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MANAGEMENT BRIEF

Do Electrofishing Activities Disrupt Stream Biofilm Standing Stocks? An Assessment from Two Headwater Streams in Western Oregon

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Abstract

Humans affect ecosystems in many ways, and scientific field studies are no exception. If data collection disrupts environments or biota too much, it can lead to inaccurate conclusions in the study of interest or in subsequent studies. We evaluated whether stream electrofishing surveys could measurably disturb the benthic biofilms in two forested headwaters in western Oregon, USA. While the consequences of electrofishing to macroinvertebrates and fish have been assessed, to date no studies have quantified its influence on benthic biofilms. We observed declines in the standing stocks of accrued benthic chlorophyll *a* directly after electrofishing in both streams. After electrofishing, the standing biofilm stocks declined by an average of ~15% in Oak Creek, a small third-order stream in the Oregon Coast Range Mountains, and by an average of ~34% in a third-order section of Lookout Creek, which is located in the western Cascade Mountains of Oregon, USA. In returning to Oak Creek 2 weeks after electrofishing, the standing stocks had fully recovered to their prefishing levels. While the benthic biofilm standing stocks did decline in association with electrofishing, the effects were small when compared with those of disturbances from common flow events and when scaling to the whole stream system. In Oak Creek, the proportional biofilm standing stock decline from electrofishing activity was about 26% of what was observed following a moderate flow event (40% of bank-full discharge), and about 15% of the decline in biofilm standing stocks following a complete bank-full discharge event (140% of bank-full discharge).

Measurements that are made on ecosystem processes and biota generally assume that the metrics that are used accurately reflect the conditions in the environment of interest. However, the act of collecting data can disrupt the environment and potentially lead to inaccurate assessments of the system. In streams, surveys of fish and macroinvertebrates, or the quantification of habitat and stream ecosystem processes, often require wading through the stream while collecting data. If our activities in the stream disrupt the system, we may then draw inaccurate conclusions about the status or function of the system. Assessments of stream fish are increasing, including measurements of biomass or abundance at lower trophic levels, such as macroinvertebrates and benthic biofilms, to account for bottom-up drivers of fish production (Townsend et al. 2003; Segura et al. 2011; Kiffney et al. 2014). While researchers have considered the effects of electrofishing on fish and aquatic invertebrates (Elliot and Bagenal 1972; Fowles 1975; Bisson 1976; McMichael et al. 1998; Hastie and Boon 2001; Snyder 2003; Kruzic et al. 2005; Myrvold and Kennedy 2017), no studies to date have considered how the activity of conducting multiple passes through a stream may affect the benthic biofilms that constitute a key resource at the base of stream food webs. Furthermore, for regulatory or permit

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purposes, researchers and managers are increasingly asked to provide data or cite studies that address the effects of their proposed research on ecosystems and to contextualize them within the natural range of variability in the relevant systems.

Autotrophic production is an important driver of secondary productivity in stream ecosystems. In small headwater streams, benthic biofilms that consist largely of algae and diatoms can be disproportionately important to instream herbivores and ultimately top consumers (Lewis and McCutchan 2010). Stream primary production is also an important driver of nutrient demand and biogeochemical cycling in streams (Sabater et al. 2000; Ylla et al. 2007; Rusjan and Mikoš 2010; Finlay et al. 2011). Therefore, processes that disrupt primary productivity and benthic biofilms in streams can influence the stream biota and stream nutrient dynamics (Uehlinger et al. 2003; Francoeur and Biggs 2006).

Previous studies have demonstrated that electrofishing can promote invertebrate drift in streams (Elliot and Bagenal 1972; Fowles 1975; Bisson 1976). Elliot and Bagenal (1972) found notable increases in drift, particularly for chironomids, but the total increase in invertebrate drift out of their study reach was only about 5%. Fowles (1975) found up to a 70% increase in drift that was associated with electrofishing activities for some taxa but an overall decline of only about 10% in benthic standing stocks. Both studies noted that invertebrate drift into the reach is an important source of recolonization after electrofishing. Bisson (1976) found variability in taxa responses to electrofishing in experimental channels. Electrofishing decreased benthic chironomid standing stocks by about half, but Bisson (1976) found no significant declines in other taxa. More recently, Kruzic et al. (2005) explored the effects of electrofishing on invertebrate communities across three stream systems in Oregon. They found that electrofishing shifted the size distribution of benthic and drifting invertebrates, but only within a short distance of the treatment area. Given the high recolonization rates and short drift distances of disrupted individuals, the effects of electrofishing on invertebrates are short-lived and unlikely to have prolonged consequences (Kruzic et al. 2005). The high mobility of stream invertebrates contrasts strongly with the immobility of benthic biofilms in streams. Biofilms are an accumulation of sessile organisms that primarily regrow rather than recolonize following a disturbance (Leite et al. 2012), which could lead to longer-term effects of biofilm scour. For example, human trampling through invertebrate and algal communities in marine intertidal areas has been shown to cause shifts in community composition lasting for years after the trampling event (Brosnan and Crumrine 1994).

