GAVIN NEWSOM
GOVERNOR

YANA GARCIA
SECRETARY FOR
ENVIRONMENTAL PROTECTION

North Coast Regional Water Quality Control Board

Gualala River Watershed Monitoring Data Assessment

Gualala River Watershed Stream Monitoring. Photo Credit: Gualala River Watershed Council

1. Executive Summary

This report assesses instream data from the Gualala River Watershed Council Monitoring Program, which collected various aquatic habitat parameters from the Gualala River watershed. Limitations in spatial and temporal data restrict the depth of statistical analysis and, consequently, limit the conclusions that can be drawn about watershed-wide conditions. However, continued data collection at four reference stream reaches reveals trends and correlations for specific instream parameters, which may be indicative of conditions in other parts of the watershed.

Trend analyses in this assessment were conducted using the Mann-Kendall test, a nonparametric method that is suitable for identifying trends in time series data without requiring assumptions of normality or specific data distributions. Data were collected annually, and both the Mann-Kendall test and the Thiel-Sen slope estimator were employed to detect monotonic trends.

Results indicate that the Gualala River watershed is highly sensitive to environmental factors, easily transporting sediment when the landscape is disturbed by either natural or human caused events. While the mainstem of the Gualala River shows progress in stream channel complexity and scouring trends, full recovery will take a long time due to the severity of degradation that has occurred historically in the watershed. Other reference reaches are either declining in aquatic habitat conditions or have inconclusive trends. Notably, median particle diameter is significantly decreasing at three of four reference reaches, suggesting that fine sediment is either still moving downstream or new inputs of fine sediment are being added from upslope watershed areas. There are no findings in this analysis that suggest conditions across the watershed have begun to significantly improve.

Temporal and spatial data gaps limit the scope of this analysis and hinder our ability to draw definitive conclusions about the entire watershed. Additionally, the lack of instream parameters related to fine sediment, such as turbidity or percent fines, limits our understanding of the presence and movement of fine sediment within the watershed, which can significantly impact various life stages of salmonids.

2. Background

The purpose of this report is to provide an assessment of the instream data collected through the Gualala River Watershed Council (GRWC) Monitoring Program (Program). The Program was established with the purpose of understanding watershed conditions through the collaboration of private landowners, community groups, and public agencies. The Program follows the Quality Assurance Program for Monitoring Sediment Reduction in the Gualala River Watershed (QAPP) (GRWC, 2008). The Program was established due to insufficient information to adequately assess the status of aquatic resources and water quality in the Gualala River watershed.

Various water quality and aquatic habitat parameters were collected throughout the lifespan of the Program (since 1997). Due to unforeseen funding restrictions, the anticipated frequency of monitoring at many locations was not met. However, the lifespan of the Program and number of sampling locations has allowed for a level of analysis that shows trends and correlations.

Fish surveys were conducted annually and tallied Coho salmon of any age, steelhead one year or older, and Redds (spawning nests). Redds data was not robust enough to include in this assessment. However, steelhead and Coho surveys spanned from 1998 to 2018. Six stations had between 11 and 17 years of observations, three stations had between six and nine years of observations, four stations had between two and four years of observations, and 10 stations had one observation on record (Figure 1).

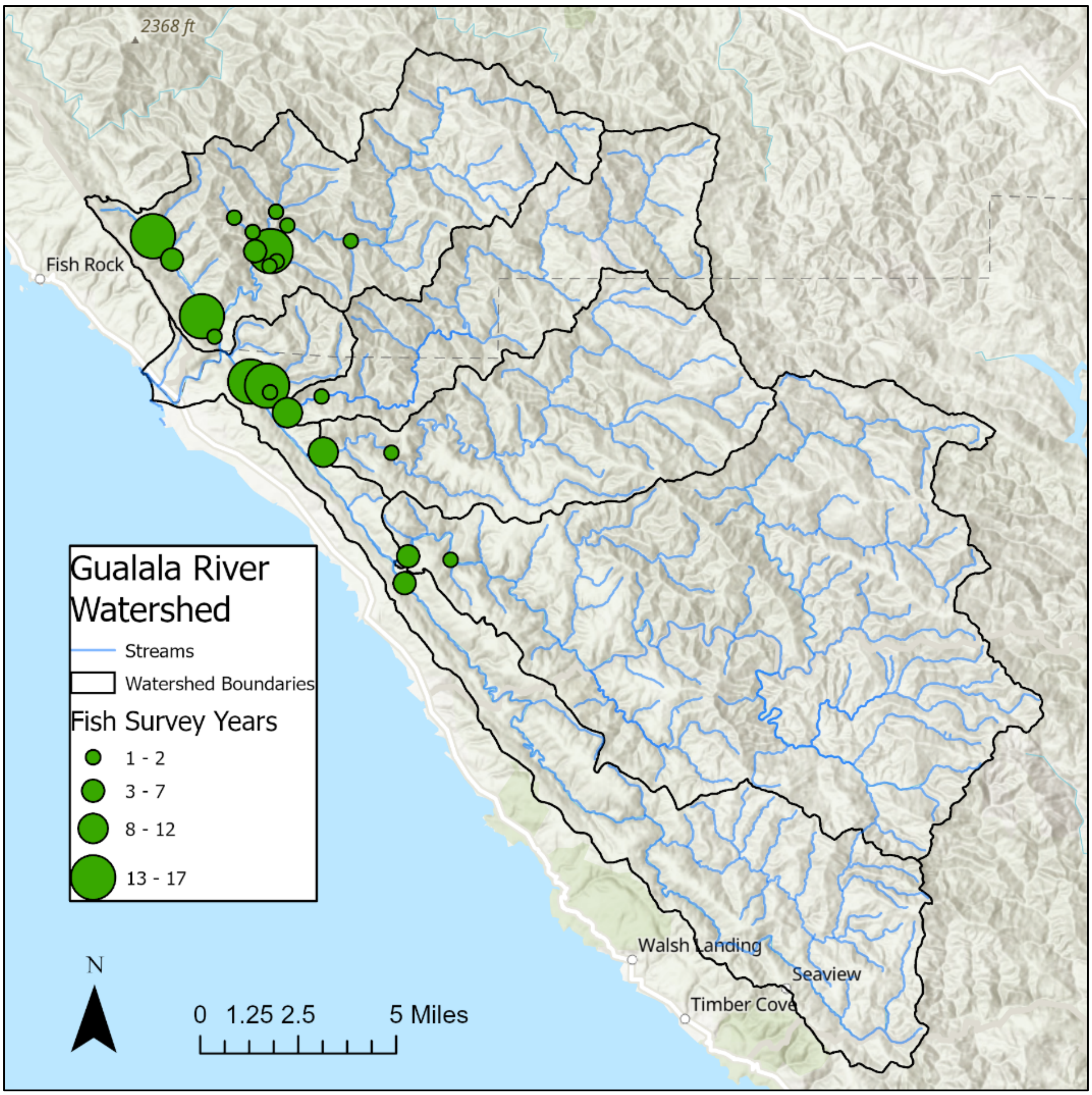

Figure 1: Total years of fish surveys conducted in the Gualala River watershed.

Instream monitoring included longitudinal profiles and benchmarks, cross-sections, pebble counts, and large woody debris (LWD) counts. Parameters included in this report include the following:

- D_{50}: The median pebble size (mm) of a 100-pebble sample. Three sample sites per reach are averaged to calculate this value. D_{50} values can provide information as to the composition of substrate particle size. Higher D_{50} values generally indicate coarser sediments, which are beneficial for salmonid spawning habitats, as coarser gravel promotes better water flow and oxygenation around fish eggs. An increasing trend in D_{50} can suggest that finer sediments are being flushed out, leading to coarser, more favorable substrates.

- Streambed Variation Index (SVI): Calculated by the [(Standard Deviation of residual depth/bank full depth) *100]. Therefore, lower SVI values have more similar data points to the mean, and high values have less similar data points to the mean. A reach with an SVI of zero would be a perfectly uniform longitudinal profile with zero variation of the streambed and streambank heights. Streams with higher SVI have more stream channel variations and are therefore more complex which is favorable for fish habitats (Madej, 1999).

- Aggradation vs. Degradation (A/D): The change in elevation of the stream channel relative to the first year of measurement (+/- feet). This value indicates whether a stream channel is scouring, and sediment is moving out or if a stream channel is depositional and accumulating sediment.

- Large Woody Debris (LWD): Total pieces per 1,000 feet and cubic volume per 1,000 feet. This value may be representative of restoration efforts in the watershed, and is known to positively impact stream channel morphology and streambed substrate to benefit native fish species.

Monitoring frequency varied at each monitoring station (also known as a monitoring reach). Four stations had 14 to 26 years of observations, ten stations had two to five observations, and 20 stations had one observation on record (Figure 2).

