants >3 m deep), percent of substrate in each of four size categories (fine, gravel, cobble, boulder/bedrock), and the percent cover of filamentous algae and rooted aquatic plants. For both substrate and aquatic vegetation, observations of percent cover were made based on visual estimation by the surveyor, aided by markings on quadrant margins showing percent cover increments. We recorded filamentous algae coverage when filaments were >2 cm long. Films of visually obvious benthic cyanobacteria were recorded, despite being more of a film than presenting as filaments. Additionally, the genus tentatively identified as *Aegagropila* was also recorded as filamentous algae, despite a lack of filaments >2 cm because this green algae forms dense mats that accumulate more biomass than adjacent biofilms (biofilms were not assessed in this study). For each species or genera observed in a quadrant (generally identified to species for rooted aquatic plants and genus for algae), we recorded species or genus code, percent cover of the specific taxa, the substrate that the vegetation type is growing on, plant condition and color, and the average length of the plant or its filaments within the quadrant (See data sheet included at end of document for details). Mat thickness was recorded in species without obvious filaments.

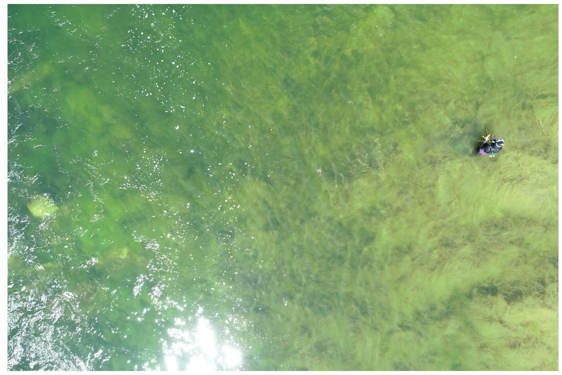
We calculated the mean percent coverage of rooted aquatic plants and filamentous algae for each reach during each survey year. We present results with taxa combined into these two general categories, as well as by individual species or genera.

3 Results

We surveyed a total of 11 reaches in 2019, and 10 reaches in 2020, in which we collected data from 612 and 619 quadrants, respectively. Six species of rooted aquatic plants occurred in surveys, as well as filamentous algae from multiple genera. *Elodia* was the most prolific rooted aquatic plant, followed by four species of pondweed in the genera *Potamogeton*, *Stuckenia*, and *Zannichellia* (Figure 3, right panel). *Cladophora* was the most common genus of filamentous algae, followed by *Ulothrix* (Figure 3, left panel). Other common filamen-



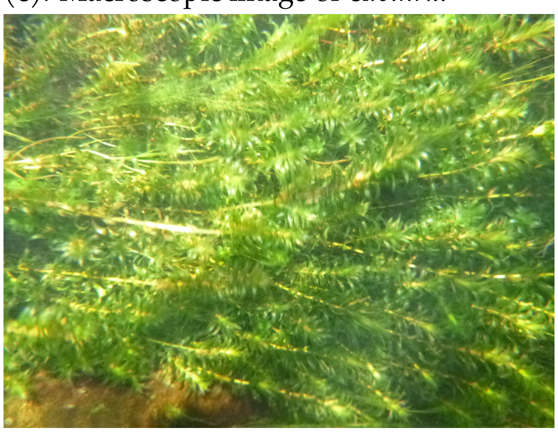
(a). Filamentous algae covering aquatic plant beds near I-5 Bridge



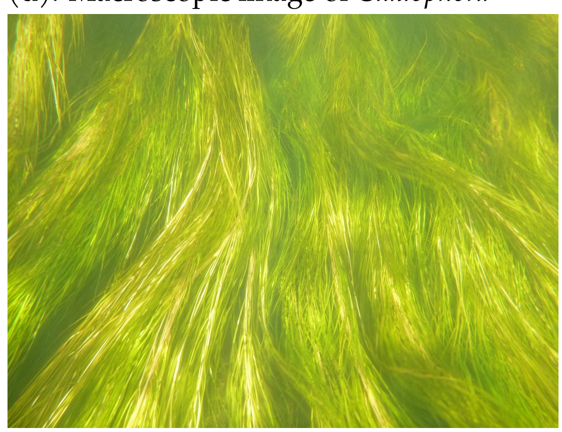
(b). *Cladophora* mats along river edges at Dolan's Bar, near Orleans, CA

(c). Macroscopic image of *Ulothrix*

(d). Macroscopic image of *Cladophora*



(e). *Elodia*



(f). *Sago Pondweed*

Figure 2. Images of dense aquatic plant and algae coverage (panels a, b), common algae genera (panels c,d), and common rooted aquatic plants (panels e,f) encountered in Klamath River surveys in 2019 and 2020. Photos by Adrienne Chenette (panels a, c, d) and Chippie Kislik (panel b), and the report author (panels e, f).