No empirical studies have assessed the effects of electrofishing activities on benthic biofilms in streams, so we do not know whether those that are associated with stream vertebrate surveys are minimal and can be ignored or are substantial and warrant further research. This study provides an initial evaluation of the effects stream electrofishing activity on aquatic biofilms and explores how they compare with those of biofilm losses that are associated with natural disturbance events. The goal of this study was to evaluate whether activity in the stream that is associated with electrofishing surveys can measurably disturb benthic biofilms and, if so, to understand how such disruptions compare to natural events (floods) that disturb and scour biofilms from stream substrates (Segura et al. 2011; Katz et al. 2018).

METHODS

Study sites.— This study was conducted in two headwater streams in western Oregon, Oak Creek and Lookout Creek. Oak Creek (location: 44.62197°, −123.33092°) is a small third-order stream that drains 7 km^2 in the western side of the Coast Range foothills near Corvallis, Oregon, and it is a tributary to Mary's River, which flows into the Willamette River. The elevation of the Oak Creek basin ranges from 143 to 664 m, and the bank-full discharge of Oak Creek is 3.4 m^3/s at our study reach (Katz et al. 2018). At our study reach, the channel bed substrate is a mixture of cobble and gravel. The gradient is about 1.5%, and the mesohabitats are characterized by long pools and riffles. The bank-full width of the Oak Creek study reach is 6 m (Table 1). The riparian forest surrounding the study site at Oak Creek is dominated by Douglas fir *Pseudotsuga menziesii*, red alder *Alnus rubra*, black cottonwood *Papulus trichocarpa*, and bigleaf maple *Acer macrophyllum*.

Lookout Creek is a subbasin of the Mackenzie River on the western side of the Cascade Mountains, and it encompasses the H. J. Andrews Experimental Forest. The Lookout Creek study reach (location: 44.23319°, −122.20919°) occurs in a third-order section of the stream that drains a catchment of 27 km^2. The channel bed of the study reach is dominated by boulders with larger cobble, and this section of stream is dominated by riffles and runs with some deep pools. The study reach in Lookout Creek had a gradient of 4%, and the average bank-full width of the Lookout Creek study reach is 9 m (Table 1). The elevation of the Lookout Creek basin ranges from 410 to 1,630 m, and the riparian areas surrounding this site are dominated by red alder and Douglas fir.

Quantifying benthic biofilms.— In headwater streams, benthic biofilms are comprised of a mix of autotrophs (predominantly diatoms) and heterotrophic bacteria and fungi. Benthic biofilms are dominated by autotrophs in

TABLE 1. Stream characteristics and sampling details from the study reaches in Oak Creek and Lookout Creek.

Site and Sampling period	Bank-full width (m)	Substrate D_{50} (mm)	Date	*n* transects assessed	Sampling interval along each transect	Total *n* rocks measured
Oak Creek	6	45				
Pretreatment			Jul 21, 2016	11	3–4 rocks every 0.5 m across wetted width	133
Treatment (3-pass electrofishing)			Jul 21, 2016			
Posttreatment 1			Jul 22, 2016	11	3–4 rocks every 0.5 m across wetted width	136
Posttreatment 2			Aug 4, 2016		3–4 rocks every 0.5 m across wetted width	129
Lookout Creek	9	94				
Pretreatment			Aug 24, 2016	3	1 rock at ~10, 25, 50, 75, and 90% of wetted width	15
Treatment (electrofishing mark)			Aug 25, 2016			
Treatment (electrofishing: recapture)			Aug 26, 2016			
Posttreatment			Aug 27, 2016	3	1 rock at ~10, 25, 50, 75, and 90% of wetted width	15

these headwater streams (Allan and Castillo 2007); thus, we used measurements of chlorophyll-*a* concentrations in the benthic biofilms as a proxy for the overall biofilm community. Throughout the two study reaches, the chlorophyll-*a* concentrations in the biofilm were quantified in situ using a BBE Moldaenke BenthoTorch (http://www.bbe-moldaenke.de). This instrument allowed us to assess the chlorophyll-*a* concentrations in the biofilms directly on the stream benthos before and after an electrofishing survey, without moving or disrupting the substrates to obtain the measurement. In Oak Creek, the biofilm chlorophyll-*a* measurements were taken on three separate occasions: once in the morning directly before the electrofishing event (July 21, 2016), once on the day after the electrofishing event (July 22, 2016), and 2 weeks after the electrofishing event (August 4, 2016; Table 1).