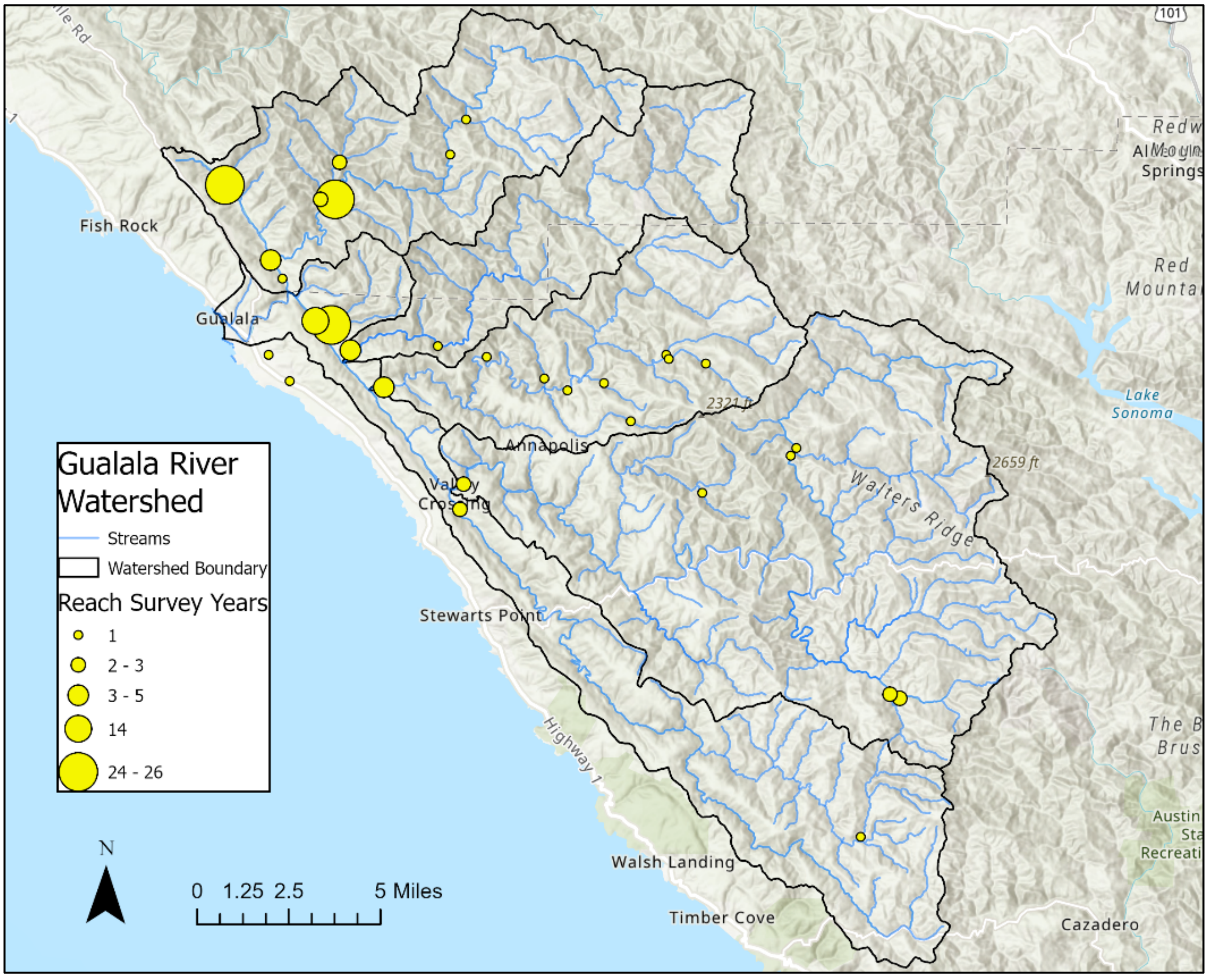

Figure 2: Total years of stream reach surveys conducted in the Gualala River watershed.

3. Methodology

Trend analyses were conducted using the Mann-Kendall test which is widely used in environmental science, hydrology, climatology, and other fields where researchers are interested in identifying trends in time series data (NNPSNP, 2011). It is especially useful when the assumptions of normality are not met or when dealing with ordinal data. The test does not require knowledge of the underlying distribution of the data, making it robust in various situations.

Given that data was collected on an annual basis for all parameters included in this assessment, the best approach would be to test for monotonic trends using the Mann-Kendall nonparametric test (MK) and Thiel-Sen slope estimator (Sen Slope). MK is specifically designed for detecting trends in time series data. It is often used to assess whether there is a monotonic upward or downward trend over time. The test produces Kendall's τ, a non-parametric correlation statistic based on the data ranks or order. Additionally, the Sen-slope is calculated as the median of all the two-point slopes. Finally, a two-sided p-value is produced to test for statistical significance.

For testing correlations between variables, this assessment used the Kendall rank correlation test. This is a non-parametric method used to measure the strength and direction of the association between two variables. This test uses the same assumptions as MK regarding normality, ordinal data, and distribution of data. The test statistic is Kendall’s tau (t), which ranges from -1 (perfect inverse correlation) to +1 (perfect positive correlation) and a p-value is produced to test for statistical significance. These analyses were conducted in R Studio using the following packages:

- mblm: Median-Based Linear Mondels
- rkt: Mann-Kendall Test, Seasonal and Regional Kendall Tests
- PerformanceAnalytics

4. Results – All Data

4.1 Fish Survey Data

Figure 3 displays all Coho salmon data and is categorized by subwatershed. Monitoring for Coho began in 1998 and ended in 2018. The last observation of Coho salmon occurred in 2004 along the Dry Creek monitoring reach in the North Fork subwatershed with an occurrence of 23 Coho per mile. The largest observation of Coho was in 1999 on the South Fork with an occurrence of 203 Coho per mile. Coho were not recorded in any of the other subwatersheds during this monitoring period. All other observations of Coho were in the North Fork along Dry Creek, Little North Fork, and Robinson Creek. The black dotted line in Figure 3, and other figures, represents the year that the United States Environmental Protection Agency (U.S. EPA) established the Gualala River Sediment Total Maximum Daily Load (TMDL) (U.S. EPA, 2001).

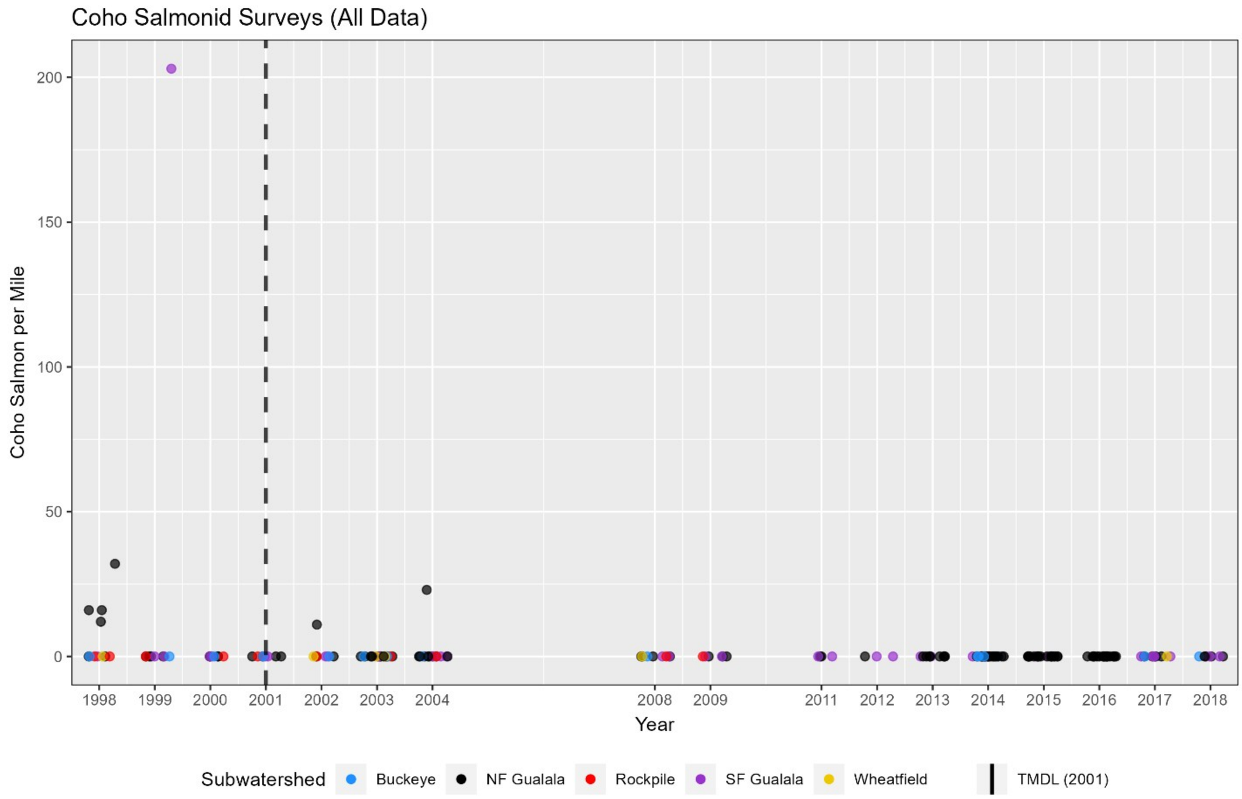

Figure 3: Coho salmon per stream mile for all subwatersheds and all years.

Figure 4 displays steelhead salmon data and is categorized by subwatershed. Steelhead salmon have been observed in every subwatershed during the monitoring period. Large observations of steelhead have occurred in the watershed, particularly in the North Fork, South Fork, and Rockpile Creek subwatersheds (> 1,000 steelhead per mile). The North Fork and Rockpile Creek subwatersheds have had the most consistent presence of steelhead throughout this record shown by having lower standard deviations of data points compared to other subwatersheds. However, due to the sampling regime, and majority of steelhead observations being taken in the North Fork, it is difficult to make accurate assumptions about the geographic spread of steelhead throughout the entire watershed.