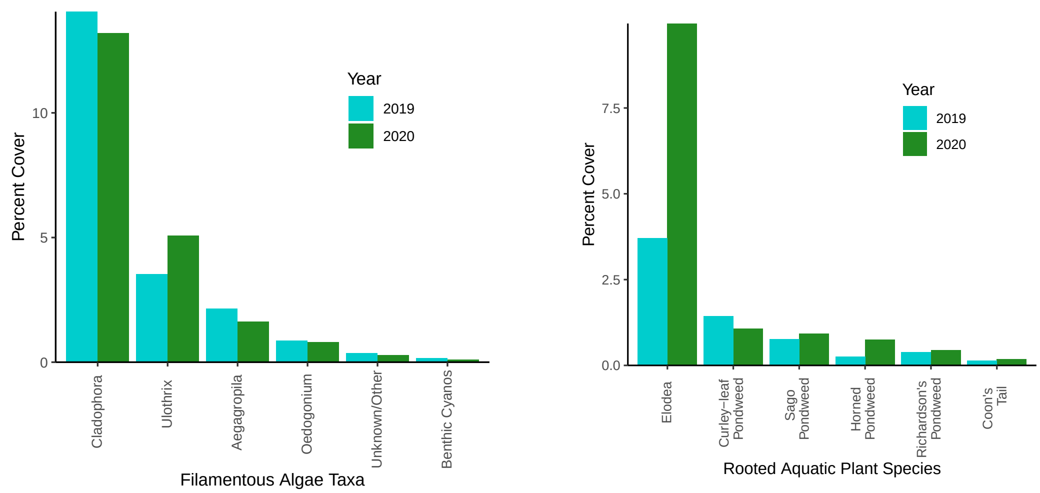


Figure 3. Mean percent cover of common filamentous algae taxa (left panel) and rooted aquatic plant species (right panel) from all sites surveyed during 2019 and 2020. The reach near Stanshaw Creek was excluded in this plot so that data is comparable among the same sites surveyed each year.

tous algae included *Oedogonium*, and algae likely in the genus *Aegagropila*, although expert consultation (personal communication, R. Lowe, 01-09-2019) provided only a "likely identification" for this genus, with a recommendation to use genomics methods to confirm the identification.

The total percent cover of filamentous algae was similar from 2019 to 2020, while the coverage of rooted aquatic plants in 2020 was approximately double from what was observed in 2019 (Figure 4). Similar coverage from all common algae genera was observed during both years of surveys (Figure 3), resulting in 19.6% mean coverage at all sites in 2019 (excluding the reach near Stanshaw Creek, which was only sampled in 2019), and 20.7% mean coverage in 2020. Rooted aquatic plants covered a mean of 6.5% of surveyed quadrant area in 2019, and 12.6% in 2020. The near double increase in rooted aquatic plant coverage was driven by an increase in coverage of *Elodia*, the most dominant aquatic plant during both years of survey (Figures 3, 5).

Although the absolute magnitude of aquatic plant coverage increased from 2019 to 2020, the longitudinal trends were consistent between years (Figure 4). The highest percent cover of aquatic plants was observed at the site above the I5-bridge, ending at the USFWS screw trap. In both years, plant coverage declined with distance downstream, with a higher relative longitudinal decline in 2019 than in 2020. In 2019, aquatic plants were nearly absent from all survey reaches below Happy Camp, whereas in 2020, aquatic