At Oak Creek, the measurements of biofilm chlorophyll *a* were collected from 14 transects along a 30-m reach (Table 1). The Oak Creek transects were established along a portion of a sampling grid that had been set up by Katz et al. (2018) for a study assessing the influence of storm events on benthic biofilm standing stocks, using a benthotorch. Sampling within this grid system and using the transect locations that were established in the Katz et al. (2018) study allowed us to examine potential changes in the benthic biofilms due to electrofishing within the context of storm-associated flood events. The first eight transects were set a meter apart. The remaining transects in the upper portions of the 30-m study reach were set 2–6 m apart. The benthotorch provides inaccurate measurements of chlorophyll-*a* concentration when the substrates are in direct sunlight (Kaylor et al 2018), so we excluded the data from three transects where our field notes indicated high light or direct sunlight in or along the transect during the sampling. The remaining 11 transects were fully shaded during all three sampling events.

For each transect, the chlorophyll-*a* concentrations were measured at regular 0.5-m intervals across the active channel of the stream (the wetted channel was generally 1.5 to 2 m in width). At each distance interval, three or four rocks were measured. This yielded a total of 133 measurements in the study reach at Oak Creek before the electrofishing and 136 total measurements in the immediate posttreatment sampling event (Table 1). In the third sampling event at Oak Creek, we again sampled at the same transects and took a total of 129 samples (Table 1). During each visit, we verified that the use of the benthotorch itself did not remove or affect the standing stock estimates by taking repeated benthotorch measurements from the same spot on a set of test rocks.

In Lookout Creek, three evenly spaced transects were established along a 15-m reach and biofilm chlorophyll-*a* concentrations were assessed before (August 24, 2016) and after (August 27, 2016) an electrofishing survey (Table 1).

In Lookout Creek, biofilm chlorophyll-*a* measurements were taken in the morning (before full sun) from five rocks that were selected across each transect from approximately 10, 25, 50, 75, and 90% of the wetted width. We conducted benthotorch measurements at three locations on each rock, and the mean value from these three measurements were used as the biofilm chlorophyll-*a* concentration for a single rock. We selected a different sampling framework for Lookout Creek due to a combination of time constraints and larger substrates at this stream. Due to limited site access, we were not able to visit Lookout Creek a third time to assess the potential recovery of the biofilm.

Electrofishing surveys.— We evaluated a multiple-pass depletion fish survey in Oak Creek (following the methods in Kaylor et al. 2019) and a mark–recapture fish survey in Lookout Creek (following the methods in Heaston et al. 2018). In both systems, the electrofishing surveys were conducted by an experienced team of four people. To eliminate bias on the electrofishing crew and to keep effort and activity consistent with that of any normal fish survey, the crews were unaware of our study question at the time of the fishing events (the crews were told that it was just a normal stream vertebrate survey). In Oak Creek, the 30-m study reach where sampling was completed extended from meter 20 to meter 50 in an 80-m (in length) electrofishing reach. In Lookout Creek, the 15-m study reach extended from meter 30 to meter 45 in a 90-m electrofishing reach. Both streams had similar aquatic vertebrate species present that consisted of coastal giant salamanders *Dicamptodon tenebrosus* and Coastal Cutthroat Trout *Oncorhynchus clarkii clarkii*. Oak Creek also has sculpin (*Cottus* spp.).

Analysis.— The experimental units in this study were the 30-m reach in Oak Creek and the 15-m reach in Lookout Creek. Although we did not have control reaches in these streams, there were no changes in streamflow during the sampling period that would affect the stream benthos. Therefore, changes in the mean biofilm chlorophyll-*a* concentrations between the sampling events were attributed to electrofishing activities. We used a single-factor ANOVA (IBM SPSS Statistics v.26) to compare the mean biofilm chlorophyll-*a* concentrations from the measurements throughout each reach before and after electrofishing in each stream. The factor (independent variable) for the ANOVA was sample period (before versus after electrofishing), and the dependent variable was biofilm standing stock in μg/cm^2. The assumptions of normality and equal sample size were met for these analyses.

