Stream Habitat Condition for Sites Managed by the Oregon Watershed Enhancement Board

W. C. Saunders, J. V. Ojala and A. R. Van Wagenen PacFish / InFish Biological Opinion (PIBO) Monitoring Program USDA Forest Service, Logan, UT May 2020.

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Background

Salmon, steelhead, and bull trout stocks have been listed under the Endangered Species Act in most drainages within the interior Columbia River Basin. While many environmental factors led to the listing of these populations, habitat degradation is one of the major causes (Williams et al. 1999). Good or improving stream habitat, and protection of processes that maintain these habitats, increases the likelihood of successful adult spawning and juvenile rearing for these listed species. A useful approach for assessing the status of stream habitat condition at a given stream reach is to compare its habitat characteristics to those of streams likely to be functioning properly (Stoddard et al. 2006). The Pacfish/Infish Biological Opinion Effectiveness Monitoring Program (PIBO) uses this approach to evaluate status of stream habitat within portions of the interior Columbia River and Missouri River basins, and to also document changes in habitat conditions (e.g. "trend") over the entirety of PIBO sampling (2001-2019).

Methods

Status and Trend

Determining the condition or status of an individual, or group of stream reaches is a difficult task because of the natural inherent variability in stream conditions due to geoclimatic and disturbance regimes (Ebersole et al. 1997). PIBO's approach is to compare the status of stream habitat conditions at sites in 'managed' watersheds (watersheds exposed to disturbance from various management actions) to habitat conditions at sites within 'reference', or relatively pristine, watersheds, which are used as a benchmark of expected condition. Because all streams are affected by natural disturbance, in assessing *status* we are most interested in how the range of stream habitat conditions expressed at managed sites compares to what would be expected if the stream had experienced only natural disturbance. To ascertain the status of a given site we created an index of habitat condition which accounts for some natural variability among sites and combines several stream habitat attributes (Al-Chokhachy et al. 2010). While an index is good for determining status, it may be less sensitive when detecting trend in habitat condition over time because it averages conditions of several attributes that may be more individually responsive. Therefore we estimate trends by measuring changes in individual stream habitat metrics, such as bank stability or large wood frequency, at a site over the duration of PIBO sampling (2001-2019).

Reach sampling

PIBO began collecting physical stream habitat and macroinvertebrate data at the reach scale (160-400 m stream lengths) within the interior Columbia River and Upper Missouri River basin in 2001. In 2006 we expanded to begin sampling reaches within the Upper Missouri River Basin in Montana. Approximately 300 sub-watersheds (6^{th} field HUCs) are selected each year for sampling using a random, nearly regular pattern. Over a five year period, 1300 sub-watersheds are sampled in the Columbia River basin and 250 sub-watersheds in the Missouri basin, which equates to about a third of the sub-watersheds managed by the Bureau of Land Management and the Forest Service within the study area. These sub-watersheds have been resampled on a five year rotation, and the data are used to assess status and trend of aquatic and riparian conditions. PIBO is in the third rotation of the five year panel; in 2015, most sites have been sampled three times.

Sub-watershed and Reach Types

The sub-watersheds are divided into two groups, either "reference" (minimally managed) or "managed", based on management history (such as livestock grazing, mining, or roads). Reference sites are primarily located in wilderness areas or in sub-watersheds with no obvious mining, no recent grazing (within 30 years), minimal timber harvest (< 5%) and minimal road density (< 0.5 km/km^2). There are 254 reference sites within the study area.

Within each reference and managed sub-watershed, we randomly select an 'integrator' site located at the lowermost, low-gradient (< 3%) reach occurring on federal land. These low-gradient sites are influenced by the reaming watershed area upstream of the site and are considered the most sensitive to changes from variable sediment and flow regimes. Integrator reaches are evaluated on a 5-year rotating panel with revisits occurring 5 years after the initial visit.

Table 1. Stream habitat attributes measured by PIBO

STREAM HABITAT ATTRIBUTES	STATUS	TREND
Average bank angle (°)	*	*
d_{50} (median substrate particle size)	*	*
Percent fine sediment (<6 mm diameter, in pool tails)	*	*
Large Wood frequency (pieces /km)	*	*
Residual pool depth (m)	*	*
Percent pool habitat	*	*
Bank stability (% bank covered with plants or rock)		*
Percent of bank with undercuts (bank angle <90°)		*
Macroinvertebrate taxa (Observed/Expected)	*	*

In addition to our integrator sites, we sample two additional site types. The first, called 'designated monitoring areas' or DMAs, occurs within grazed sub-watersheds at sites representative of grazing impacts typical for the pasture. The second type we sample are sites on public lands upon special request of individual National Forests, BLM units, and National Parks, this site type is referred to as a contract site.

