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Evaluating benthic macroinvertebrate populations in response to scouring events in the Trinity River, CA

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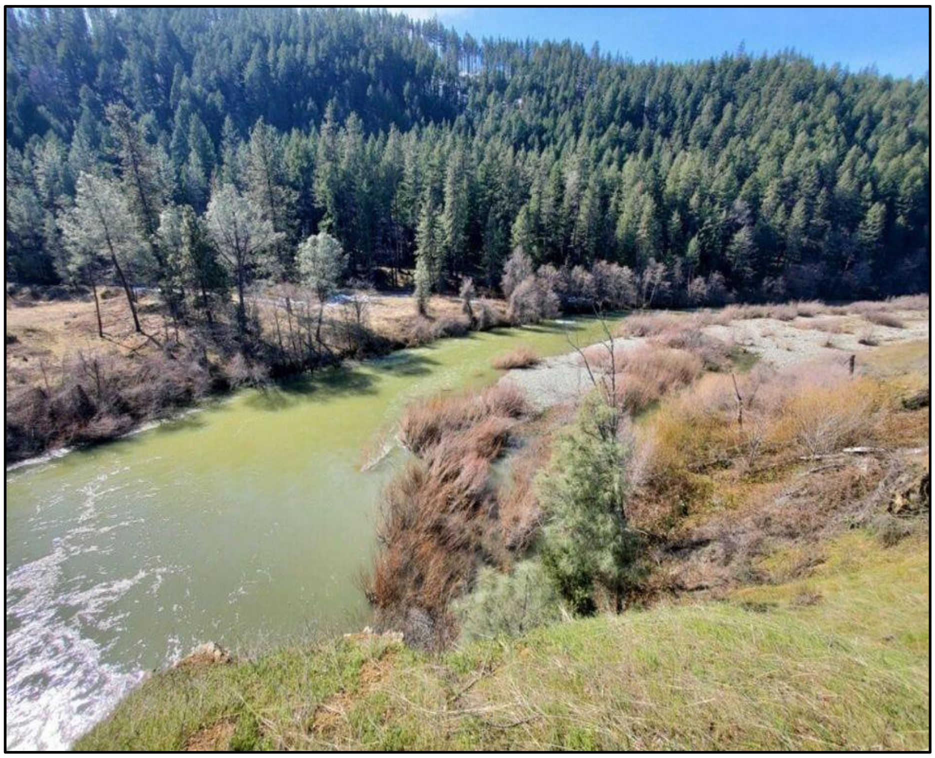

(Photo by Ben King, 2022)

Ecological Restoration Capstone (ESM 455)

Department of Environmental Science & Management

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ABSTRACT

River systems across California have been impacted by appurtenant structures such as dams and diversions. These structures have had an adverse impact on Benthic invertebrate (BMI) communities by regulating river systems and changing the natural hydraulic pulses that follow seasonal precipitation. Benthic invertebrates are a critical food resource for salmonids and serve as an indicator of ecosystem health. Our study was interested in seeing the effects of scouring events on BMI in the Trinity River of Trinity County, C.A. Following a large precipitation event that occurred in the region in December 2022, an influx of water entered the river through flood releases from Lewiston Dam, natural storm runoff, and accretion from regional tributaries along the Trinity River. The BMI samples from the Pear Tree Gulch site were used to measure the effects of the scouring event that occurred between January 8 and January 14, 2023. Our results showed that the Shannon Diversity Index (SDI) increased after the scouring event, the composition changed, and overall abundance decreased after the scour event. This study suggests that an isolated period of scouring in a regulated system does not result in BMI metrics associated with unregulated systems that experience frequent scouring events.

INTRODUCTION

Urban and agricultural development in California have inflicted major impacts on riverine systems across the state, largely through the construction of dams for hydraulic power, flood control, and water storage (Adkins, 2007; Caldwell et al., 2018; Kennen et al., 2010; Merz et al., 2005; Qiaoyan et al., 2022). The construction of dams has been shown to have significant impacts on salmonid populations in rivers within the state, whose populations were bountiful prior to colonization (Adkins, 2007; Moore et al., 2007; Power et al., 2008).

The Trinity River in northern California is an example of an ecosystem that is affected by dams and diversions. Since the original construction of the Trinity (1962) and Lewiston (1963) dams, populations of anadromous fish species in the Trinity River have declined significantly (Adkins, 2007). The construction of the dams, along with other anthropogenic disturbances, have contributed to the population decline of salmonids (Adkins, 2007; Beechie et al., 2014; Power et al., 2008). In the past few decades, restoration efforts have been conducted on the Trinity River to assist in the remediation of riverine habitats and revitalization of salmon species (Beechie et al., 2014).

Benthic macroinvertebrates (BMI) are an important food source for salmonids and act as indicators of ecosystem health in aquatic systems (Adkins, 2007; Beechie et al., 2014; Power et al., 2008). Prior research suggests that, following scouring events, there is a greater abundance of "vulnerable" BMI species, which are the preferred food species for salmonids (Parker et al., 1997, Power et al., 2008). Sub-alpine riverine systems are of particular interest as they are more susceptible to potential scour events and consequential recolonization of benthic communities (Power et. al., 2008).