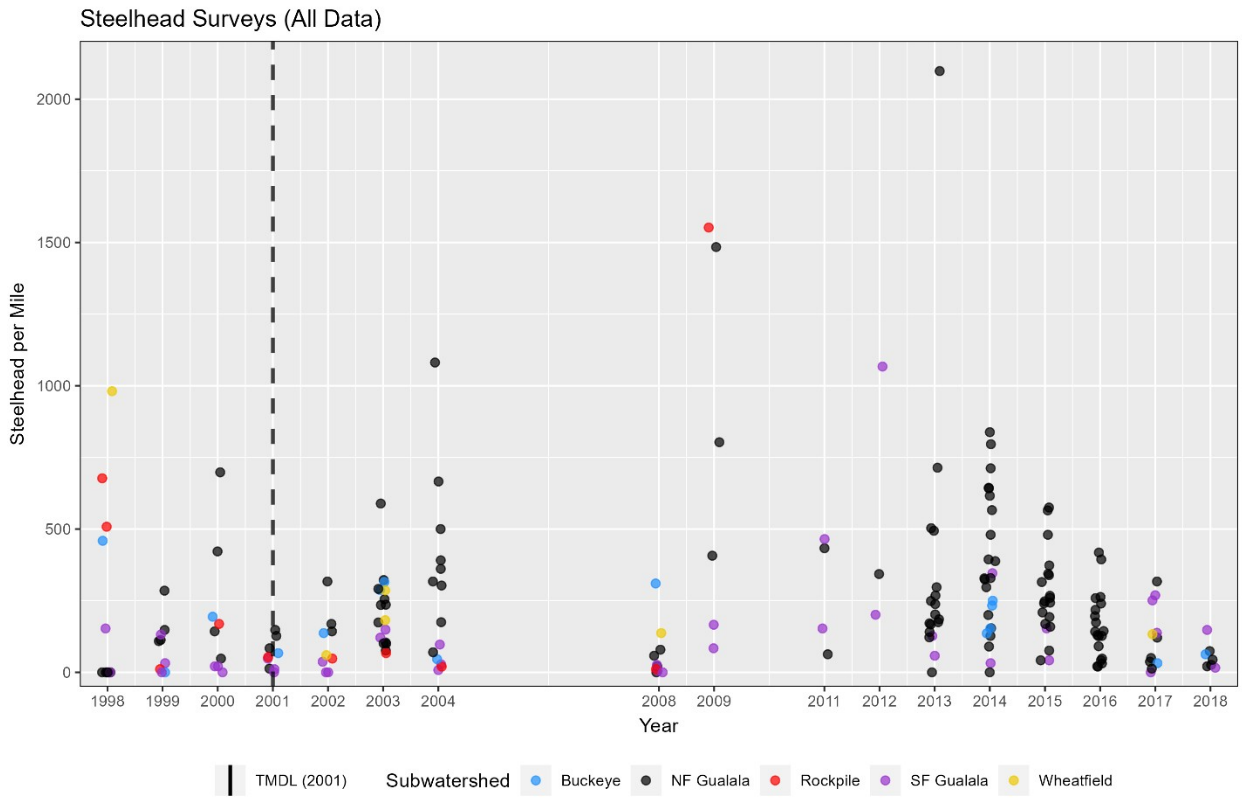

Figure 4: Steelhead salmon per mile for all subwatersheds and all years.

4.2 Reach Survey Data

Pebble counts were conducted to calculate median particle diameter (D_{50}). This assessment provides insights on the composition of the substrate along the streambed. Figure 5 displays all D_{50} data points collected and are categorized by subwatershed. The red target line represents the Aquatic Properly Functioning Conditions (APFC) target values for habitat needs of anadromous salmonids and other aquatic species (Knopp, 1993). These thresholds have not been calibrated to the Gualala watershed specifically, and may not be achievable, but are instead a reference value that D_{50} should be trending in a positive direction towards.

The North Fork and Buckeye Creek subwatersheds have higher mean D_{50} compared to other subwatersheds. Prior to 2005, only four observations met APFC targets. The latter part of the monitoring period has shown notably lower D_{50} values compared to the beginning of the monitoring period. Less observations were recorded in the second half of the monitoring period, however, the information that is available does not seem to indicate that D_{50} is trending in a positive direction over time. Trends in D_{50} at specific reference reaches with a long enough monitoring period are included in section 5.2.

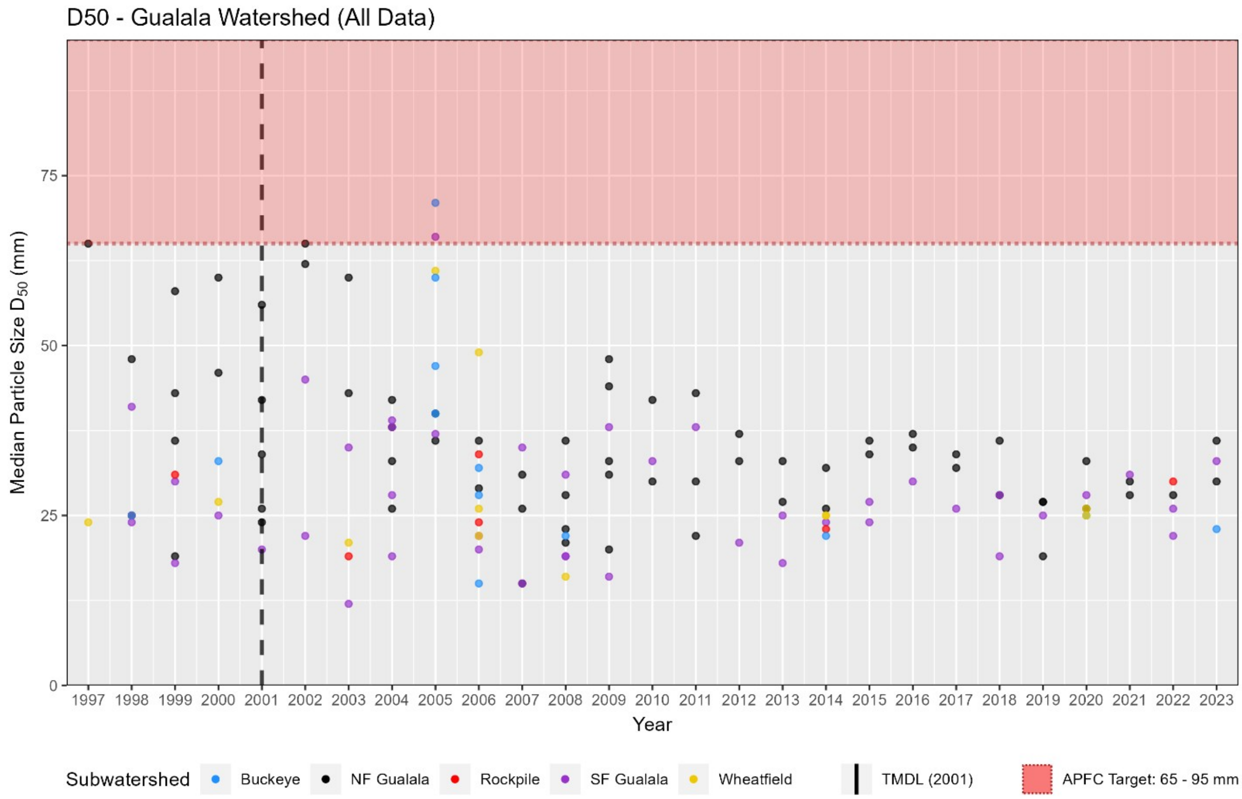

Figure 5: Median particle size (D_{50}) for all subwatersheds and all years.

Figure 6 displays streambed variation index (SVI) values for all data and is categorized by subwatershed. Figure 6 includes a reference target which is taken from a literature value of an old growth redwood forest. The GRWC QAPP has identified this value as a good indicator of recovery. Although there is a lack in other target thresholds for SVI in the literature, it is assumed that higher values have greater stream channel complexity and would have better aquatic habitat suitability.

SVI does not appear to show obvious temporal trends in the watershed as a whole or at the subwatershed level, however, majority of the higher values are in the upper reaches of the watershed and majority of the lower values are in the lower reaches of the watershed. Mean SVI throughout the record was highest in the Buckeye Creek subwatershed (48.1) and was lowest in the South Fork subwatershed (22.1). In all years of observations (except 2021), at least half or more of the observations were above the reference target. Similar to D_{50}, the second half of the record of data decreased in number of observations recorded, however, SVI maintained a high variation of values compared to D_{50}.

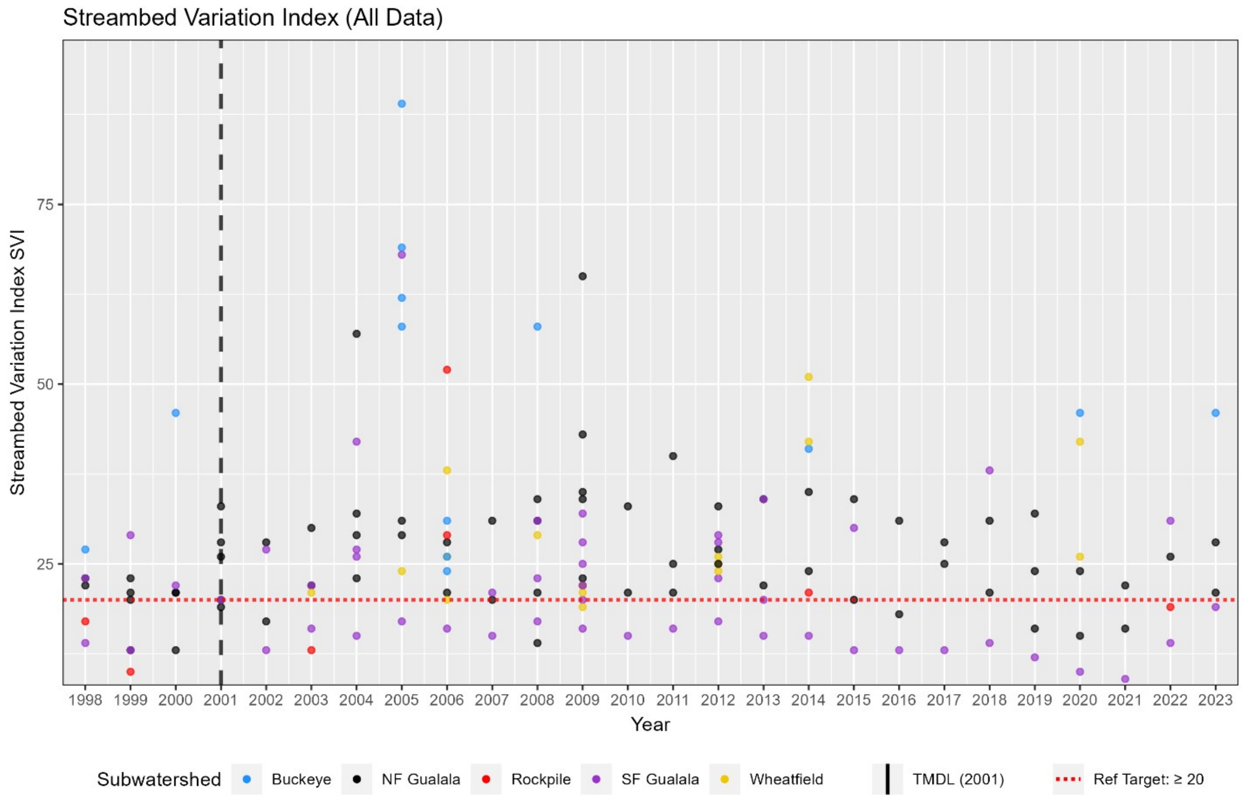

Figure 6: Streambed variation index (SVI) for all subwatersheds and all years.