Field Data Collected for Status and Trend

Physical Habitat Attributes

To estimate status of physical stream habitats at each site, we focus on six stream channel attributes that (1) influence the production or survival of native salmonids; (2) are sensitive to land-use changes; and (3) can be measured consistently by observers (see Table 1). For a complete description of these variables and field methods used, see Kershner et al. (2004) and Archer et al. (2013).

Biological Attributes

To evaluate a biological component of habitat status, we sample macroinvertebrates using the protocol recommended by the Center for Monitoring and Assessment of Freshwater Ecosystems, Utah State University (Hawkins et al. 2000). Macroinvertebrates are sampled from 8 fast-water habitats per site and combined into a composite sample. Macroinvertebrate taxa are identified by the BLM/USU National Aquatic Monitoring Center in Logan, UT.

Attributes Used for Trend

We estimate trend using the same six physical stream habitat attributes and one biological attribute (macroinvertebrate O/E) used for status, plus two additional metrics, bank stability and percent undercut banks (see Table 1).

Calculating Physical Habitat Index Scores to assess Status

To evaluate the status of stream habitat conditions at a given site, we first developed an index score for each physical habitat attribute. We began construction of the index by using multiple linear regression to explain inherent differences among sites. To account for local differences in stream type and geographic location we included landscape 'predictor' variables, such as average precipitation, percent forested and slope of the valley (see Table 2), as well as some measures of stream power (reach gradient, and catchment area) as covariates in the regression models. We selected the best multiple regression model to fit each attribute using data only from the reference sub-watersheds (n = 217; 10% of reference were set aside to verify model performance) to provide 'expected' stream habitat conditions in the absence of land management activities (Al-Chokhachy 2010).

Table 2. Landscape predictor variables used in model development

Catchment area (km^2)
Average precipitation (m)
Slope of valley along reach (%)
Percent forested along reach (%)
Drainage density in catchment (km/km^2)
Reach Gradient (%)
Elevation (m)
Dominant geology type (categorical)

We then compared observed conditions to what would be expected after controlling for local and landscape characteristics. This can be visualized as a regression line through a series of points, with the regression line predicting expected conditions and the distance between each point and the line representing deviations from expected conditions, or residuals. We created an index for each stream habitat attribute by re-scaling these residuals (distance from the predicted line) from 0-10, using the 5^{th} and 95^{th} percentiles of the residuals at reference reaches as floor (index score = 0) and ceiling (index score =10) values. This process was repeated for each physical stream habitat attribute used to estimate status in Table 1. A site scored high (closer to 10) if the measure of observed habitat condition was better than expected and low if it was lower than expected (closer to 0). The distribution of index scores for a particular area represents the scatter around the line. Sites with sub-watershed areas < 3 km^2, > 300 km^2 were excluded from the analysis because they were outside of the range of conditions present at reference sites.

For reference sites, residuals are considered to represent natural variation due to natural disturbances, such as fire, beetle kill, climate, or variance unexplained by our models. For managed sites, residuals are considered to represent a combination of natural factors, unexplained variation in the model, and a management effect. A significant difference between the reference prediction and the actual managed site index scores can potentially be attributed to management.

To create an overall index of physical habitat condition for a site, we summed the individual attribute scores included in the index and then rescaled this sum from 0-100. For complete details and a better understanding, see Al-Chokhachy et al. 2010.

Calculating a Macroinvertebrate Taxa Index O/E score to assess Status

To assess biological status at each site, we compared the macro-invertebrate taxa 'observed' at managed reaches (O) to the assemblages 'expected' to be found in relatively pristine reference reaches (E) based on a modeling exercise similar to that used for stream habitat (see Hawkins et al. 2000 for more specific details). The PIBO O/E model was developed using macro-invertebrate samples collected at 201 reference reaches between 2001 and 2005; taxa were identified by the BLM/USU National Aquatic Monitoring Center. The O/E index score for each reach was estimated by dividing the number of expected taxa by the number of observed taxa. A monitored site with an O/E value of '1' indicates that all of the macroinvertebrate taxa expected at a reference site (with similar geographical setting and characteristics) were found at the site, while a value of '0' indicates that none of the taxa expected were found. Scores > 0.8 are generally considered similar to references reaches. Scores > 1 are either equivalent to what would be expected at a reference location or may have an enhanced insect community as a result of some type of enrichment.

Displaying Status

Box plots, Histograms, and Line Graphs

We use boxplots, histograms, and line graphs to visually compare the distribution of index scores at managed reaches to that of reference reaches. Boxplots show the median and range (25^{th} and 75^{th} percent) of index values (see Fig.1). We also combine a histogram with a line graph to display the distribution of index values for the managed reaches (histogram) compared to the expected values at reference reaches (the line graph) (see Fig. 2). If a large percentage of the histogram lies under the line, this indicates conditions are similar at managed and reference reaches.