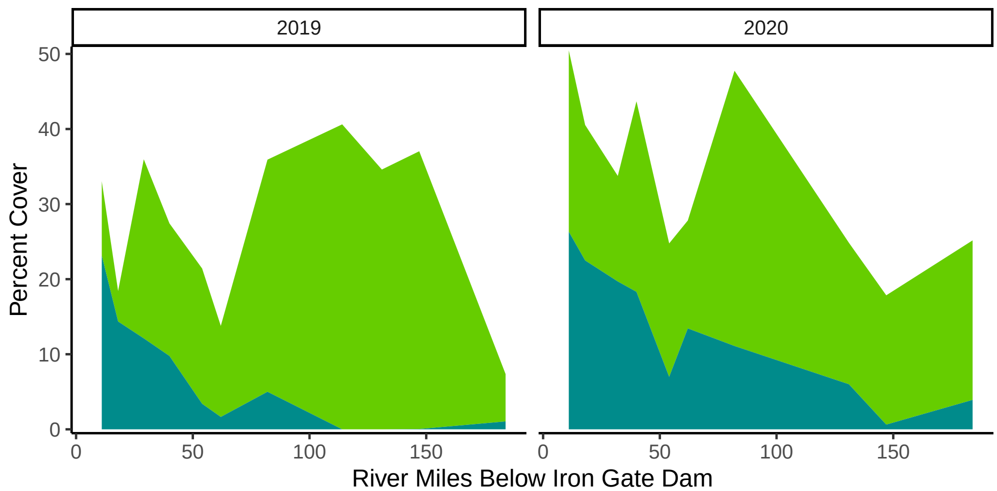


Figure 4. Percent cover of rooted aquatic plants (blue) and filamentous algae (green) decreased downstream from Iron Gate Dam. Primary producer types are stacked, so that the top of the green area shows the total percent cover of aquatic macro vegetation (algae and plants combined).

plants were observed in survey quadrants at all sites, with *Elodia* being the primary species at these downriver sites (Figure 5). The percent cover of aquatic plants was higher at all 11 sites in 2020 than in 2019, showing that no specific reach below Iron Gate Dam is disproportionately driving the trend of increased plant coverage. Instead, increased establishment of aquatic plants appeared to influence all surveyed reaches of the Klamath River.

The total coverage of filamentous algae did not follow the same longitudinal trend as rooted aquatic plants downstream of Iron Gate Dam. In 2019, the total percent cover of filamentous algae was lower at sites above Seiad Valley, and noticeably higher from Happy Camp to Weitchpec, and then decreased again at the most downstream site (KAT, Figures 4, 6). In 2020, most sites had similar algal coverage and higher coverage sites (I5, BB, and HC) were distributed among sites of more moderate algal coverage, rather than creating a longitudinal pattern of higher algal coverage.

The dominance of specific algal genera was consistent between 2019 and 2020. In both years, *Ulothrix* was the dominant genus at sites above Seiad Valley (SV) and *Cladophora* was dominant from Seiad Valley to Klamath Glen (KAT) (Figure 6). These upriver sites, dominated by *Ulothrix*, had more sub-dominant genera present including *Cladophora*, *Oe-*

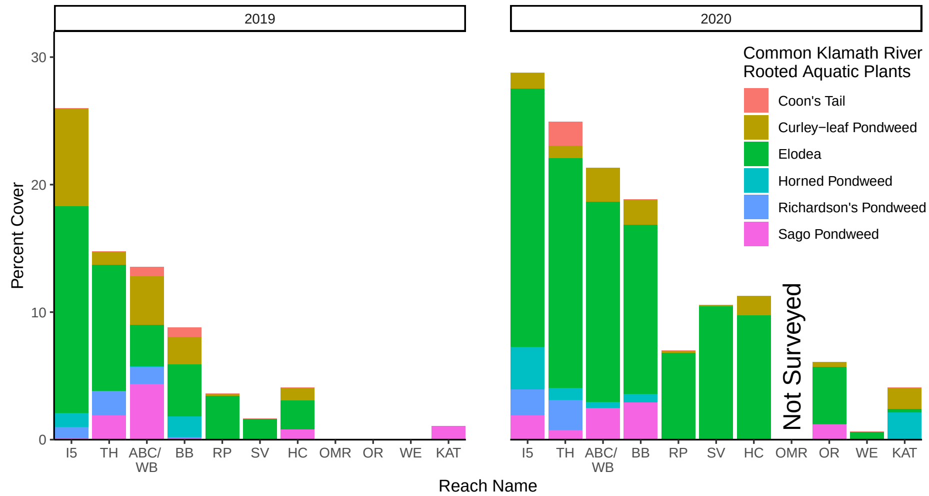


Figure 5. Percent cover of rooted aquatic plants decreased longitudinally downstream of Iron Gate Dam in both 2019 and 2020. Bars at each survey reach show total percent cover, with colors showing the different species at each reach. Reach OMR was not sampled in 2020.

dogonium, and the genus tentatively identified as *Aegagropila*, while sites dominated by *Cladophora* had lower coverage of sub-dominant macro-algae genera.