Figure 7 displays large woody debris (LWD) pieces per 1,000 feet and is categorized by subwatershed. The APFC target is highlighted in red for pieces of wood per 1,000 feet was calculated by multiplying the APFC target (5.1 pieces per 100 feet) by 10 equating to 51 pieces per 1,000 feet. Alternatively, U.S. EPA suggests an appropriate target for LWD to be an increase in frequency and volume (U.S. EPA 2001).

LWD pieces have increased since the development of the U.S. EPA TMDL (black dotted line). Recent data is lacking spatially, but the stations that do have observations show a noticeable increase in LWD pieces over time. Higher LWD counts are found in Buckeye Creek, North Fork, and the South Fork subwatersheds. Some stations in the watershed have greater amounts of LWD pieces due to restoration efforts.

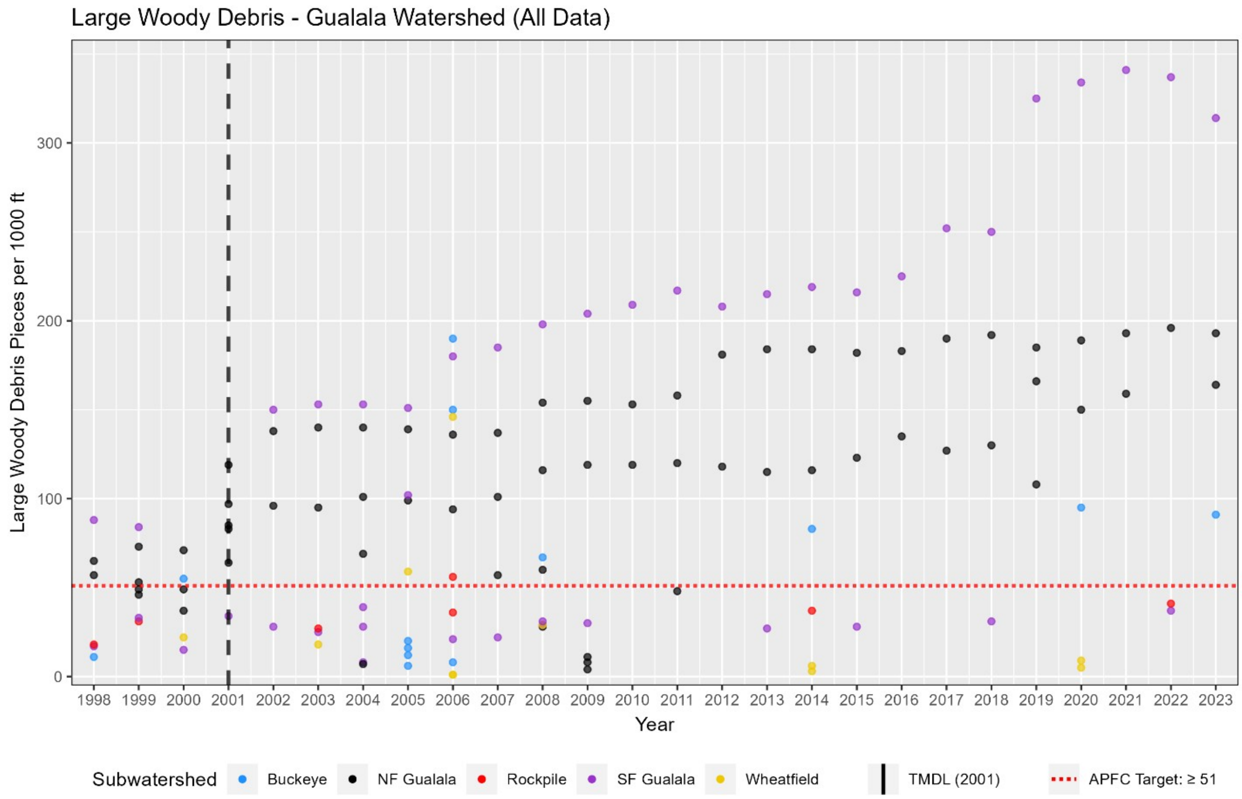

Figure 7: Large woody debris, pieces per 1,000 feet, for all subwatersheds and all years.

5. Statistical Analysis

5.1 Correlations

Correlation matrices which display the dependence between multiple variables are shown in Figure 8. The values above the diagonal list of parameters show the Kendall's tau value between two variables. A value of 1 represents a perfect positive correlation, a value of 0 represents no correlation, and a value of -1 represents a perfect inverse correlation. Statistical significance levels for correlations between parameters are also provided, representing the p-value (<0.001***, <0.01**, <0.05*). Lower p-values indicate greater statistical significance. Boxes below the diagonal list of parameters show the bivariate scatter plots with fitted lines. Figure 8 includes median particle diameter (D50), streambed variation index (SVI), aggradation vs. degradation (AVD), large woody debris pieces (LWD), and steelhead survey counts (Steel).

Significant positive correlations associated with steelhead included D50 and SVI. Significant positive correlations associated with LWD included D50 and AVD. A significant negative correlation was found between LWD and SVI. No correlations were found between the three streambed parameters (D50, SVI, and AVD).

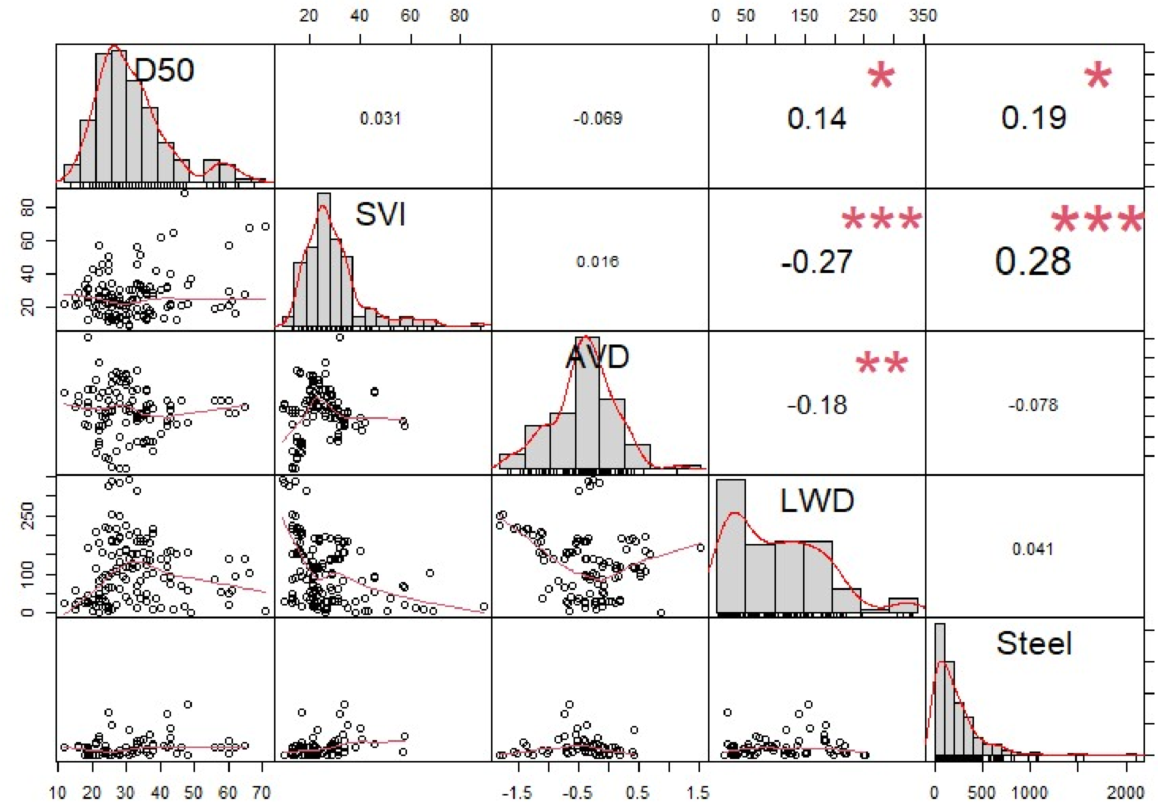

Figure 8: Correlation matrix displaying statistical relationships between D50, SVI, AVD, LWD, and Steel.

5.2 Trend Analyses - Mann-Kendall Results

Four monitoring stations continued to collect data throughout the lifetime of the Program. These stations are referred to as reference reaches. These include Station 203 (Little North Fork), Station 211 (Dry Creek), Station 217 (SF Mainstem), and Station 218 (Big Pepperwood Creek). These monitoring stations and their draining watershed boundaries are displayed in Figure 9.