The purpose of this study is to examine the effect of scouring events that occurred over the course of a week between January 8 and January 14, 2023 (Figure 1), on BMI communities of the Trinity River downstream of Lewiston Dam and upstream of the confluence with the North Fork Trinity River (also known as the Trinity River Restoration Reach). This study will serve as a preliminary analysis within a longer-duration study that will be conducted by Cal Poly Humboldt graduate student Benjamin King. Understanding the influence of scouring events on salmonid food sources will be important in achieving fisheries restoration goals (Merz et al., 200; Power et al., 2008; Qiaoyan et al., 2022). More specifically, these findings could inform ongoing flow restoration efforts in the Trinity River to help ensure they align with broader salmonid restoration goals (*Trinity River Restoration Program*, 2023).

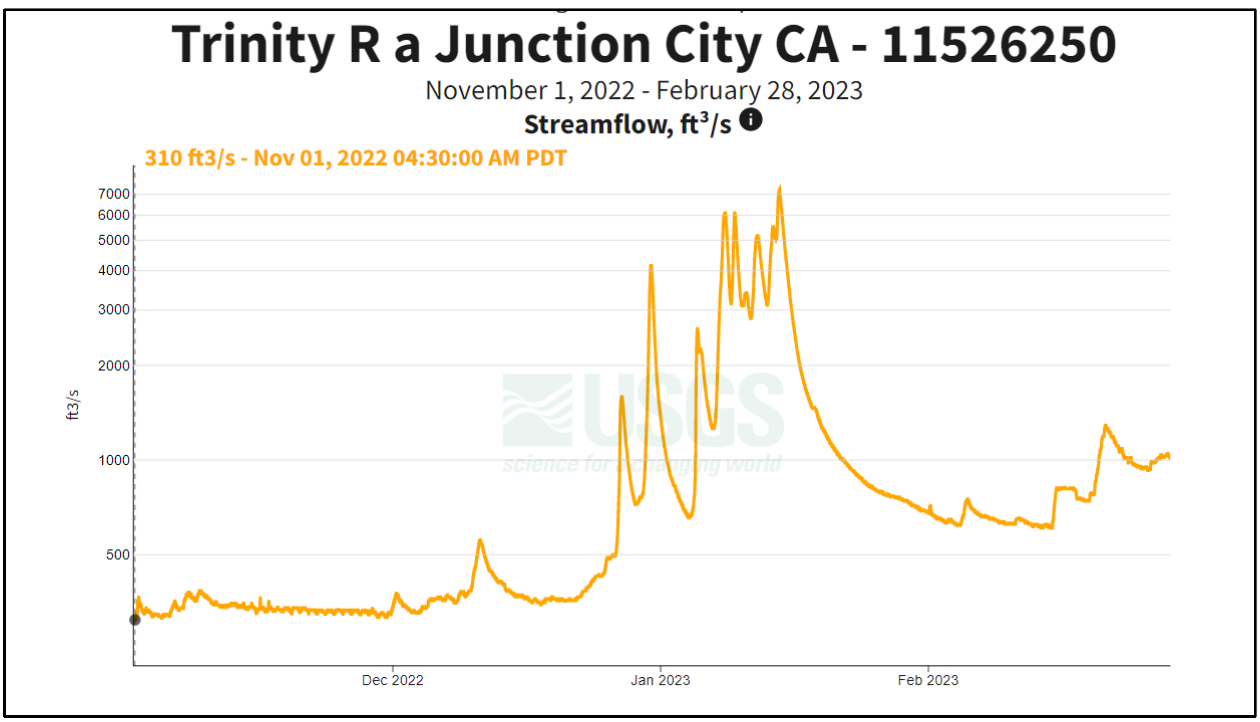

Figure 1. United States Geological Survey (USGS) hydrograph in cubic feet per second at the Junction City Gauge with a custom time span (*Trinity R a Junction City CA*, n.d.). The peaks in late December and early January show the scour event that we studied.

MATERIALS AND METHODS

Study Location

The study site is located along the Trinity River in Trinity County, California. The Trinity River is a tributary of the Klamath River in Northern California with its headwaters in the Trinity Alps (Adkins, 2007). The Trinity River provides habitat for multiple threatened salmonid species, including the Southern Oregon/Northern California Coast (SONCC) Evolutionary Significant Unit (ESU) of coho salmon (*Oncorynchus kisutch*) (CNDDB, 2023). A majority of the Trinity River watershed is managed by the U.S. Forest Service (Forest Service, 2023). The data was collected near Pear Tree Gulch, approximately 23 miles downstream from Lewiston Dam (Figure 2). The sampling site is located at a public boat launch site adjacent to Highway 299.