4 Discussion

4.1 River Flows

The difference in flows between 2019 and 2020 likely influenced algal and rooted aquatic plant cover each year. The first year of surveys, 2019, was an overall higher than average water year, with multiple flood peaks occurring throughout the winter and spring. In contrast, 2020 experienced one natural flow pulse in January, which was driven primarily by tributaries in the lower watershed, and thus had a larger effect on down rivers site (Figure 7). A second pulse flow released from Iron Gate Dam in April of 2020 was a salmon disease mitigation release, and although lower than flows released from Iron Gate Dam in 2019, this flow pulse was the largest flow that occurred on the Klamath River at up-river locations (Iron Gate and Seiad Valley gauges) in 2020.

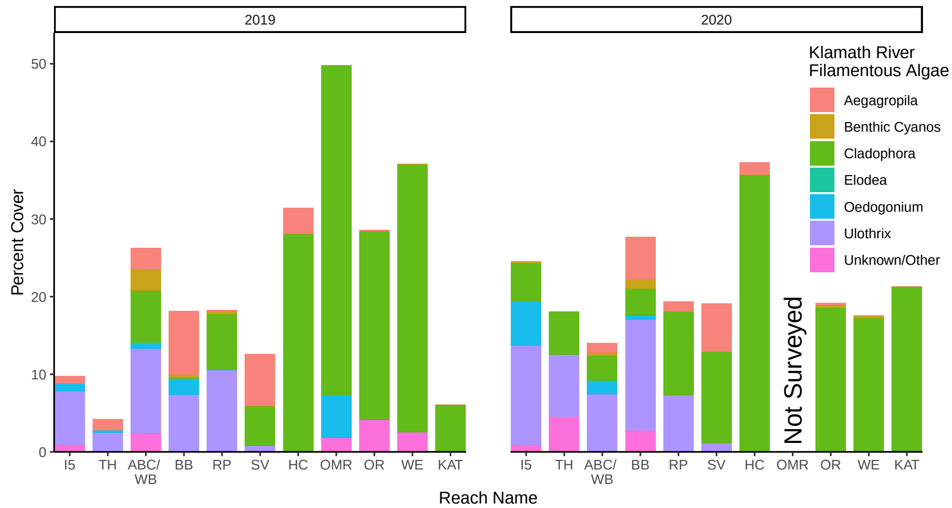


Figure 6. Percent cover of filamentous algae at survey reaches downstream of Iron Gate Dam in both 2019 and 2020. Bars at each survey reach show total percent cover, with colors showing the different species at each reach. Reach OMR was not sampled in 2020.