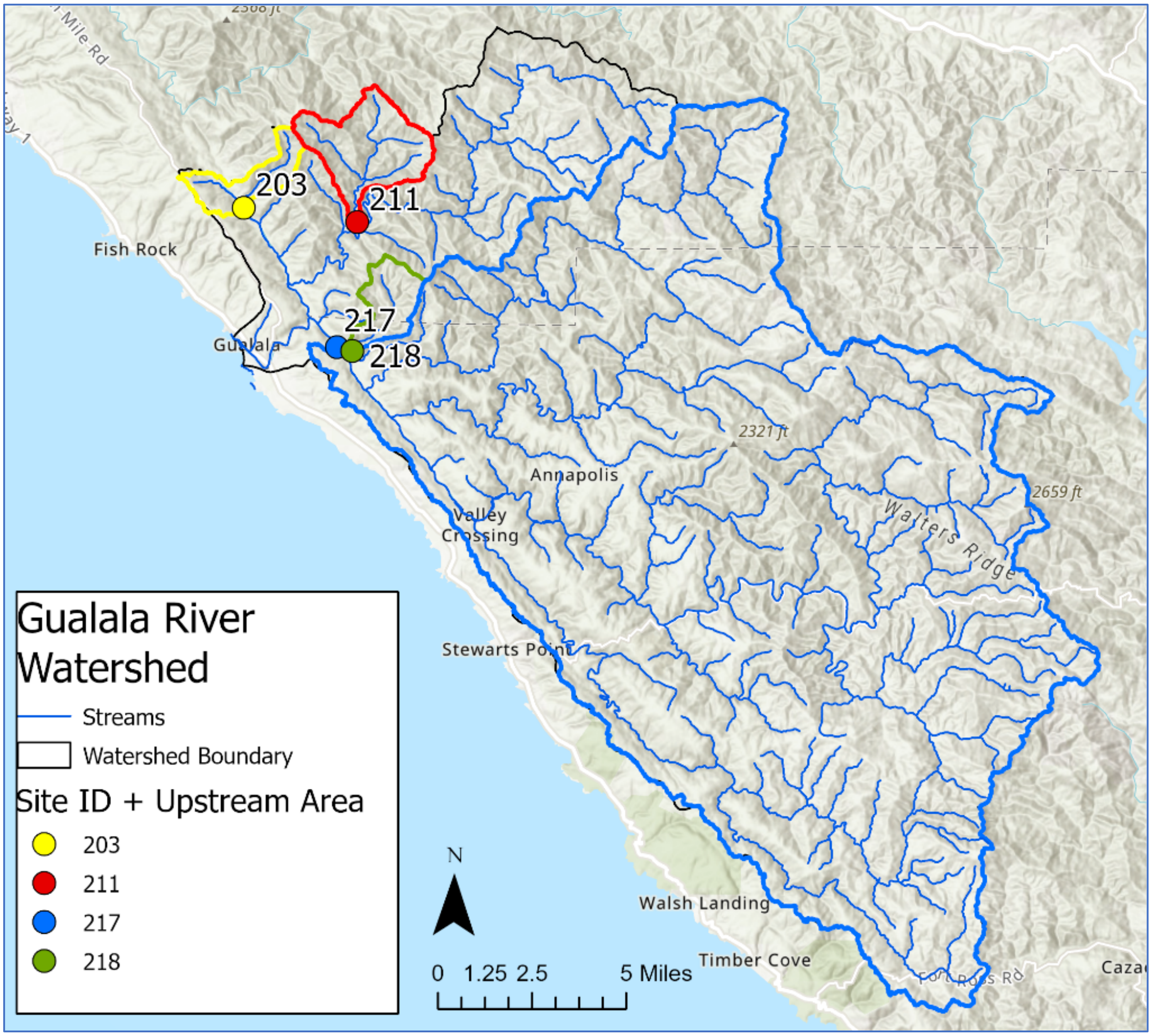

Figure 9: Location of the four reference reaches and their upstream draining watershed boundaries.

The Mann-Kendall trend test was conducted and produced the Kendall's τ, a non-parametric correlation statistic based on the data ranks or order. Additionally, the Sen-slope is calculated as the median of all the two-point slopes. Finally, a two sided p-value is produced to test for statistical significance. The Mann-Kendall test was run on 20 combinations of stations and parameters that had a minimum sample size of 10. Eleven tests showed a statistically significant trend by having a p-value of less than 0.05 (Table 1). A trend test with a p-value below 0.05 and a positive Sen Slope value is referred to as a "positive trend," and a trend test with a p-value below 0.05 and a negative Sen Slope value is referred to as a "negative trend." If a trend test had a p-value above 0.05, it is referred to as having "no trend."

Table 1: Mann-Kendall trend test results for parameters with statistically significant trends at specific stations.

Station Number	Parameter	Sample Size	Start	End	Missing	Sen Slope	tau	p-val
203	D_{50}	26	1998	2023	0	-0.6875	-0.3662	0.009
211	D_{50}	25	1998	2023	1	-0.8496	-0.3867	0.007
217	SVI	13	1998	2022	11	0.5	0.4359	0.042
203	LWD	26	1998	2023	0	3.818	0.8554	9.97E-10
211	LWD	25	1998	2023	1	3.333	0.7633	9.86E-08
217	LWD	14	1998	2022	11	0.5714	0.4396	0.032
218	LWD	24	1998	2023	0	8.602	0.8949	1.04E-09
203	Elevation	25	1999	2023	0	0.03225	0.3	0.038
211	Elevation	24	1999	2023	0	0.01893	0.3116	0.035
217	Elevation	12	2000	2022	11	-0.04971	-0.697	0.002
217	Steelhead	15	1999	2018	5	12.2	0.4286	0.029

Figures 10, 11, and 12 display trend results for individual stations that had statistically significant trends. All four stations had postive trends in LWD but were not included in the following figures (see Figure 7 for LWD data). Station 218 had no trends for instream channel parameters and therefore is not included in the following figures. Station 203 (Figure 10) had a decreasing trend in D_{50} and an increasing trend in elevation. Station 211 (Figure 11) also had a decreasing trend in D_{50} and an increasing trend in elevation. Station 217 had an increasing trend in SVI, a decreasing trend in elevation, and an increasing trend in steelhead per mile (Figure 12).

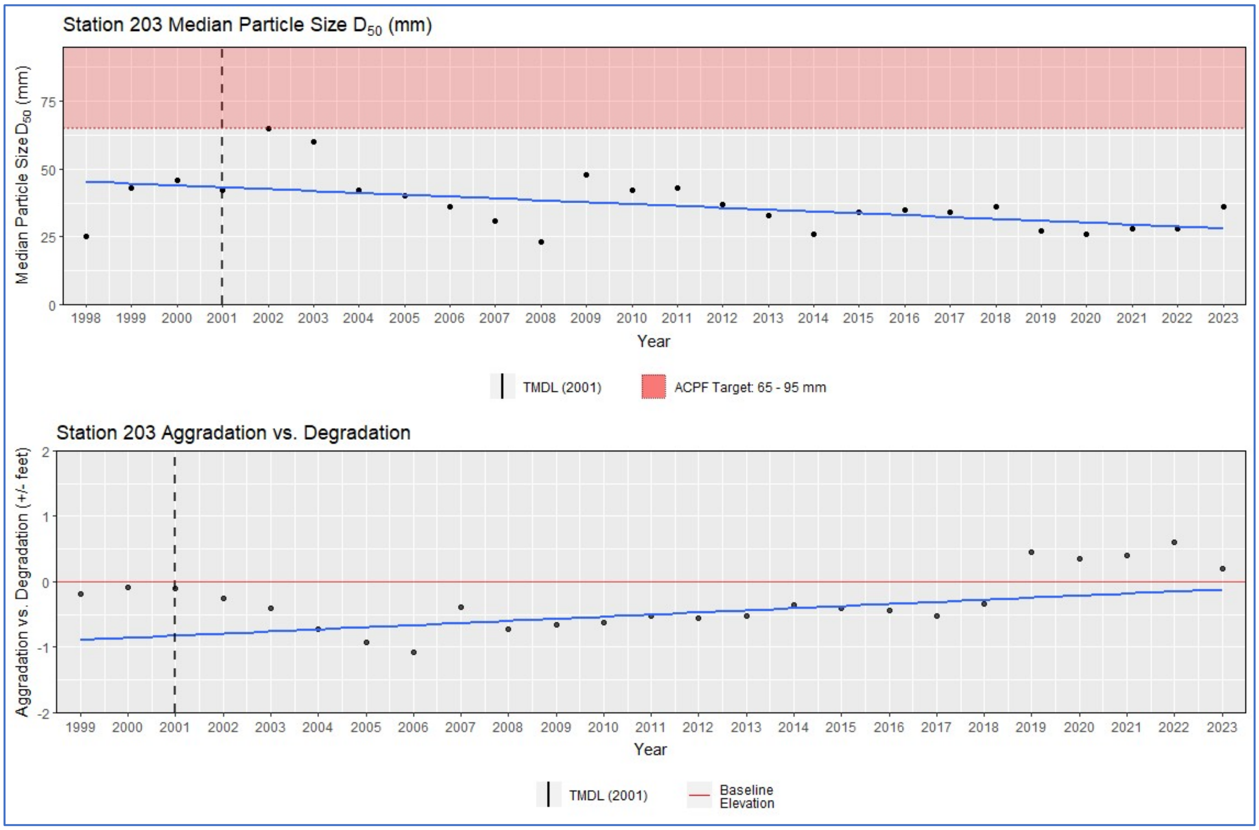

Figure 10: Statistically significant trends for D_{50} and change in elevation at Station 203.