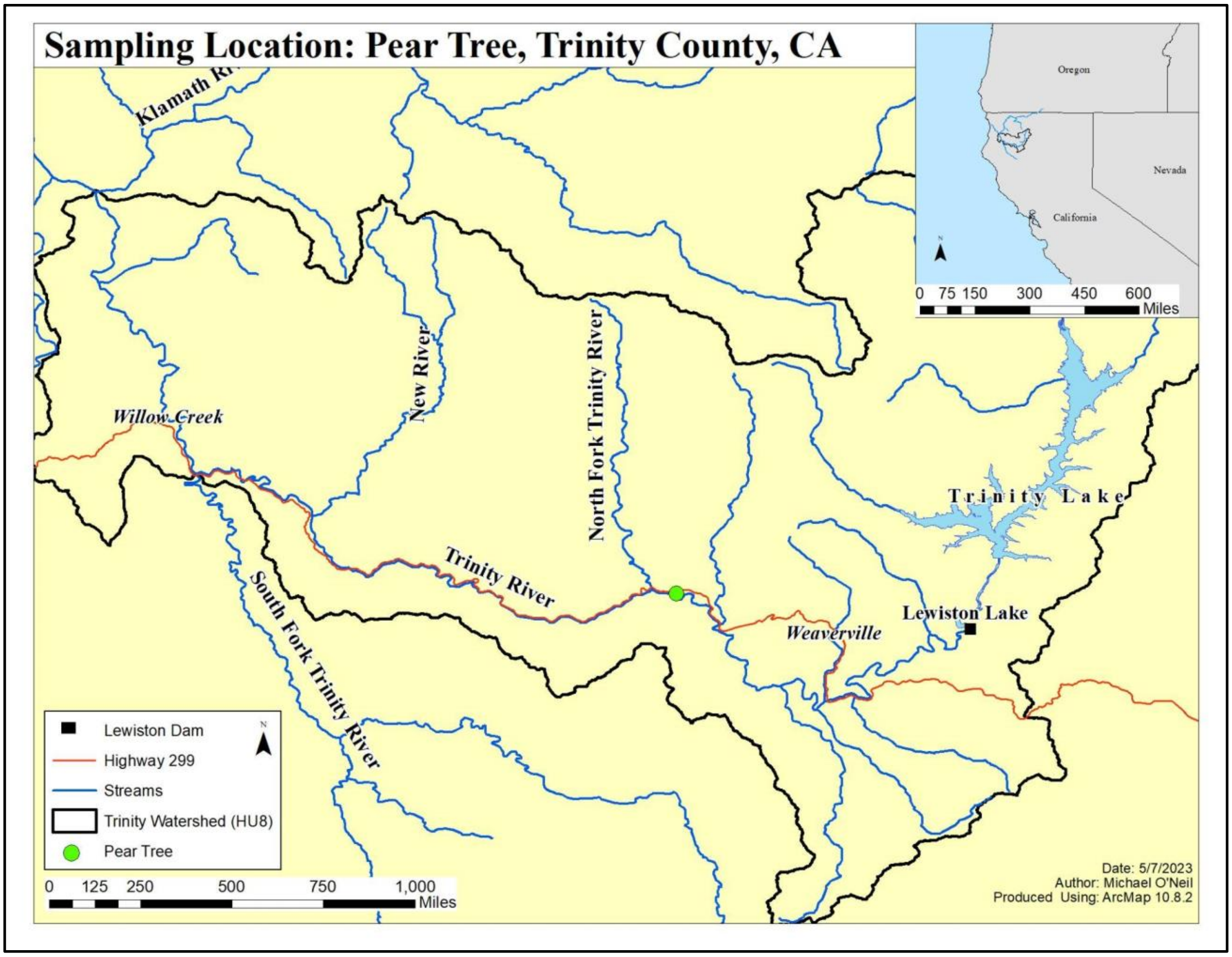

Figure 2. A map showing where benthic macroinvertebrate samples were collected for this study (Nov 2022 -Feb 2023). Samples were collected from the Pear Tree Boat Launch area in the mainstem Trinity River watershed in northern California. Map created by Mic O'Neil (2023).

Field Methods

Benthic sampling was conducted by Cal Poly Humboldt graduate student Benjamin King on 11/18/2022, 12/14/2022, 1/26/2023, and 2/16/2023. Utilizing a Hess sampler, two benthic samples were collected every month in the riffle along the perennial channel stream margin. A $0.09 m^2$ Hess sampler with a 500 µm mesh screen was placed in the streambed with the mesh screen on the front, perpendicular to the flow in order to allow water through the sampler and into the net. Cobbles inside the Hess sampler area were scrubbed with a plastic brush to free up invertebrates into the Hess sampler collection net. Debris and invertebrates were then captured into the filter located at the end of the collection net, transferred into a jar, and preserved in 90% ethanol. Jars were given a label to indicate the location, date, and type of sample.