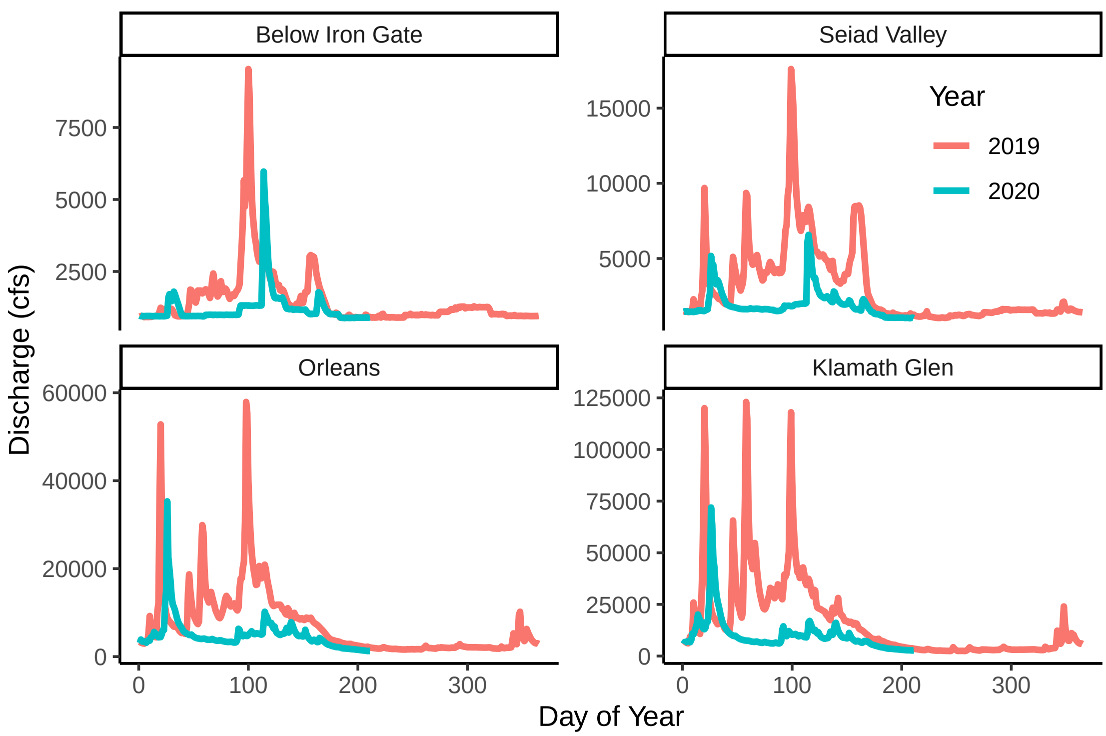


Figure 7. Discharge (cubic feet per second, cfs) for Klamath River U.S. Geological Survey gauging station for 2019 and 2020

4.2 Rooted Aquatic Plant Distribution Patterns

The reduction in the number and magnitude of flood flows from 2019 to 2020 may have facilitated the increased coverage of rooted aquatic plants in the Klamath River. Rooted aquatic plant coverage can decrease with increased flood disturbance (Riis and Biggs, 2003; Henry et al., 1996). Experiments have shown that the decrease in rooted aquatic plant cover in rivers is likely due to uprooting associated with bed disturbance, which would suggest that flow thresholds which cause bed movement would influence the ability for roots to over-winter or seeds to be maintained in the sediments (Riis and Biggs, 2003). Below dams, further interactions between flows and lack of mobile sediments may cause the river bed to be especially resistant to bed movement and the uprooting of aquatic plants, even with flows otherwise large enough to cause bed movement (Ibáñez et al., 2012; Benítez-Mora and Camargo, 2014). Continuing to monitor rooted aquatic plant coverage in the Klamath River over a range of flow conditions will bring further insight into the variability and drivers of aquatic plant dynamics.

Rooted aquatic plants can interact with sediment storage and transport, causing fine sediments to accumulate within rooted aquatic plant patches (Cotton et al., 2006; Kleeberg et al., 2010; Jones et al., 2012). The accumulation of fine sediment in these patches can lead to changes in river bed morphology by increasing sediment storage and decreasing water velocities within dense patches of rooted aquatic plants, while simultaneously promoting higher velocities and channel bed erosion in unvegetated areas of the channel (Schoelynck et al., 2012; Jones et al., 2012). Fine sediment deposition retained in plant patches may create positive feedback loops for more aquatic plants to grow (Schoelynck et al., 2012), but deposition of large amounts of fine sediment may lead to burial that inhibits growth, depending on the quantity and adaptive characteristics of individual species (Brookes, 1986). With removal of the hydroelectric dams and expected deposition of fine reservoir sediments, models of sediment dynamics following dam removal will benefit from considering the extent and coverage of rooted aquatic plants, which are most dense at reaches nearer to Iron Gate Dam, the same reaches where fine sediment is expected to accumulate (Figures 4, 5). Understanding how rooted aquatic plant coverage changes with variable flows in the Klamath River may provide tools for sediment management associated with dam removal.