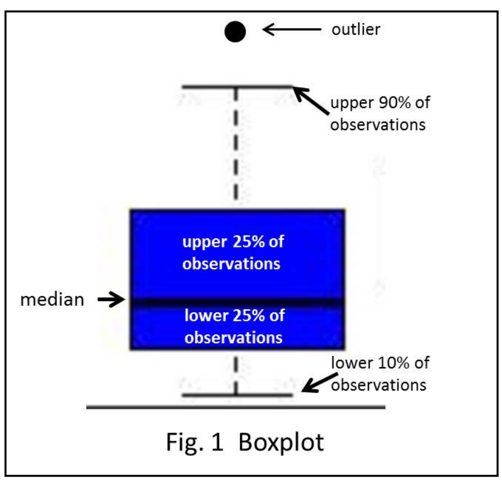

Fig.1. Description of a boxplot distribution.

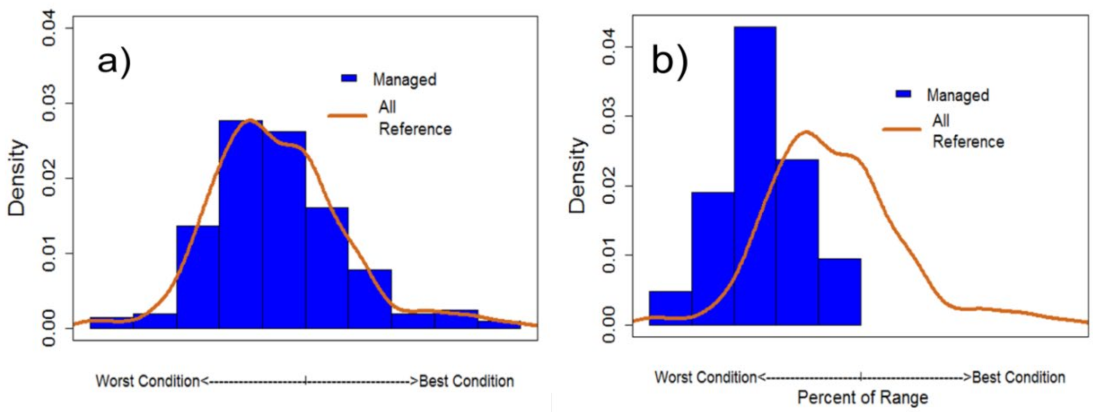

Fig.2. Distribution of index values for managed (histogram) and reference (line) sites. (a) an example of managed and reference sites with similar habitat conditions; and (b) managed sites skewed towards lower condition compared to reference sites.

Summary Tables

Managed reaches within the 'area of interest' (e.g., forest-wide; a 4th field HUC) were analyzed by comparing them to reference reaches at three landscape scales: (1) reference reaches within the area of interest (if present); (2) reference reaches within the ecoregion; and (3) reference reaches throughout the PIBO study area (n = 254). The ecoregions included were the Blue Mountains, Idaho Batholith, Middle Rockies, Canadian Rockies, and Northern Rockies (for details, see Omernick 1987). If at least one managed site was located within a given ecoregion, then we included all reference sites from that ecoregion in our analysis. At least five managed reaches for a given area were necessary to run the analysis. In addition, at least five reference reaches had to be present in the area of interest in order to make a comparison at that scale.

We used a t-test, assuming variance was not the same in managed and reference, to determine if differences between index scores for each metric at managed and reference reaches were statistically significant; a p-value < 0.10 was considered significant.

Estimating Trends in Stream Habitat Conditions

Since 2010, PIBO has sampled sites throughout the MFJD IMW three times. As a result, we have undertaken two approaches to analyzing trends in stream metrics through time.

First vs Last Observation

To estimate trends in stream habitat condition, we used actual measured values (and not index scores) for eight stream habitat attributes (see Table 1). We compared data collected at the first sampling visit with data from the last visit using the Wilcoxon signed rank summed test, a non-parametric statistical test that evaluates repeated measurements at the same site to determine if there has been a change in the metric value. A p-value < 0.10 indicates that the change is significant. Desirable changes could be either in a positive or negative direction, as, for example, increased bank stability or fewer fine sediments. The desired direction of change (+ or -) for each habitat attribute is shown in the summary tables. We also indicate the general direction of change across reference sites sampled by PIBO. Summary tables also show the mean value for each attribute for the first and last sampling events, and the percent change in the metric over the evaluation period.