Sample Processing

Samples were drained through a 500-micron steel sieve with waste ethanol captured in a plastic tray below. This waste ethanol was then transferred to a designated glass waste container. Contents in the sieve were then inserted into a five-gallon bucket filled with water. The sample was then elutriated several times until fine sediment was completely removed. The contents of the buckets were then filtered through a sieve and the water was disposed of. The sample within the sieve was further rinsed under a running faucet. Contents of the sample were separated into two equal subsamples and any large observable invertebrates were removed by hand and divided respectively into each subsample. Subsamples were then labeled individually. These labels were then placed inside each subsample on waterproof paper and the samples were filled with 70% ethanol until the contents were fully submerged. When choosing a sub-sample to process, random selection was utilized. Using a dissecting microscope, organisms were identified and counted as they were removed from the sample. Organisms were identified to family or to the lowest possible taxonomic level and placed in respective vials. Counts for each taxon were recorded in a Microsoft Excel spreadsheet. For subsamples where the total counts of invertebrates were below 300, the second subsample was processed as well. Counts of invertebrates exceeded 300 for only two subsamples that were processed, HS1 from November 18, 2022, and HS2 from December 14, 2022. For all other samples, both subsamples were processed.

BMI Analysis

Data were analyzed in Microsoft Excel to assess BMI metrics in relation to the winter scouring event that occurred over the course of a week between January 8 and January 14, 2023. For samples where only one subsample was processed, data points were multiplied by two to estimate counts at the full sample size prior to calculating BMI metrics. Metrics calculated included abundance, composition, taxa richness, and diversity. Abundance is the total number of invertebrates found in each sample. Taxa richness was calculated by counting the number of different taxa observed in each sample. The Shannon-Weiner Diversity Index was used in order to estimate taxonomic diversity. The Shannon-Weiner Diversity Index was calculated using the equation: $-\Sigma$ pi *ln(pi), where p_i is the proportion of the total abundance that each taxon accounts for. For the purpose of analyzing sample composition, p_i was converted to a percentage.

Two sample t-tests assuming unequal variances were used to analyze changes in BMI metrics before and after scouring events. Samples collected on November 18 and December 14, 2022, were grouped together to form the pre-scour metrics. January 26 and February 16, 2023 samples were combined to form the post-scour metrics. An individual t-test was run for each of the metrics being analyzed. Two sample t-tests assuming unequal variances were also performed to evaluate change in relative abundance (p_i) for the dominant taxon in each sample group.

RESULTS

BMI abundance, taxon richness, and diversity were compared across pre and post-scour sample groups. Taxon richness and abundance decreased between pre and post-scour samples while SDI was higher in post-scour samples (Table 1). There was no significant difference in any of the BMI metrics between pre and post-scour sample groups using an alpha of 0.05 (Table 1).

Table 1. A summary of the benthic invertebrate metrics that were compared across pre and post-scour samples. Metrics include taxon richness, abundance, and Shannon-wiener diversity index (SDI). P-values are from two-sample t-tests assuming unequal variances comparing pre and post-scour sample groups.

	Pre-Scour 11/18/2022 Average	Pre-Scour 11/18/2022 Standard Deviation	Pre-Scour 12/14/2022 Average	Pre-Scour 12/14/2022 Standard Deviation	Post-Scour 1/26/2023 Average	Post-Scour 1/26/2023 Standard Deviation	Post-Scour 2/16/2023 Average	Post-Scour 2/16/2023 Standard Deviation	t-test (Pre vs. Post)
Taxon Richness	21	2	18.5	2.5	18	2	17.5	2.5	0.35
Abundance	1435	1215	517	89	92.5	38.5	130	44	0.22
SDI	1.85	0.21	1.89	0.30	2.49	0.02	2.10	0.13	0.07

Benthic Macroinvertebrate Abundance

Benthic macroinvertebrate abundance varied greatly across the samples. The highest BMI abundance was in the HS1 sample from November 18, 2022, with 2,650 organisms counted. BMI abundance was lowest in the HS2 sample collected on January 26, 2023, where only 54 BMI were counted. BMI data for pre-scour abundance showed a positively skewed distribution with a standard deviation of 976. Data from the post-scour samples were normally distributed with a standard deviation of 199. The mean BMI abundance was 976 for pre-scour samples and 111 for post-scour samples (Figure 3). A t-test yielded a p-value of 0.22, indicating that there is no significant difference in BMI abundance between pre- and post-scour using an alpha of 0.05.