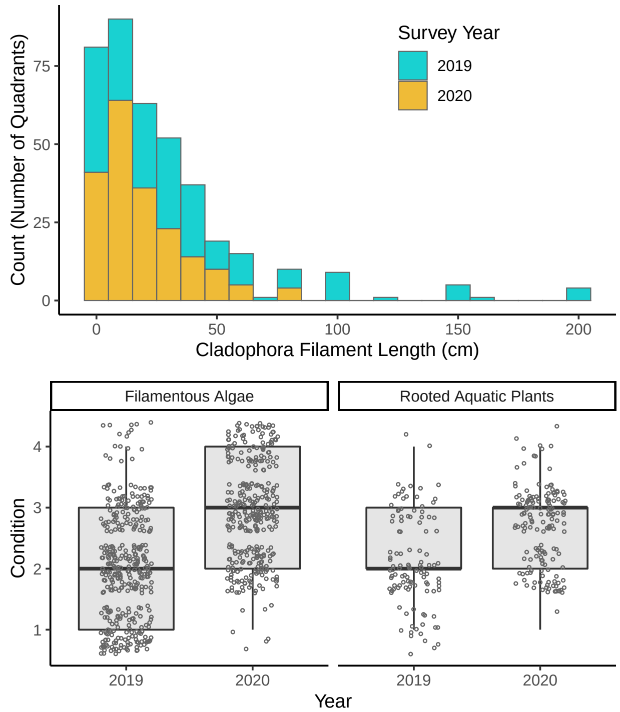


Figure 8. Histogram of *Cladophora* filament lengths for each quadrant where *Cladophora* was observed (top panel) and box plots with overlying individual data points (bottom panel) showing median Filamentous Algal and Rooted Aquatic Plant condition values between years.

4.3 Filamentous Algae Distribution Patterns

As with rooted aquatic plants, differences in flow patterns between 2019 and 2020 likely influenced filamentous algae coverage among years. Specifically for *Cladophora*, it is likely that 2019 surveys were conducted when the algal filaments were in good condition and still attached to their substrate. Overall, we observed longer filaments, in better condition in 2019 than in 2020 surveys (Figure 8). In 2020 surveys we observed extensive areas covered by short filaments of highly decayed *Cladophora*, leading us to believe that longer filaments (leading to higher total percent cover) had been growing on these substrates earlier in the season, but had senesced and detached prior to our surveys. Differences in the condition of filamentous algae between 2019 and 2020 surveys was shown in the field data collected, where median algal condition in 2019 was a "2", meaning algae was in a newer condition with only some epiphytes and maintaining structure, whereas in 2020, mean condition was "3", meaning that algae was heavily epiphytized, and structure was beginning to weaken (Figure 8).

The ability of *Cladophora* to proliferate is dependent on hydrodynamic processes, such that higher shear stress associated with high flow conditions likely limit the establishment of *Cladophora* (Dodds and Gudder, 1992). Once flows recede and *Cladophora* begins to grow, it can add biomass very rapidly, resulting in filaments over a meter long. The lack of high flows in the spring of 2020, and earlier onset of summer low-flow conditions, likely allowed *Cladophora* to begin growing earlier than in 2019, shifting the timing of *Cladophora* proliferations between 2019 and 2020. Despite surveying at similar time periods these two years, we likely did not capture the *Cladophora* at the same phenology due to these differences in water-year. Seasonal surveys occurring bi-weekly or monthly of filamentous algae would be beneficial in understanding the within-year variation in *Cladophora* growth and senescence, and how this variation contributes to reach-scale primary productivity and water quality dynamics in the Klamath River.

High biomass, along with high water temperatures, likely promote the mid-summer senescence of *Cladophora*, which leads to its detachment. The photosynthetic efficiency of *Cladophora* decreases per unit mass as the filaments increase, and the cells near the attachment point may not be maintained sufficiently to keep the filaments attached to the substrate as biomass increases (Dodds and Gudder, 1992; Kuczynski et al., 2020). Although water temperature limits vary widely for *Cladophora* of different species and habitats, Wong and colleagues found an upper tolerance limit of 23.5 degrees C. for *Cladophora* in seven Canadian rivers (Wong et al., 1978), which is a temperature that often occurs in the Klamath in early to mid-July at sites dominated by *Cladophora*(Asarian and Kann, 2013). Flow is a strong driver of water temperatures in the Klamath River, especially in June and July, with cooler water temperatures in high-flow years than low-flow years (Asarian and Kann, 2013). Earlier onset of high water temperatures in 2020 may have contributed to earlier senescence than in 2019.