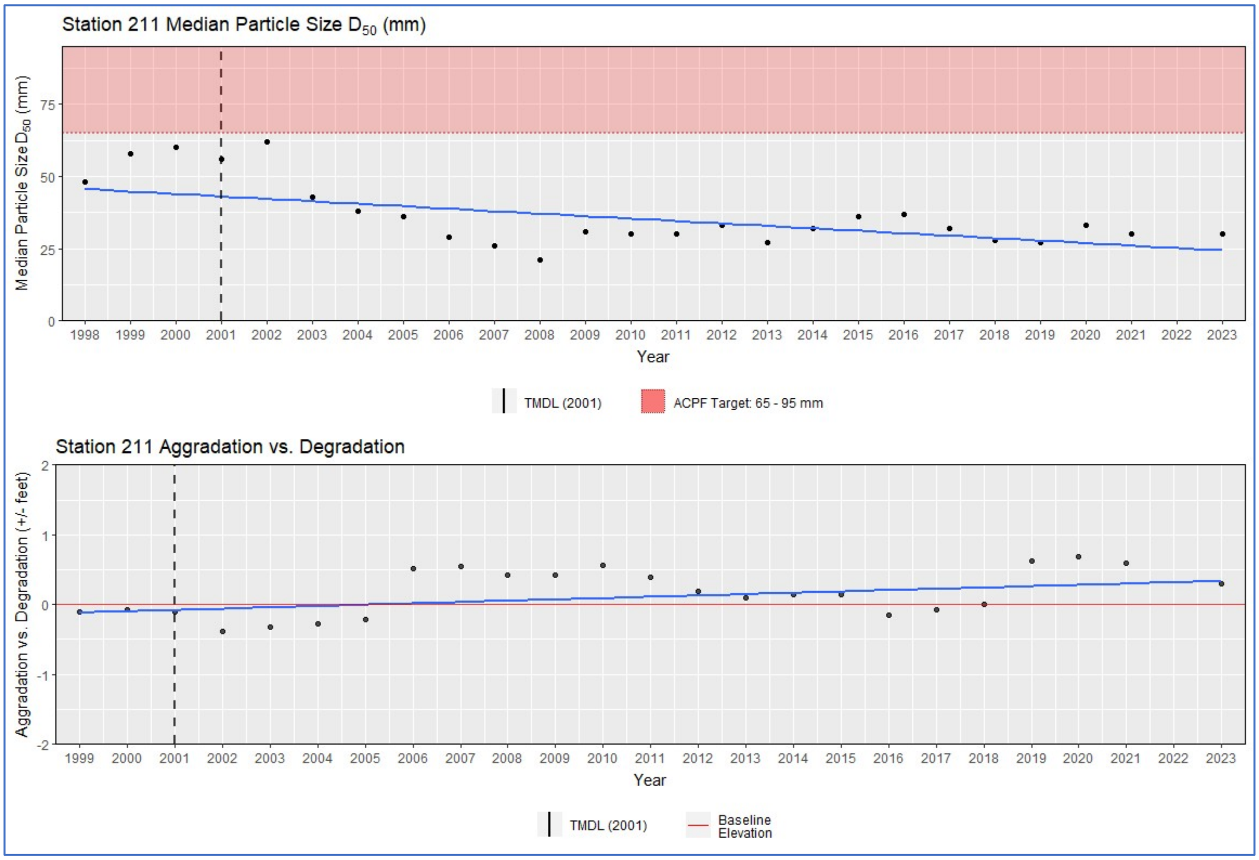

Figure 11: Statistically significant trends for D_{50} and change in elevation at Station 211.

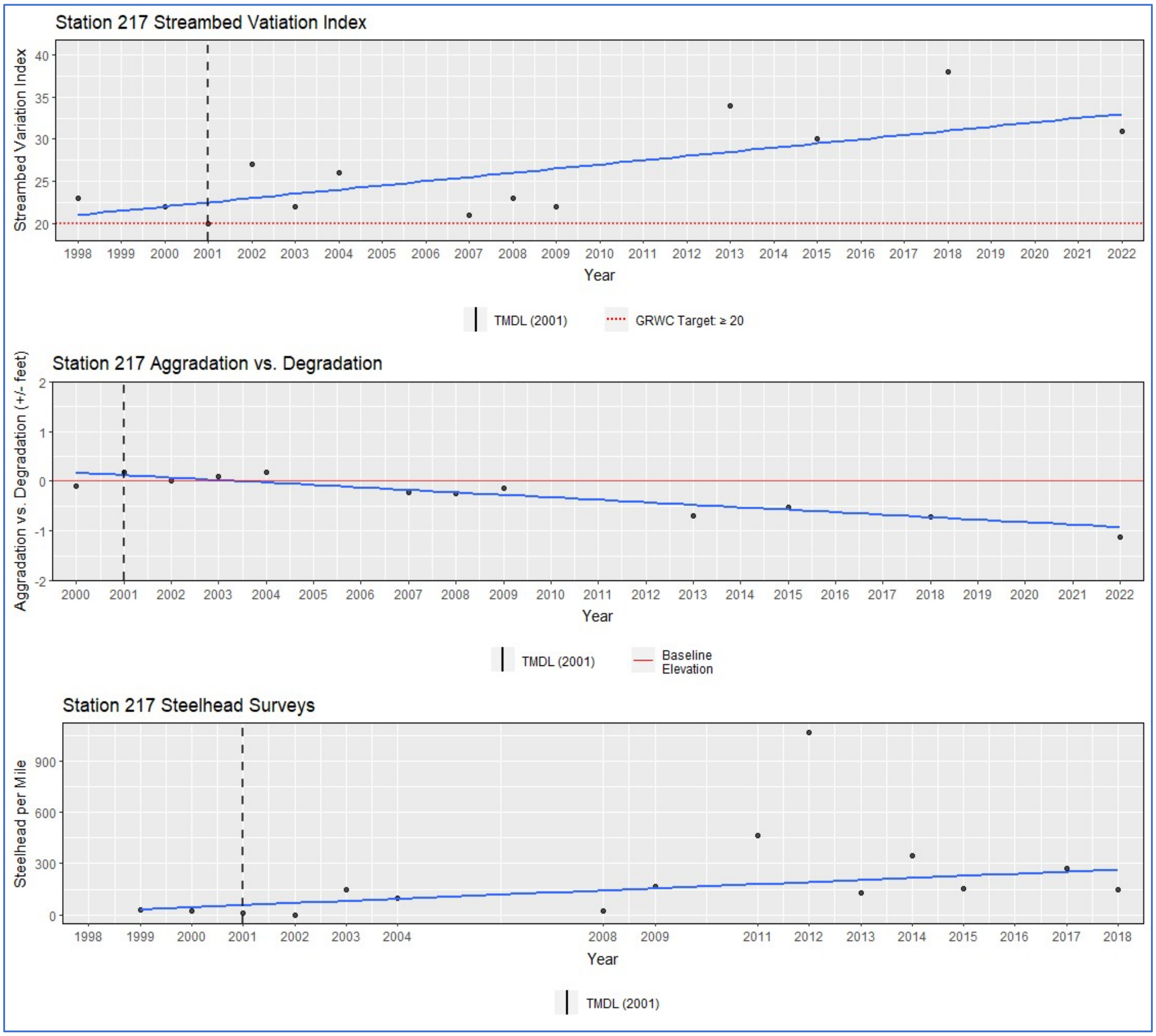

Figure 12: Statistically significant trends for SVI, change in elevation, and steelhead per mile at Station 217.

5.3 Historical Trend Analyses

Table 2 displays trend analyses for the four reference reaches. The data were separated into three different groups to display how trends have changed over time. The groups include 1998-2013 (2013) to show trends over first 15 years of record, 1998-2018 (2018) to show trends over the first 20 years of record, and 1998-2023 (2023) to show the entire record of data (also detailed in section 5.2). Instream parameters were used for this assessment to identify changes in aquatic habitat trends over the various periods of the record. These parameters include D_{50}, Streambed Variation Index (SVI), and change in elevation (+/- feet). Each group of data (parameter by station by period of record) displays the Sen Slope of the trend and the p-value for statistical significance. Table cells with a positive slope are highlighted in blue and cells with a negative slope are highlighted in red. If a trend is statistically significant with a p-value lower than 0.05, the p-value cell is highlighted in yellow.

Table 2: Mann-Kendall trend results on instream parameters at reference reaches over various periods of the monitoring record.

Period of Record	D_{50}	D_{50}	SVI	SVI	Elevation (+/-)	Elevation (+/-)
Station 203	slope	p-val	slope	p-val	slope	p-val
2013	-0.5	0.258	1	0.0003	-0.03	0.151
2018	-0.559	0.065	0.5	0.005	-0.005	0.82
2023	-0.688	0.009	0.1	0.464	0.032	0.037
Station 211	slope	p-val	slope	p-val	slope	p-val
2013	-2.232	0.002	0.101	0.311	0.045	0.112
2018	-1.171	0.013	0	0.623	0.011	0.495
2023	-0.85	0.007	-0.072	0.286	0.019	0.035
Station 217	slope	p-val	slope	p-val	slope	p-val
2013	-0.5	0.042	0.167	0.584	-0.043	0.076
2018	-0.225	0.218	0.585	0.083	-0.045	0.008
2023	-0.111	0.439	0.5	0.042	-0.05	0.002
Station 218	slope	p-val	slope	p-val	slope	p-val
2013	-0.667	0.227	0.154	0.113	-0.06	0.001
2018	-0.636	0.049	0	0.471	-0.06	1.08E-05
2023	-0.392	0.077	-0.118	0.124	-0.029	0.315

Trend tests with a p-value below 0.05 and a positive Sen Slope value is referred to as a “positive trend,” and a trend test with a p-value below 0.05 and a negative Sen Slope value is referred to as a “negative trend.” If a trend test had a p-value above 0.05, it is referred to as having “no trend.”