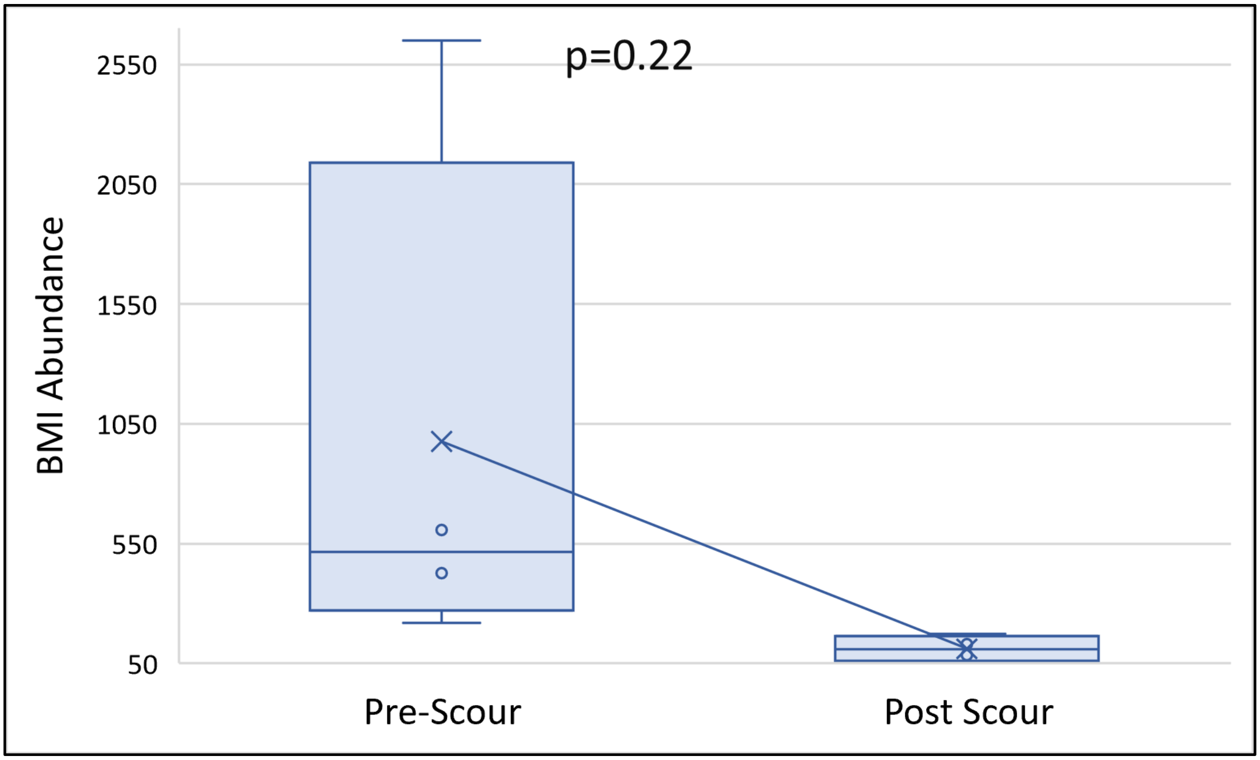

Figure 3. Comparison of BMI abundance in the months before (Nov/Dec 2022) and after (Jan/Feb 2023) a scouring event in the Trinity River.

Taxa Composition

The four highest percentages of taxa present in the pre/post-scour samples were displayed to represent the dominant taxa and the others were totaled as 'Other taxa' (Figures 4a and 4b). Only two of these taxa (*Chrionomidae* and *Hydropsychidae*) were present in the top four across the pre- and post-scour sample groups. Pre-scour samples consisted predominantly of *Oligochaeta*, totaling 47% of the sample group. However, there was a significant reduction in *Oligochaeta* relative abundance between pre and post-scour groups (p=0.03). The largest individual taxa found within the post-scour samples was *Chironomidae*, totaling 27% of the sample group (Figure 4b). *Chironimidae* relative abundance increased between pre and post-scour but the difference was not significant (p=0.88).

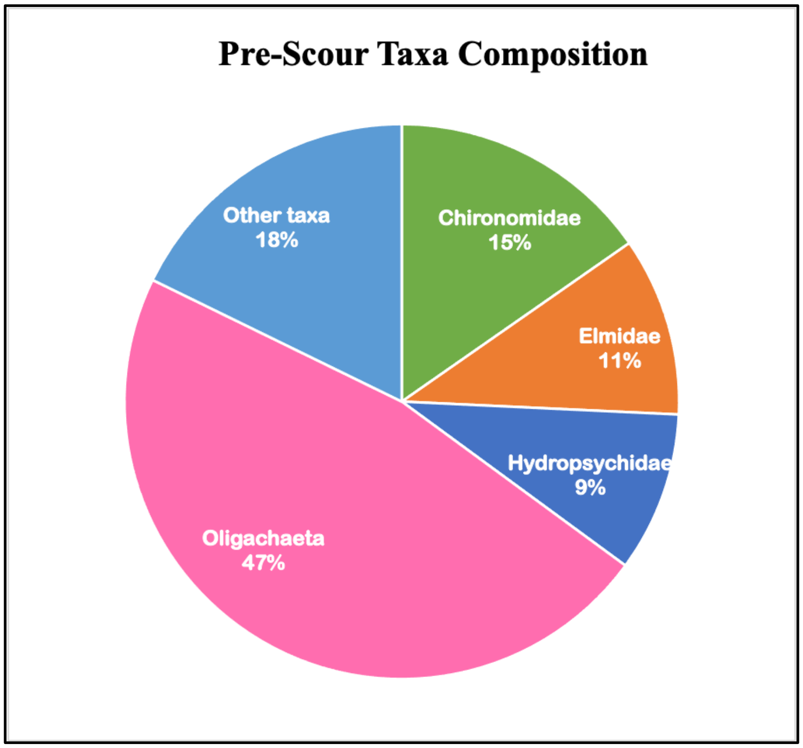

Figure 4a. Taxa composition of benthic macroinvertebrates from pre-scour samples (11/18/22 and 12/14/22).