Linear Regression Model

Linear models provide a powerful statistical tool to test the significance of hypothesized factors while modeling the effects of continuous variables (e.g., environmental drivers). PIBO has incorporated the use of linear models to evaluate the magnitude and significance of trends in stream metrics through time. In addition, this approach facilitates the incorporation of trends observed at reference sites over the concurrent time period to better inform inferences about the impact of management over time. The approach used for this analysis is described in detail by Roper, Saunders, and Ojala (2019; found at https://doi.org/10.1007/s10661-019-7716-5). Briefly, we used linear mixed effects models to model temporal autocorrelation resulting from repeatedly sampling contract sites. In this analysis, we also incorporated the covariates used to calculate the index (see above), that provide a means to account for landscape setting while estimating the magnitude of change in metrics through time. While this approach provides a powerful statistical tool and lends itself to useful visual graphics of trend, test for statistical significance are dependent on assumptions of normality. Therefore, both stream metrics and covariates are transformed to meet these assumptions. As a result, the figures provided in this report show back-transformed observations where the impact of very large and very small observations are minimized, and reported means (solid lines in the following figures) and y-axis values are typically conservative measures of central tendencies as metric averages are calculated ***after*** data are transformed to meet assumptions of normality. A further result of back-transformation is that the range of y-axis values on regression plots are not comparable with time period averages (e.g., Time 1 and Time 2 values) presented in table presented first-last observation comparisons, as values in first-last observation comparisons are calculated from raw (i.e., untransformed) data. An additional strength of this analysis is that it facilitates comparison of trends across study groups (e.g., managed and reference sites). This provides managers with additional tools to draw inference about whether observed trends are likely the result of management/restoration actions or instead driven by environmental drivers (i.e., similar trends occurring at reference sites). P-values for test of significant trends for each of the linear models are presented in a table form following the figures to reduce clutter on individual figures, and significance evaluated for alpha = 0.1.

Map of Study Area

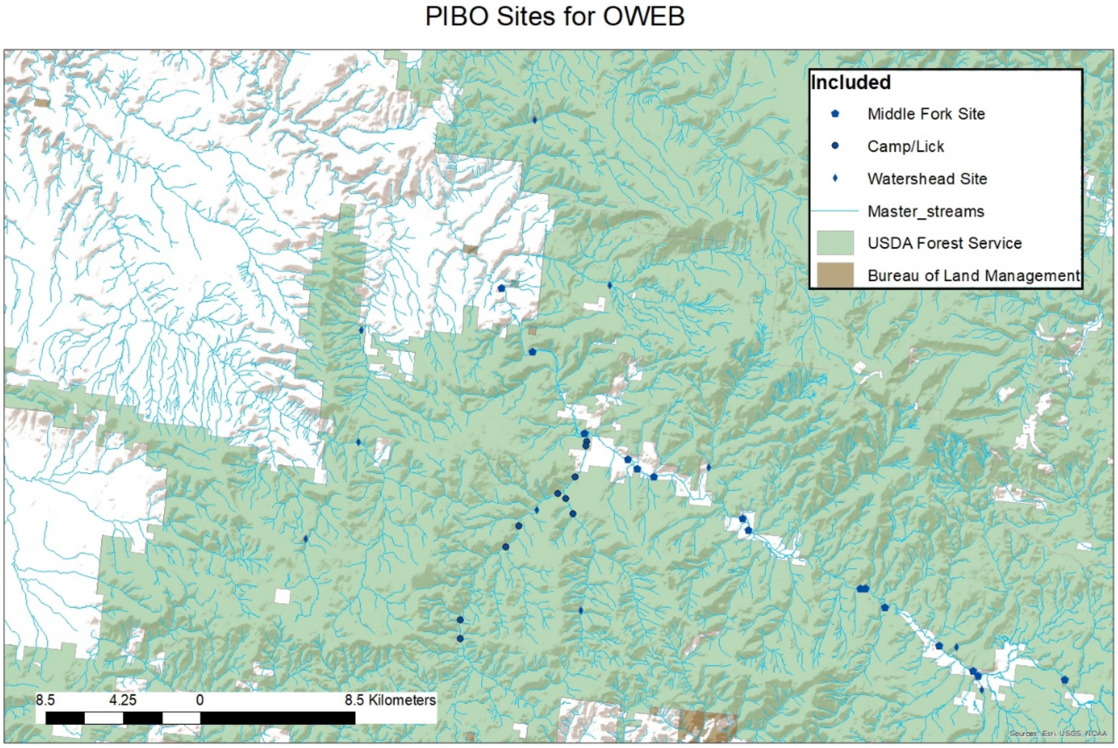

Fig.3. Map of the study area.

Interpreting the Data—Important Considerations

Navigating to Graphs and Tables

To easily find and navigate to graphs and tables in the results section, go to View>Navigation Pane and check the Navigation Pane box.