RESULTS

In Oak Creek, the mean biofilm chlorophyll-*a* concentration prior to electrofishing was 8.26 μg/cm^2 ($n = 133$, SD = 4.45). The day after electrofishing, the mean biofilm chlorophyll-*a* concentration was significantly lower ($F = 4.67$, $P = 0.032$), decreasing to 7.14 μg/cm^2 ($n = 136$, SD = 4.02; Figure 1)—an overall decline of 15.6%. Two weeks after electrofishing, the biofilm chlorophyll-*a* concentrations in Oak Creek had recovered to their pre-

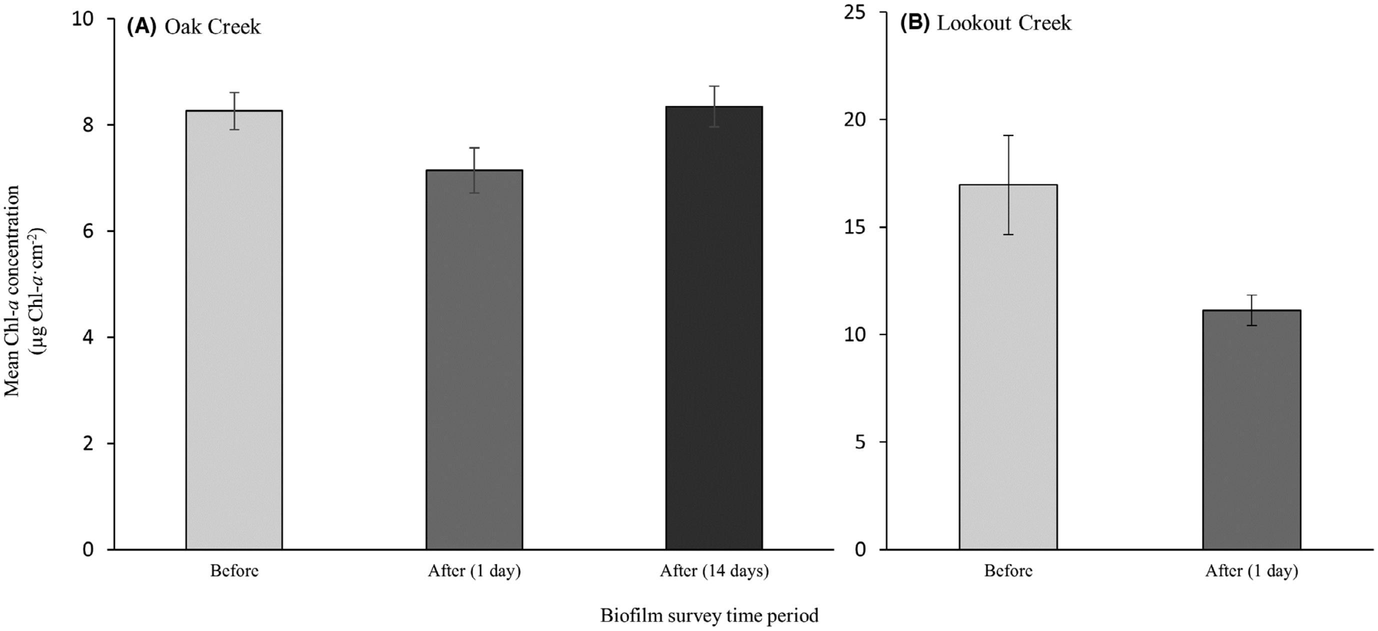

FIGURE 1. Mean biofilm chlorophyll-*a* (Chl-*a*) standing stocks (μg/cm^2) on the stream benthos, measured at **(A)** Oak Creek and **(B)** Lookout Creek before and after electrofishing. The error bars represent ±2 SE.