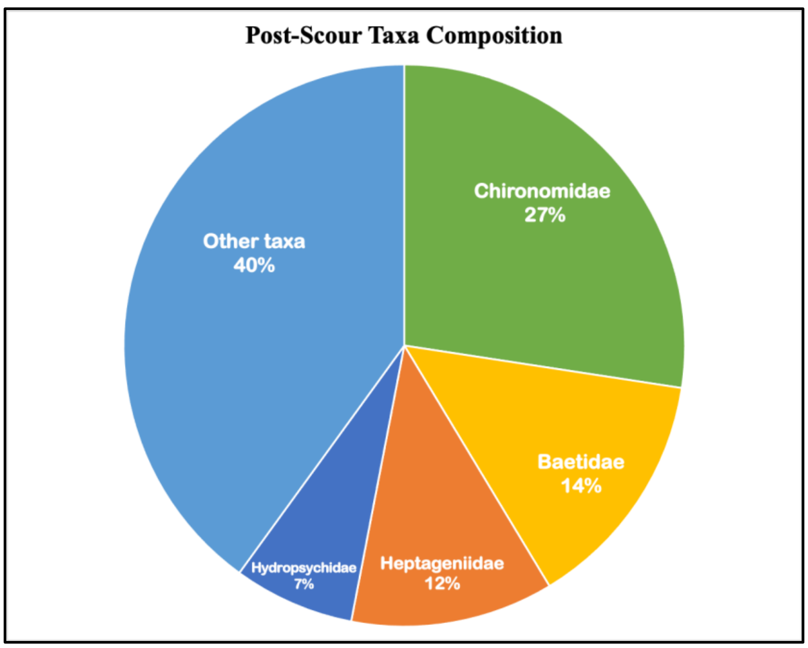

Figure 4b. Taxa composition of post-scour samples from 1/26/23 and 2/16/23.

Taxa Richness

The pre-scour sample group had a total of 31 different taxa, whereas the post-scour samples contained 28 different taxa. Values for taxa richness ranged from 15-23, with the highest taxa richness value being found in the pre-scour sample group and the lowest in the post-scour sample group (Table 2). There was a slight reduction in mean taxa richness between the pre-scour and post-scour sample groups, from 19.75 to 17.75 respectively (Figure 5). There was no significant difference in taxa richness between the two sample groups (p=0.35).

Table 2. Benthic macroinvertebrate taxa richness in samples collected from Pear Tree on the Trinity River. There was no significant difference between Pre- and Post-Scour groups (p=0.35).

Sample	Date	Group	TAXA RICHNESS
HS1	11/18/22	Pre-Scour	23
HS2	11/18/22	Pre-Scour	19
HS1	12/14/22	Pre-Scour	21
HS2	12/14/22	Pre-Scour	16
HS1	1/26/23	Post-Scour	20
HS2	1/26/23	Post-Scour	16
HS1	2/16/23	Post-Scour	15
HS2	2/16/23	Post-Scour	20