Station 203 had a negative trend in D_{50} in the 2023 period. SVI at Station 203 had a positive trend in the 2013 and 2018 periods but no trend in the 2023 period. Elevation had no trend in 2013 and 2018 with a negative slope, but in 2023 the slope turned positive and the trend was statistically significant.

Station 211 had similar trends as Station 203. In all periods, D_{50} at Station 211 had a negative trend. SVI at Station 211 never showed any trend. And similar to Station 203, in the 2023 period, Elevation had a positive trend.

Station 217 had a negative trend for 2013 but in 2018 and 2023 the slope flattened out and no longer had a statistical significance. SVI at Station 217 had no trend in 2013 and

2018 but reached a positive trend in 2023. Similarly, Elevation had no trend in 2013, but in 2018 and 2023, there was a negative trend.

Station 218 had a decreasing trend in D_{50} in the 2018 period but had no trend in 2023. SVI at Station 218 showed no trends over the three time-period groups. Elevation at Station 218 had negative trends in the 2013 and 2018 periods, but the slope has flattened out there was no trend in 2023.

6. Discussion

6.1 Salmonid Data

Historical data analyzed in the Gualala River Sediment Technical Support Document (TSD) (NCRWQCB, 2001) indicates that declines in steelhead populations began in the 1970s. Coho salmon data is more limited, but it appears the Coho that were once plentiful have all but vanished. Coho salmon and steelhead trout surveying has continued in the watershed since the development of the TSD through the GRWC monitoring program and the data are presented in section 4.1 and discussed below. Coho salmon were last observed in the North Fork Gualala River subwatershed in 2004 and have not been detected in subsequent monitoring surveys. While steelhead remain present throughout the watershed, their abundance has steadily declined over the years of observation (Figure 2). Notably, Station 217, located on the mainstem of the South Fork near the mouth of the Gualala, has shown a statistically significant positive trend in steelhead population. Although the steelhead per mile count at this station is lower compared to historical data from other locations, the continued presence of steelhead indicates that the species is still entering the watershed, albeit in reduced numbers compared to previous years.

Steelhead values showed statistically significant positive correlations with instream habitat parameters including median particle size (D_{50}) and streambed variation index (SVI). This may indicate that steelhead prefer locations with larger substrate particle sizes and stream channel complexity. This could also be incidental correlation as over time D_{50}, SVI, and Steelhead values have decreased due to a variation of factors. Regardless, the relationship between sediment and steelhead is known to be strong and the data presented here shows that trends in fish and instream habitat are not moving in a positive direction.

6.2 Large Woody Debris Data

Large woody debris (LWD) projects have been occurring in the Gualala watershed since the monitoring program began. Some stations have had significant inputs of LWD from restoration activities while other stations' LWD is natural.
At the four reference reaches where data is available over the entire period of record there were statistically significant positive trends in LWD pieces. LWD volume was also assessed and showed statistically significant increases at the four reference reaches. These stations are achieving the U.S. EPA target for LWD to be an increase in frequency and volume (U.S. EPA 2001).

LWD data was also compared to various instream parameters to identify correlations. LWD and D_{50} had a statistically significant positive correlation. This could indicate that large wood inputs are leading to retainment of more coarse sediment while releasing more fine sediment out of the system. LWD and change in elevation (+/- feet) showed a statistically significant negative correlation. This may indicate that large wood inputs are affecting the stream system and causing more scour than deposition of sediment. LWD and SVI showed a negative correlation which is counterintuitive to what would be expected as a response from wood inputs. One possible explanation could be that this is an incidental correlation. This could also be due to the lag in response time of a stream channel to become more complex once wood has entered the stream channel.

6.3 In-stream Data

Instream data collected during the monitoring period for the most part does not show signs that instream habitats are currently trending in the direction towards recovery. Although many environmental factors can influence sediment movement, it is noted that 2019 was a significantly wet year and may have been a driver of sediment movement (GRWC, 2024). The following subsections discuss trends identified in Table 2 for the four reference reaches.

6.3.1 Station 203 – Little North Fork

Station 203 is located on Little North Fork of the North Fork Gualala River subwatershed (Figure 9). Station 203's upstream draining area is 2.7 square miles and has a road density of 9.1 road miles per square mile. Station 203 and Station 211 were originally selected to be paired together to look at the impact of large woody debris, but over time, wood placement began happening in both locations. Station 203 is notably a wet location with a thick redwood stand in the draining area.

Station 203 shows signs of recent sediment accumulation and decreases in particles sizes with a positive trend in elevation and negative trend in D_{50}. At the lowest elevation point on the record (2006), the stream channel was -1.1 feet below the baseline observation and in 2023 the stream channel was back to +0.2 feet. The highest D_{50} value was recorded in 2002 (65mm) and in 2023 D_{50} was at 36mm. SVI was previously trending upwards, but after the 2019 year, the trend lost its significance and the slope of the trend flattened out to near zero.

This information may indicate that trends at Station 203 have recently moved away from desirable conditions, given that particle sizes are decreasing, sediment is accumulating, and stream channel complexity is no longer trending in a positive direction.

6.3.2 Station 211 – Dry Creek

Station 211 is located on Dry Creek of the North Fork Gualala River subwatershed (Figure 9). Station 211's upstream draining area is 6.5 square miles and has a road density of 6.2 road miles per square mile. This location is known to be drier than Station 203 and has a larger draining area with a thinner tree stand in the draining area. Given the characteristics of the upstream area, this location would be expected to be flashier with sediment movement when precipitation events occur compared to Station 203.

Station 211 has consistently had a negative trend in D_{50}. The largest D_{50} value on record was 60mm in 2000 and in 2023 D_{50} was at 30mm. SVI at Station 211 had no trend and the 2023 value (21) is only slightly down from the maximum SVI recorded in 2004 and 2005 (29). Change in elevation at Station 211 has fluctuated throughout the record as it has flipped between aggrading and scouring four different times. At no point has the change in elevation from baseline (+ or - feet) been greater than 0.7. In 2023 the trend in elevation was statistically significantly positive, but that value was only at +0.3 feet compared to baseline.

SVI and change in elevation at Station 211 has not shown much change over the record, however recent change in elevation could indicate a strong influence of the heavy rain event in 2019. Continued decreases in D_{50} with statistical significance at each of the three time periods shows that stream substrate at this reach is not making progress in a positive direction towards a desirable condition.

6.3.3 Station 217 - Mainstem

Station 217 is located on the mainstem of the South Fork Gualala River subwatershed (Figure 9). Station 217's upstream draining area is 243 square miles and has a road density of 4.7 road miles per square mile. This location has a low slope and is known to be depositional in its nature and has been impacted by historical legacy loads of sediment. All the South Fork, Rockpile Creek, Buckeye Creek, and Wheatfield Fork subwatersheds drain to Station 217. This station is also the closest station to the mouth of the Gualala where salmon can enter the watershed.

In the first period of record (1998-2013), D_{50} had a statistically significant negative trend. Since then, that significance level has gone away, and the values have flattened out. D_{50} values are still low (22mm in 2023) compared to other stations in the watershed, but they currently have no trend. SVI values reached a significant positive trend in the 2023 period, after having no trend the prior two periods. Change in elevation did not show a trend in the first period of record, but the 2018 and 2023 periods did show a significant negative trend. By 2023 the elevation was 1.12 feet lower than baseline.

These trends may indicate that Station 217, which has been impacted by legacy loads of sediment, may be transitioning to be more complex. Additionally, sediment is beginning to move out of this reach as shown in the trend in decreasing elevation. The values of SVI and change in elevation are low, but statistical trends may indicate that the shape of the channel is progressing in a positive direction. D_{50} has not begun to trend in a positive direction, however, it is no longer showing significant negative trends as seen in the 2013 period.

6.3.4 Station 218 – Big Pepperwood Creek

Station 218 is located on Big Pepperwood Creek, a small tributary that drains to the South Fork Gualala River just above Station 217 (Figure 9). Station 218's upstream draining area is 2.8 square miles and has a road density of 4.7 road miles per square mile. This reach overlaps a timber harvest plan boundary and may be influenced by management practices occurring upstream. The upstream area is also heavily forested with some woody wetland characteristics in the riparian area. One other environmental factor at Station 218 is the recent event of a large log jam upstream releasing which led to a large amount of sediment being released downstream.

Station 218 does not show any trends over the entire record (1998-2023). One positive note is that D_{50} is no longer showing a significant negative trend which was present in 2018. Elevation notably increased after 2018 moving from -1.83 feet to -0.49 feet. Previous periods had significant negative trends in elevation but the 2023 trend was no longer significant. It is difficult to come to conclusions about the status of Station 218. The change in elevation between 2018 and 2023 is most likely due to a combination of the released log jam along with the heavy rain year.

6.4 Environmental Factors, Uncertainties, and Limitations

Various environmental variables may be driving these data and trends. Historical loads of sediment may still be working their way through the system. Additionally, the geographic area of the watershed is prone to significant precipitation and is known to be very reactive regarding sediment movement. With changes in climate regimes including the frequency and severity of storms, it is expected that sediment will continue to naturally erode from the landscape and enter the stream system at flashy rates due to the sensitivity of the landscape. Additionally, habitat data related to sediment is not the only driver for salmonid presence as various other factors influence their migration and health such as ocean conditions.

These analyses are not intended to be extrapolated to represent the conditions of the entire watershed. To better understand conditions throughout the watershed, data would need to be collected at regular intervals at lower and upper reaches of the various subwatersheds. Additionally, sediment impaired waterbodies can take decades to fully recover from significant legacy loads of sediment (Carter, 2006). Specifically, Knopp (1993) demonstrated that the relationship between stream channel stability and hillslope disturbance can take as long as 40 years to discern. However, the timeframe of recovery will be shorter if anthropogenic sediment sources in the upper watershed are controlled to levels identified in the Gualala River Sediment Total Maximum Daily Load (TMDL) (U.S. EPA 2001).