Despite a difference in overall coverage of filamentous algae between year, spatial patterns of dominance by specific genera were consistent between 2019 and 2020. *Ulothrix* was the dominant genus at sites above Seiad Valley (SV) and *Cladophora* was dominant from Seiad Valley to Klamath Glen (KAT) (Figure 6). The reasons for different genera to dominate different parts of the Klamath River are unknown, but other studies have also documented variation in dominance of these two genera. In studies in the Laurentian Great Lakes, researchers found *Ulothrix* growing in the more shallow splash zone of the lake, while *Cladophora* was dominant in deeper, more calm areas of the lake (Auer et al., 1983). They note that *Ulothrix* optimizes its photosynthetic capacity at higher light conditions, while *Cladophora* is most productive at lower light conditions. Although light conditions are relatable in the Klamath on a reach scale, where mean reach depth is shallower at upriver sites and deeper at down river sites, we did not observe *Ulothrix* and *Cladophora* within a reach colonizing these habitats according to light conditions along a vertical gradient. Other reasons for the spatial differences in these two species may be related to conditions present during early colonization, including the ability of *Ulothrix* to establish in the spring at sites where flows are lower. Understanding why these dominant species occur where they do, their seasonal growth trajectories, and the impacts they have on further algae growth (such as epiphytes and benthic cyanobacteria) and nutrient cycling will lead to a better understanding of nuisance algae and associated water quality problems in the Klamath River.

5 Future Monitoring

Continued monitoring of filamentous algae and rooted aquatic plants in the Klamath River will help describe the range of variation that occurs from year to year, and is a crucial first step to identifying the mechanisms responsible for algal and aquatic plant growth dynamics. Further, this data can be used in studies seeking to identify drivers of water quality and fisheries health by considering how high vs. low algae and aquatic plant coverage drives ecosystem processes.

Continuation of the surveys described in this report would facilitate direct comparisons with data collected in 2019 and 2020, but these surveys are physically demanding and require a swimmer who is both trained in algal and plant identification and who is comfortable snorkeling in the Klamath River. Opportunities for modifying these surveys include conducting quadrant surveys focused on near-shore vegetation (primarily in wadeable locations) and use of remote sensing with areal images from drones. In the case of near-shore quadrant surveys, surveys very similar to the ones described in this report could be collected, although only the two or three quadrants closest to shore would be surveyed. Additional transects would be surveyed so that data from 60 quadrants or more would be used to assess a reach. This survey modification would select for areas of high algae and plant growth, thus total percent cover estimates would not describe an entire reach, but would instead be used to compare among reaches or through time, using the same survey technique.

Photos taken with drones are another useful tool to document the coverage of filamentous algae and aquatic plants. Methods were tested in 2019 to assess algal and aquatic plant cover using drones in the Klamath River (Kislik et al., 2020). Recommendations for drone surveys include taking photos at lower solar angles (morning and evening) to avoid sun glint on the water, and conducting in-river surveys at the site when the photo is being taken so that image characteristics can be related to visible plant and algae growth at variable depths and water clarity conditions. Because of computationally intensive processing of photos and the labor associated with this processing, drone images may be best suited for surveying a subset of sites to monitor changes through time, rather than to characterize extensive reaches along the river. Drone images will be most useful during windows of higher water clarity, when sediment from high flows and planktonic algae from upstream lakes and reservoirs are low.

Studies assessing the seasonal dynamics of algae and aquatic plant growth within a year will help direct the timing of continued annual monitoring, and put the data set describing year-to-year variation in context of seasonal shifts. Seasonal dynamics can be documented using similar techniques described in this report, including the modifications described in the above paragraphs, but conducted on more frequent time scales throughout the season. Other opportunities for exploring seasonal dynamics include the use of automated photographic technology, and exploring quadrant data collected as part of past years periphyton monitoring (Gillett et al., 2016).