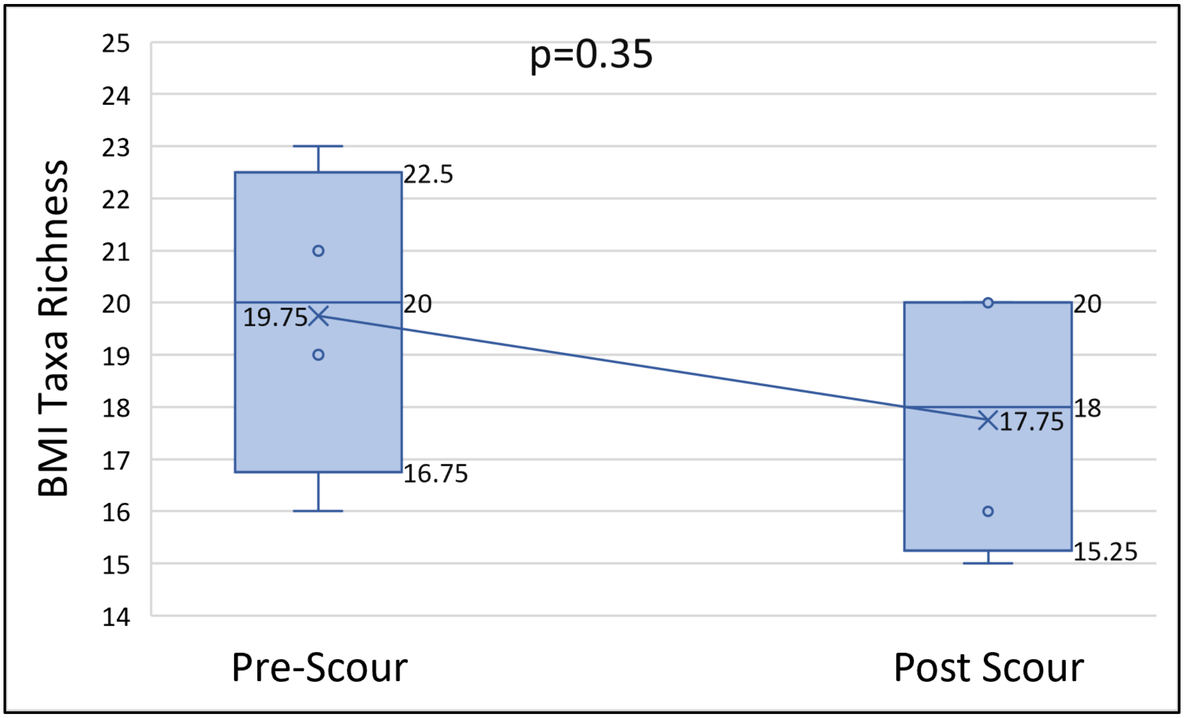

Figure 5. A comparison of benthic macroinvertebrate taxa richness in Pre- and Post-Scour sample groups. Samples were collected from the Trinity River in northern California before and after a high-flow event that caused the scouring of the stream channel.

Shannon-Weiner Diversity Index

Values for Shannon-Weiner Diversity Index (SDI) ranged from 1.6 to 2.5. The mean SDI was higher in post-scour samples. The mean SDI increased from 1.9 in the pre-scour sample group to 2.3 in the post-scour samples. Pre-scour sample data had a relatively symmetrical distribution ($\boldsymbol{\sigma}$=0.26) whereas post-scour data was skewed negative ($\boldsymbol{\sigma}$=0.22) (Figure 6). A t-test evaluating pre- and post-scour SDI values yielded a P-value of 0.07, indicating there is no significant difference in SDI between the two groups when using an alpha of 0.05.

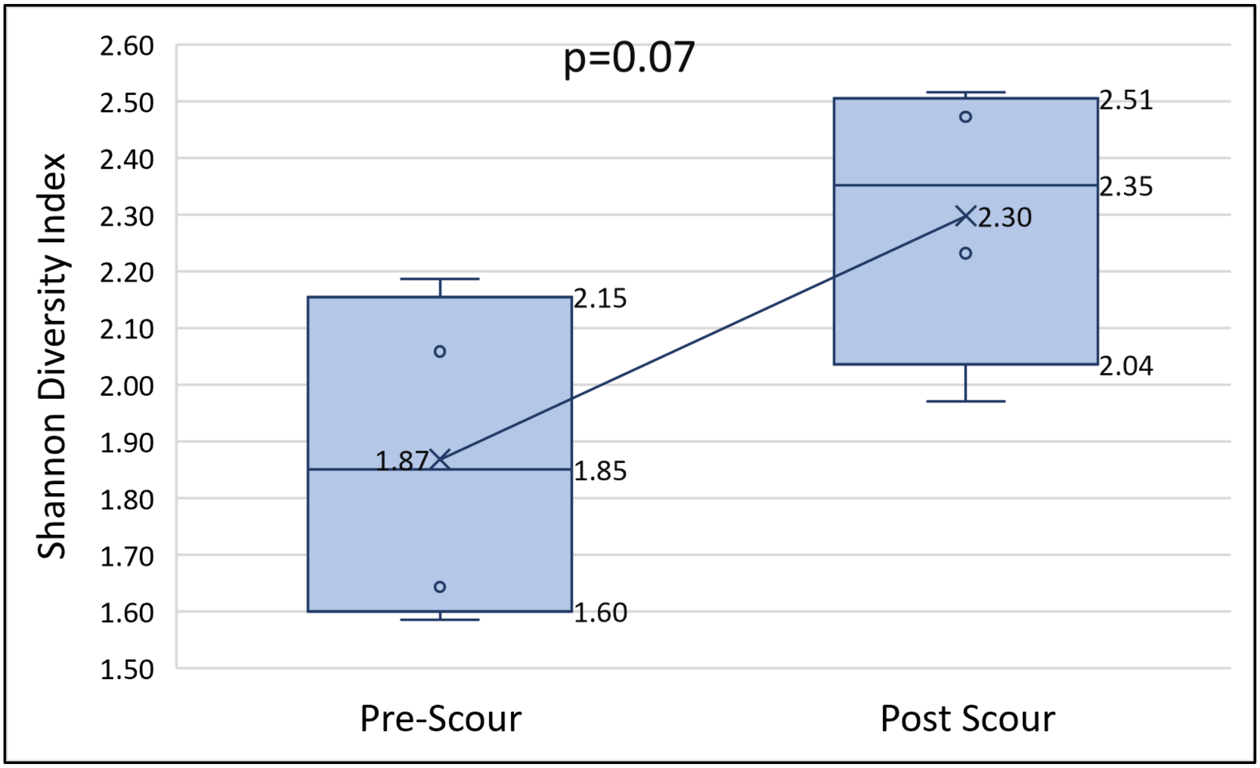

Figure 6. A comparison of benthic macroinvertebrate diversity in Pre- and Post-Scour sample groups. Samples were collected from the Trinity River in northern California before and after a high-flow event that caused the scouring of the stream channel.