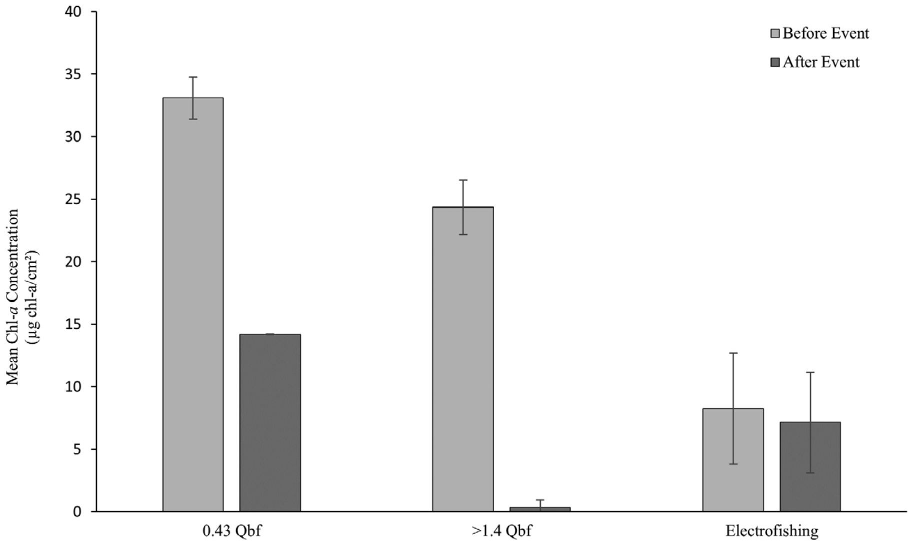

FIGURE 2. Changes in the benthic biofilm chlorophyll-*a* (Chl-*a*) concentration following two storm events and in response to the electrofishing surveys in Oak Creek. The storm events were characterized in Katz et al. (2018) by proportion of bank-full discharge (Qbf). The error bars represent ±2 SD.

electrofishing levels (mean = 8.34 μg/cm^2 =, n 129, SD = 4.78; Figure 1). In Lookout Creek, the mean biofilm chlorophyll-*a* concentration prior to electrofishing was 16.96 μg/cm^2 ($n = 15$, SD = 8.97). Directly after electrofishing, the mean biofilm chlorophyll-*a* concentration decreased significantly ($F = 5.81$, $P = 0.023$) to 11.13 μg/cm^2 ($n = 15$, SD = 2.73), a 34.4% decrease in the benthic periphyton standing stocks (Figure 1).

DISCUSSION

The effects of electrofishing on fish and aquatic macroinvertebrates in streams have been evaluated, but to date no studies have focused on the degree to which this activity disrupts stream biofilms. In this study, we found evidence that electrofishing activities can lead to a short-term decline in biofilm standing stocks; however, the degree of disruption differed between our two case study streams. In Lookout Creek, we documented a significant (34%) decline in biofilm chlorophyll-*a* concentrations following electrofishing, and in Oak Creek the biofilms declined by about 15%. Although the data from our two case study systems do suggest that electrofishing activities have the potential to negatively affect stream biofilms, given the limited scope of this work (data from two streams in one region) more research is needed on this topic before definitive conclusions can be made about the magnitude of the effects of electrofishing on stream biofilms. Further work is also needed to understand the ecological relevance of any documented declines in stream biofilms that are associated with electrofishing activities.

The effect from electrofishing on mean chlorophyll-*a* concentrations at Oak Creek was small compared with that of natural disturbances that are associated with high-flow events (Figure 2). While electrofishing activities in Oak Creek decreased biofilm chlorophyll *a* by about 15%, Katz et al. (2018) found for the same stream section that a small storm with a peak discharge of 1.46 m^3/s (slightly less than half of a bank-full flow event) resulted in a 57% decrease in biofilm chlorophyll *a* (Figure 2). And, a larger event of ~ 5 m^3/s (1.4 times bank-full discharge) resulted in a >99% decrease in biofilm chlorophyll *a* (Figure 2).

In earlier studies that have assessed the effects of electrofishing on aquatic biota, the most notable negative consequences to fish are associated with spinal injuries to adult fish and stress that is associated with handling after capture (Snyder 2003). Dwyer and Erdahl (1995) also documented significantly higher mortality when Cutthroat Trout eggs were exposed to greater than 250 V. The effects of electrofishing on whole populations of common and widely distributed fish have been minimal (Shill and Beland 1995; McMichael et al. 1998), whereas electrofishing has been identified as a concern in sampling endangered fish (Myrvold and Kennedy 2017). Early studies that assessed the effects of electrofishing on stream macroinvertebrates found substantial increases in drift rates but more limited influence on the larger community or benthic standing stocks (Elliot and Bagenal 1972; Fowles, 1975; Bisson 1976). In each of those studies, as in ours, replication was limited and the effects of the electrical current versus wading activities could not be easily parsed. Taylor et al. (2001) explicitly focused on electrical current as the key driver of drift and found that the increase in drift that was associated with electrofishing could be used to conduct quantitative sampling of stream invertebrates. Kruzic et al. (2005) explicitly evaluated the effects of wading, electrical current, and the combined effects of wading and electrical current on invertebrate drift at multiple distances along three replicate streams. In that study, the combined effects of wading and electricity were most substantial, but the overall consequences for total invertebrate abundance were still relatively small. Kruzic et al. (2005) provides a study design that could inform future assessments of electrofishing activities on benthic biofilms. Future research should include replications across streams that encompass multiple stream gradients and substrate sizes and, if possible, unmanipulated control reaches to allow for a before-after control-treatment analysis.