6 Conclusions

Rooted aquatic plants in the Klamath River displayed a longitudinal pattern below Iron Gate Dam, while patterns in filamentous algae coverage were more complex. Highest coverage of rooted aquatic plants were observed at sites closest to Iron Gate Dam in both years, and decreased with distance downstream from Iron Gate Dam. *Elodia* was the dominant rooted aquatic plant observed in the Klamath River during 2019 and 2020, followed by multiple species of pondweed. Percent coverage of filamentous algae did not follow a distinct longitudinal pattern, although taxa present did display a longitudinal pattern. At sites closer to Iron Gate Dam (above Seiad Valley), *Ulothrix* was the dominant filamentous algae, whereas *Cladophora* dominated sites from Seiad Valley to Klamath Glen.

Differences in river flows between 2019 and 2020 likely caused variation in aquatic vegetation cover between years. 2019 was a wet year on the Klamath, with multiple high flow events and later onset of summer low-flows, while 2020 had very few winter and spring high flows and earlier onset of summer low-flow conditions. Longitudinal decreases in rooted aquatic plant coverage were present in both years, but overall coverage was higher in 2020 at all sites. Increased coverage was attributed primary to increases in *Elodia*. Similar patterns of filamentous algal taxa distribution were present between years, but coverage of *Cladophora* was lower in 2020 surveys. Decreased *Cladophora* coverage was likely due to the surveys being conducted after the peak biomass of *Cladophora* had occurred, as indicated by the shorter filaments and older condition of the observed *Cladophora*. Flows are likely a major driver of primary producer biomass and composition, with both the timing and magnitude of winter flushing flows and the timing and magnitude of summer low-flow onset influencing the community composition, spatial distribution, and seasonal timing of primary producer assemblages in the Klamath River.

Further research documenting the spatial and temporal patterns of primary producer assemblages will help explain patterns of ecosystem scale productivity and water quality dynamics in the Klamath River. Documenting primary producer assemblages under a range of conditions prior to dam removal will provide baseline data on conditions that exist on the Klamath River with dams in place, which are essential in comparing conditions following dam removal. Understanding the spatial and seasonal patterns in primary producer assemblages can also inform predictions about sediment dynamics associated with dam removal, while information about changes in assemblages associated with flows could provide management tools aimed at improving water quality and fisheries health in the Klamath River.

7 Acknowledgments

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Supplementary Materials

S1: Klamath River Vegetation Study Data Sheet

Transect Meta-Data

Transect: _____ of _____	Page: _____ of _____	Date: _____/_____/_____ Time: ______:______
Surveyors:		Transect narrative:
Site:	River width (m):	
Pool Run Riffle	Bankside start: LB RB	
GPS LB: N W	RB: N W	

Quadrant Data

Quad. #	(m) from start	Depth (m)	Velocity (m/s)	% fines (< 2mm)	% gravel (2-64mm)	% cobb (64-256)	% bould/ bedrock	Macrop % Cover	Fil. Alg. % Cover	Photo time	Notes
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											

Species-Specific Data

Quad #	Sp. code	% Cover	Condition	Color	Substrate	Strand length (cm)	Sample ID	Notes

Klamath River Aquatic Vegetation Study

Transect: _____ of _____	Page: _____ of _____		Date: _____/_____/_____
Surveyors:			Time: ______:______
Site:	River width (m):	Max depth (m):	Bankside start: L R

Quad #	Sp. code	% Cover	Condition	Color	Substrate	Strand length (cm)	Sample ID	Notes

Common Species	
Name	Code
Cladophora sp.	CLAD
Oedogonia sp.	OEDO
Spirogyra sp.	SPIR
Ulothrix sp.	ULOT
Phormidium sp.	PHOR
Anabaena sp.	ANAB
Gomphonemia sp.	GOMP
Biofilm	BIOF
Elodia canadensis	ELCA
Potamogeton crispus	POCR
Potamogeton pectinatus	POPE
Zannechellia palustris	ZAPA
Ceratophyllum demersum	CEDE
Potamogeton richardsonii	PORI

New Species	
Name	Code

Condition	
Description	Code
New growth, bright color, few epiphytes	1
Plants material mostly whole, some-many epiphytes	2
Plant material breaking up and decomposing, heavy epiphytes	3
Plant material unidentifiable or only remnant	4

Color: record for all species, but is most relevant to CLAD	
Description	Code
Green, clean	GR
Gold, epiphytized	GO
Rust, epiphytized	RU

Klamath River Aquatic Vegetation Study