Uses

The status and trend information PIBO provides for physical and biological stream habitat attributes has several practical applications for planning, NEPA analyses, and consultation for listed fishes.

Land management plan development, amendments, or revisions

Land management plan development, amendments, or revisions usually require descriptions of current status and trends in aquatic habitat conditions across the planning area, whether forest- or field office-wide.

In addition, for planning purposes the overall condition of lands in the planning area can be compared to conditions at a broader scale, such as the basin or ecoregion. This is the scale of analysis for which PIBO data is designed, with a sufficient sample size to make reasonable and easily defensible conclusions.

Range of Natural Variation

Often, the land management planning process includes the range of natural variation of ecosystem characteristics under historic disturbance regimes as an important context for evaluating current and future desired conditions. The PIBO 'reference' reaches sampled in wilderness and other areas not heavily influenced by human disturbances can be used to estimate the expected distribution of stream conditions in the absence of management-induced disturbance. Incorporating a distribution of reference reach conditions recognizes that even relatively pristine streams may have poor habitat conditions due to natural disturbance regimes. Subsequently, distribution of habitat conditions in reference areas can be compared to the distribution of stream conditions in managed sites as a measure of status. If the distribution of your managed site conditions mimics the reference condition distribution, it can be assumed that managed sites fall within the range of natural variation. Conversely, if the distributions of reference and managed sites are different, then management may have had an effect on stream condition. The Summary of Index Scores tables show p-values that indicate whether managed index scores are statistically different than reference index scores.

Plan Monitoring and Evaluation

Plan monitoring provides managers status and trend information required to evaluate progress toward meeting objectives and to determine need for changes or revisions to planning documents. Because the area of analysis for plan monitoring is at least as large as the forest, field office, or other comparable administrative unit (but may be larger as appropriate), PIBO status and trend data provide valuable information for use in plan evaluation of aquatic ecosystems.

Species-specific Analyses

Status and trends of aquatic habitats at the sub-basin scale (4^{th} Field HUC) are especially useful for ecological sustainability analyses of focal fish species (bull trout, interior redband, cutthroat, or salmon). These fish populations are typically addressed by both U.S. Fish and Wildlife Service and National Marine Fisheries Service at the sub-basin scale, and the viability status for each Designated Population Segment and Ecologically Significant Unit is first described based on sub-basin boundaries.

Caveats

Pay attention to scale

PIBO status and trend data are useful at the planning area scale or in broader contexts, such as sub-basin, basin, or ecoregion. However, to interpret status or trend with confidence, a sufficient number of monitored managed sites must occur in the area of interest at those scales. As reach sample size drops below ~ 10, use caution when interpreting the data, as statistical confidence in both the distributions and individual values is not as great. Non-significant differences between managed and reference sites at low sample sizes do not necessarily mean that management had no effect.

However, even at a single site, PIBO status and trend data can be helpful. For instance, if habitat condition scores at a site are on the lower end of the range of that observed at references sites, this could suggest that more conservative management or additional restoration activities are needed to maintain or improve habitat conditions. PIBO data also can be integrated with monitoring information collected locally to better inform project decisions.

Ground-truthing

PIBO data and analyses indicate status or trends of stream habitat attributes, but not necessarily their causes. Field visits or local knowledge are essential to assess possible reasons for poor habitat conditions and the nature of on-the-ground impacts to a specific site. For example, poor habitat conditions could be due to natural factors such as erosive soils or recent fires, as well as management such as roads or grazing. Field visits can also be used to verify how well the index scores reflect actual habitat conditions. Some error surrounds individual index score estimates because the models cannot incorporate all environment factors. In addition, our landscape predictors are GIS-derived, which also involves some associated error.

OWEB – Middle Fork of the John Day (MFJD)

Results

M.F. John Day Status

We resampled 15 sites on the M.F John Day River Basin (Figure 3) that were originally sampled in 2009 and previously resampled in 2014. Our Index model is built using over 200 Reference reaches throughout the Columbia River Basin. The model uses covariates to make predictions for each habitat metric. Because the drainage area of these sites on the M.F. John Day River are larger than our reference reaches, we do not feel that our models can correctly predict status. Therefore, box-and-whisker plots for reference site distributions are not presented for comparison to M.F. John Day contract sites. Overall, box-and-whisker plots for the Overall Index and most individual Index Metrics indicate that there is very little variation among sites in the M.F. John Day sites.