Although the current study cannot clearly separate the effects of the electrical current from those that are associated with wading, we hypothesize that the effects of electrofishing activities on biofilms that were documented here are due primarily to wading in the stream. We hypothesize this because studies have used electricity in streams explicitly in research on aquatic biofilm to exclude grazers and thereby quantify top-down control on benthic biofilms (Opsahl et al. 2003; Lourenço-Amorim et al. 2014; Beck et al. 2019). In those studies, electricity is not identified as a factor limiting primary production. In one example, electrified tiles where grazers were excluded had biofilm standing stocks that were two to three times greater than those on control tiles, with the highest biofilm abundance occurring closest to the electrical wires (Opsahl et al. 2003). Beck et al. (2019) evaluated the potential effect of electrical fields on biofilms in their study and found some differential responses among a few taxa in the algal community but no significant overall effects of the electrical field on biofilm ash-free dry mass.

Storm events that move or disrupt even a moderate amount of the substrate can disturb the standing stocks and rate of primary production in streams at the reach scale (Biggs and Stokseth 1996; Cronin et al. 2007; Atkinson et al. 2008; Segura et al. 2011). Even smaller storm events can influence rates of algal primary production as well as standing stocks (Townsend et al. 1997; Biggs et al. 1999; Cronin et al. 2007). While we did observe a decline in biofilm standing stocks following our electrofishing surveys, these effects were small relative to the system-wide effects of the storm events that we evaluated here. Further, although flow disturbances are relative rare in midsummer the recovery of standing stocks to predisturbance levels was robust in Oak Creek, highlighting the resilience of stream algal communities to small disturbance events in summer. Recovery rate is a particularly important consideration when assessing the overall effects of benthic scour. For example, in a forested mountain stream in Colorado, Segura et al. (2011) found the algal recovery from a scour event that occurred early in the growing season never plateaued, suggesting that in this system with slow growth rates the effects of spring snowmelt scour on primary production could persist throughout the growing season. In contrast, Roberts et al. (2007) found that in a headwater stream in the southern Appalachian Mountains, stream primary production rates were negatively affected by high spring flow events. However, the system recovered relatively quickly and the storms did not have a substantial effect on overall annual or seasonal gross primary production rates.

Ultimately, whether one considers a localized 15% to 35% decline in biofilm standing stocks associated with electrofishing scour to be ecologically important will be context dependent. In Oak Creek, recovery occurred within 2 weeks (or less). If surveys were conducted to characterize benthic biofilms immediately after electrofishing, the estimates would likely be inaccurate. However, given recovery within 2 weeks, it is unlikely that electrofishing scour had a persistent effect on long-term primary productivity in this study reach. Considering systems beyond Oak Creek, periphyton recovery from disturbance events may be influenced by a range of contextual controls, including light, temperature, grazing pressure, and nutrient availability (Biggs et al. 1999; Hoellein et al. 2007; Warren et al. 2017). Further, just as the temporal dynamics of biofilm recovery can affect the overall effects of electrofishing-associated scour, spatial context is also an important consideration in evaluating the influence of electrofishing surveys on stream primary production. Electrofishing surveys in Oak Creek and Lookout Creek encompassed 80 and 90 m of stream, respectively. If one is focused on the processes in those specific reaches alone (as is often the case in studies that link food-web compartments), reductions in biofilm standing stocks in the survey area are potentially meaningful. However, the survey study reaches themselves represent a fraction of the total area of each stream network, and if the question around survey effects is broader and concerns the larger system, the effects of electrofishing-associated scour may indeed be quite small (McMichael et al. 1998). Overall, this study provides a useful initial assessment of whether electrofishing activities can significantly disrupt benthic biofilms in headwater streams. More work is needed beyond our case study streams to understand how the effects of electrofishing activity fit within the spatial and temporal dynamics of disturbances that occur naturally across a range of geomorphic and climatic conditions.

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