DISCUSSION

Our study compared taxon richness, composition, abundance, and Shannon-Weiner Diversity Index (SDI) of benthic macroinvertebrate samples collected at a site known as Pear Tree along the Trinity River. The collection site is on a relatively straight stretch of the Trinity River and consists of a series of riffles and small pools followed by a long straight run. Samples were collected in a riffle following major scouring events that happened on December 30th, January 8th, and January 14th (Figure 1). Decreases in mean abundance and taxon richness, as well as an increase in mean SDI were observed. However, these changes were not significant (Table 1). These scouring events are likely to have contributed to the decrease in abundance (Figure 3), and also to the increase in SDI (Figure 6) that was observed.

Using an alpha of p=0.05, the reduction in SDI between pre- and post-scour samples would be not significant, although the probability that this was a random result is still relatively low (p=0.07). SDI data for both groups showed a fairly even distribution with the pre-scour group being slightly skewed positive ($\boldsymbol{\sigma}$=0.26) and post-scour skewed slightly negative ($\boldsymbol{\sigma}$=0.22) (Figure 6). Given the small sample size (n=4) in this study, this result has limited statistical power and is worth investigating with larger sample groups that may yield a more definitive result.

No significant differences were observed between taxon richness but the composition of the taxa shifted quite dramatically (Figure 4a and Figure 4b). Before the scour event, a majority of taxa composition was *Oligachaeta* (47%) and a second majority was “Other Taxa” (18%). After the scour event, the majority shifted to “Other Taxa” (40%), and a second majority to *Chironomidae* (27%). These results may have implications for the effects scouring events have on regulated and non-regulated systems (Milner, 2019). In a 1997 study, Parker and Power found that regulated rivers had lower densities of Chironomids than non-regulated systems that experience frequent high-flow events, like the scour event we studied. *Chironomidae* are among the preferred prey for juvenile salmonids, such as steelhead (*Oncorhynchus mykiss)*, which were also found in greater abundance in non-regulated systems (Parker & Power, 1997). Our result suggests that there is no significant change in *Chironomidae* abundance in the month following a scour event (p=0.22), however, this could be investigated over a longer period to better capture prior conditions and post-scour BMI community recovery and variability. Prior research has shown that BMI composition fluctuates seasonally (Kennen, J. G., et al., 2010; Milner, V. S., et al., 2019; Wallace, J. B., et al., 1996). It is possible that this study reflects the effects of seasonality rather than changes influenced by scour. Continuing to track BMI metrics over multiple years could help to flush out which differences are due to seasonality and what can be attributed to scouring events. Furthermore, as the frequency of high-flow events in the Trinity River increases due to flow restoration releases, it will be of interest to track the effect this has on preferred juvenile salmonid prey, like *Chironomidae* and other soft-bodied BMI's (TRRP, 2023; Cross, W. F., et al., 2011).

Our research had fundamental limitations that should be accounted for when making conclusions. Due to the time constraints of this study, the general sample size was small (n=4). Fortunately, this project was a small division of a larger research project being conducted by Cal Poly Humboldt graduate student Ben King. In future research, the effects of scour and seasonality on BMIs in the Trinity River should be extended to multiple years. This would ensure that both drought and scour years are being observed before formulating a conclusion.

This study provides insight into the immediate response of BMI communities to scouring flows in a dam-regulated river system. Dams often reduce the frequency of scouring flows, shifting BMI communities towards larger slower growing taxa that are less vulnerable to predation by juvenile salmonids (Parker & Power, 1997;Power et al. 2008). Because of this and altered physical habitat conditions in regulated systems, dams have been associated with the decline of salmonid species (Parker & Power, 1997). Recently, large-scale restoration efforts have targeted the recovery of salmonid species, with some projects incorporating variable dam releases to mimic a more natural flow regime (CDFW, 2023; TRRP, 2023). This study suggests that an isolated period of scouring in a regulated system does not result in BMI metrics associated with unregulated systems that experience frequent scouring events. This exposes a need to track BMI metrics over multiple years, flow levels, and scour frequencies. Doing so could provide valuable information about how flow releases may influence food availability for juvenile salmonids (Parker & Power, 1997). This information could then be used by water managers to ensure that dam releases align with salmonid restoration goals.

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