M.F. John Day Trend

PIBO conducted two separate analyses of trend using the data from the 10 sites (see methods). Traditionally, PIBO has used the data from the first and last visit to evaluate trend at sites. These data are analyzed in their raw, untransformed state using a Wilcoxon signed rank test, a nonparametric statistical test for differences in two samples (see methods section). Results from this analysis are presented in Table 4 below. Additionally, as PIBO has now completed three sample visits at sites on Camp and Lick creeks, the above analysis of trend potentially lacks power to assess trend as only data from the first and last samples are used. Further, the above analysis does not lend itself to graphical displays of trends. Therefore, PIBO also used a linear modeling framework to evaluate trend at these 15 sites through time (Figures 12-20, Table 5).

The 15 sites were trending in the desired direction for the Overall index, but this trend is not statistically significant under either trend test. The median particle size and macroinvertebrate O/E metrics were trending in the desired direction. These trends were significant in the analysis of first and last sample dates and using linear regression analysis (median particle size). One metric was trending in the opposite direction of desired (pooltail fines, Tables 4 & 5, Figure 17). This is not unexpected given the increase in the amount of woody debris in the reaches, which creates hydrological complexity and can lead to sediment sorting, and the low amount of fines present during the first sampling events. The pool percent metric was not statistically significant in the Wilcoxon signed rank test, but was in the regression model (Tables 4 & 5, Figure 20). Why the two models disagree isn't entirely clear, but it is likely the effect of metric values collected between the first and last observation being better accounted for in the regression model. Reference data was withheld from the regression analysis as stream size of the Middle Fork of the John Day is not comparable to the PIBO reference network.

Status: M.F. John Day River

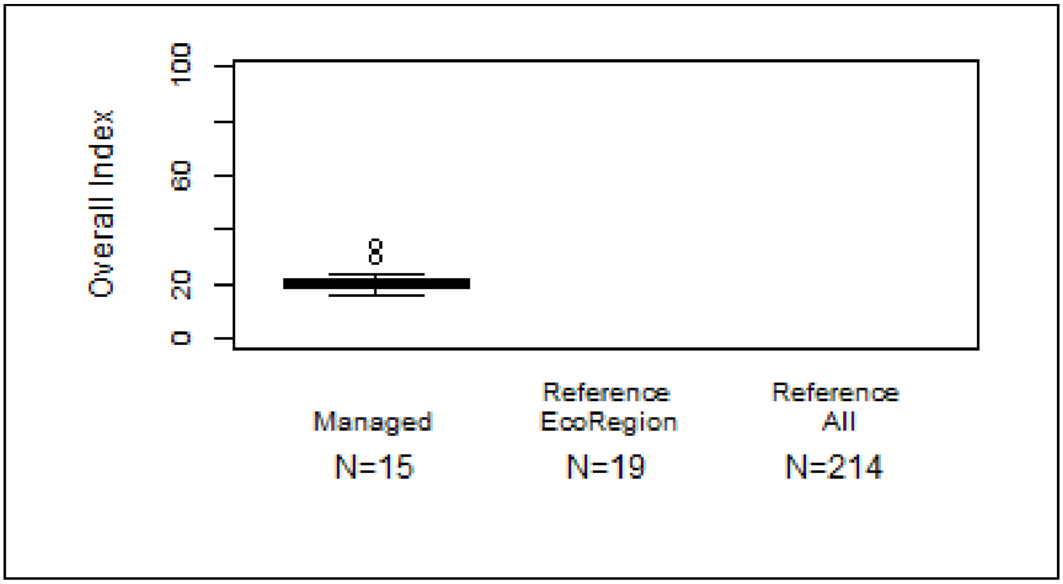

Figure 4. Overall Index values across the OWEB - MFJD. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