One uncertainty of this analysis is that targets are not calibrated to the Gualala River watershed. The best judgement that can be made is whether trends are either increasing or decreasing in a favorable direction. There are also uncertainties due to variations in sample sizes per sampling location which could influence statistical significance levels. Uncertainties also come from the design and age of the QAPP, along with field uncertainties such as human error including instrument use and field observations.

6.5 Data Gaps

Due to the limitations in spatial and temporal data, it is difficult to come to conclusions as to whether instream conditions across the watershed as a whole are trending in positive or negative directions. Watershed wide trends could not be tested due to the lack of spatial distribution and frequency of monitoring stations in the watershed. One assumption that could not be met to conduct Regional Mann-Kendall tests was that a similar number of observations would need to be taken at each sampling location within the watershed or within individual subwatersheds. If requirements for Regional Mann-Kendall tests were met, trend analyses could be conducted for entire subwatersheds to assess conditions at a larger scale.

Figure 13 displays instream monitoring stations and the most recent year that a data point was collected. The majority of upper reaches have discontinued monitoring. The Wheatfield subwatershed is not well understood and data in the lower reaches could provide information about conditions in the subwatershed as a whole. Additionally, a majority of recent observations are clustered together, specifically in the North Fork and South Fork subwatersheds.

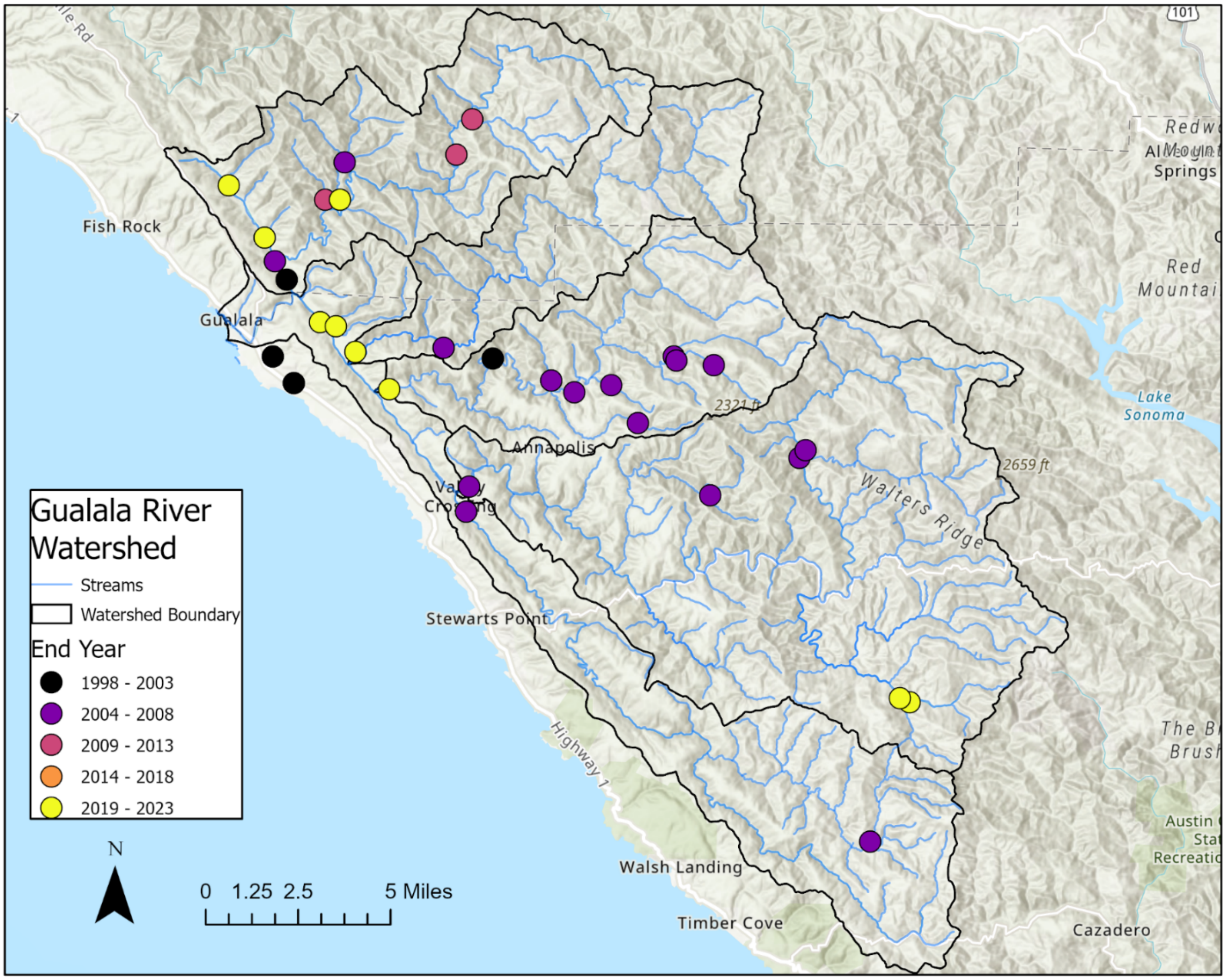

Figure 13: Instream monitoring station points colored to represent the most recent year that data was collected.

A lack of reliable precipitation data also limits our ability to use rain as an independent variable which could be tested against instream parameters as dependent variables. Precipitation data in the watershed was collected in the past, but not recently enough to use for this analysis. Additionally, precipitation is significantly different near the coast compared to the upper area in the watershed to the east, and the only available precipitation gages are outside of the watershed.

Suspended sediment concentration (SSC) or turbidity data could provide insight into how activities on the landscape influence water quality and aquatic habitats. Turbidity measures the clarity of water and is an indicator of the amount of suspended particles. High turbidity levels can clog the gills of fish, reduce feeding efficiency, and increase mortality rates. Additionally, monitoring SSC and turbidity over time can help identify ongoing sediment contributions to the watershed and evaluate the effectiveness of implemented sediment source controls. Persistent high turbidity levels may suggest that existing controls are inadequate or that additional sediment sources are contributing to the system.

Percent fines or riffle embeddedness could also provide useful information that cannot be drawn from D_{50} observations. Fine sediments can fill in the spaces between larger substrate particles, reducing habitat complexity and the availability of spawning grounds for salmonids. This can significantly impact the various life stages of salmonids, from egg incubation to the emergence of fry, and can also affect the invertebrate communities that serve as food sources.

Due to unforeseen funding restrictions, the anticipated frequency of monitoring at many locations by GRWC was not met. However, the efforts by GRWC to continue collecting data throughout the many challenges that have limited the Program do not go unnoticed or unappreciated. Future funding opportunities to continue to collect data will provide pivotal feedback to managers and decision makers that implement policies and regulatory requirements within the watershed. Future monitoring efforts can help guide adaptive management and provide insights on the status of the watershed.

7. Conclusion

Results from this analysis indicate that the Gualala River watershed is highly sensitive to environmental factors. The mainstem of the Gualala River (Station 217) shows progress in stream channel complexity and scouring trends but still may require a long period of time for recovery. Other reaches where data are available are either declining in trends for aquatic habitat conditions or are inconclusive. Notably, median particle diameter was statistically significantly decreasing in size at two of the four reference reaches. Additionally, elevation data indicates sediment accumulation is occurring at locations in the upper watershed. This accumulation, coupled with a decrease in D_{50}, could be the result of fine sediment within the streams of the upper watershed working its way downstream. This may also be the result of new inputs of fine sediment being added to the streams from the hillslopes of the watershed. Although there are signs of improvement at the mainstem, upstream locations show signs of worsening conditions for salmonid habitats. Overall, there are no findings in this analysis that suggest conditions have begun to significantly improve across the watershed.

Temporal and spatial data gaps limit the scope of this analysis and hinder our ability to draw definitive conclusions about the entire watershed. Additionally, the lack of instream parameters related to fine sediment, such as turbidity or percent fines, limits our understanding of the presence and movement of fine sediment within the watershed, which can significantly impact various life stages of salmonids.

8. Acknowledgements

We thank the Gualala River Watershed Council (GRWC) staff and volunteers for their ongoing dedication to monitoring and collecting essential field data across the Gualala River watershed. Their efforts in the collection, processing, and management of instream data, as well as their commitment to maintaining a robust database, have been invaluable in supporting this analysis. We also appreciate their collaboration with local stakeholders and landowners in facilitating the data collection process, which is crucial for understanding watershed conditions and informing future management strategies.

9. References

Carter, Katharine. (2006). Desired Salmonid Freshwater Habitat Conditions for Sediment-Related Indices (Desired Conditions Report). North Coast Regional Water Quality Control Board. July 28, 2006.

GRWC (2008). Quality Assurance Project Plan for Monitoring Sediment Reduction in the Gualala River Watershed. Version 3.1. Gualala River Watershed Council. (https://grwc.info/Assets/Reports/grwc-qapp-ver-3-1.pdf)

GRWC (2024). Discussion on Gualala River Watershed Conditions. Gualala River Watershed Council. Verbal communication with Sean Case, Monitoring Program Coordinator.

Knopp, Christopher 1993. Testing indices of cold water fish habitat. North Coast Regional Water Quality Control Board in cooperation with the California Department of Forestry and Fire Protection.

Madej, M. A. (1999). Temporal and spatial variability in thalweg profiles of a gravel-bed river. Earth Surface Processes and Landforms, 24(12), 1153-1169.

NCRWQCB (2001). Gualala River Watershed Technical Support Document for Sediment. North Coast Regional Water Quality Control Board.

NNPSNP (2011). Statistical Analysis for Monotonic Trends. National Non-point Source Monitoring Program. (https://www.epa.gov/sites/default/files/2016-05/documents/tech_notes_6_dec2013_trend.pdf)

U.S. EPA (2001). Gualala River TMDL for sediment. United States Environmental Protection Agency.