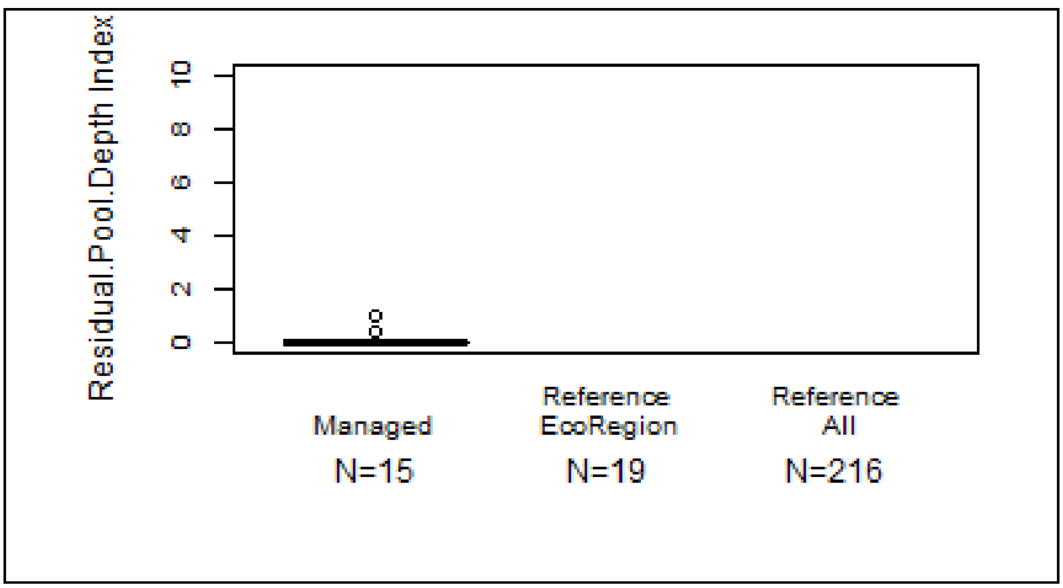

Figure 5. Residual Pool Depth Index values across the OWEB - MFJD. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

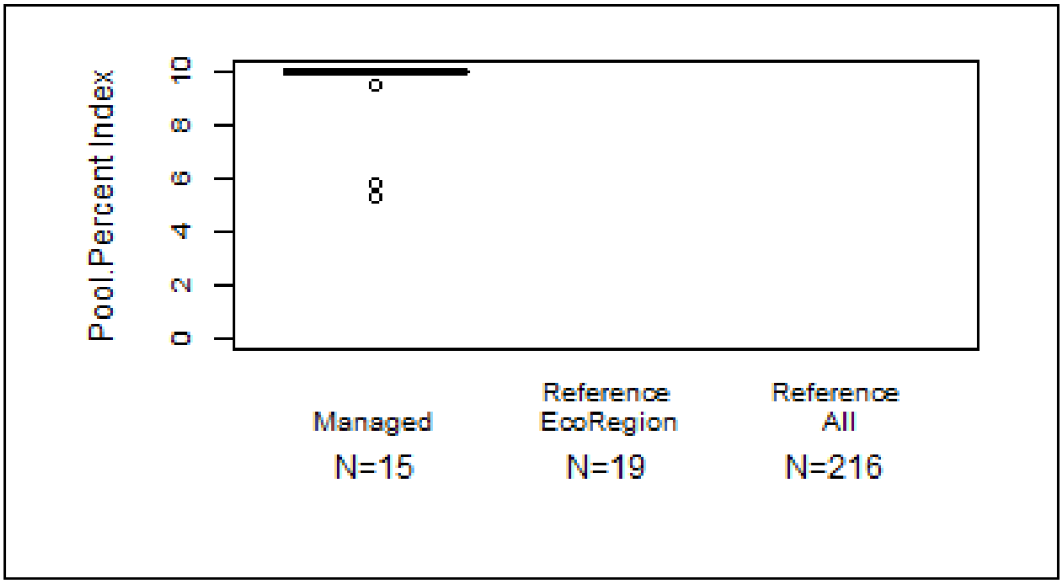

Figure 6. Pool Percent Index values across the OWEB - MFJD. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

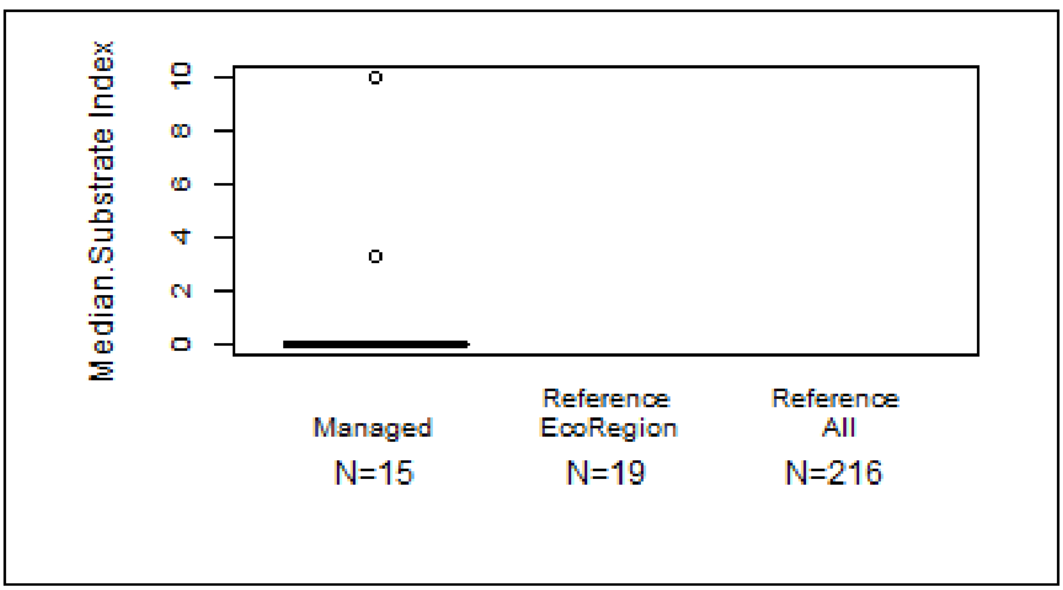

Figure 7. Median substrate Index values across the OWEB - MFJD. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

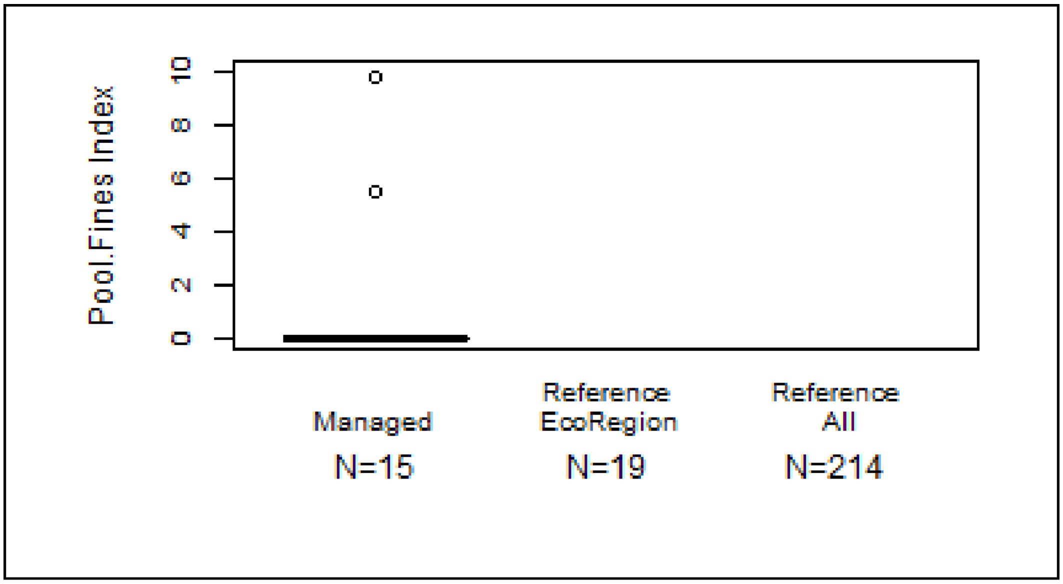

Figure 8. Pool Fines < 6 mm Index values across the OWEB - MFJD. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

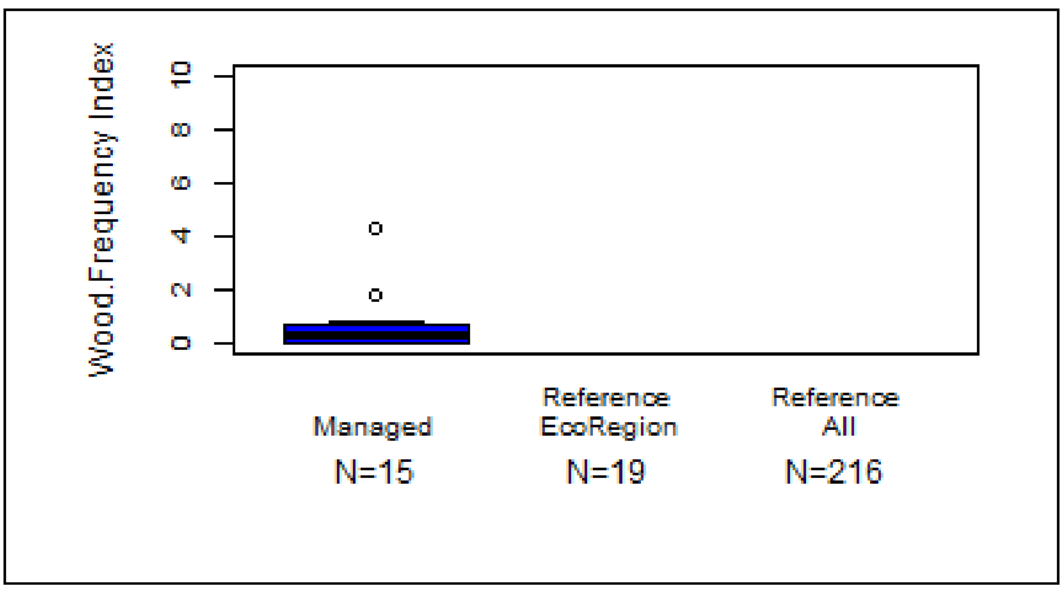

Figure 9. Wood Frequency Index values across the OWEB - MFJD. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

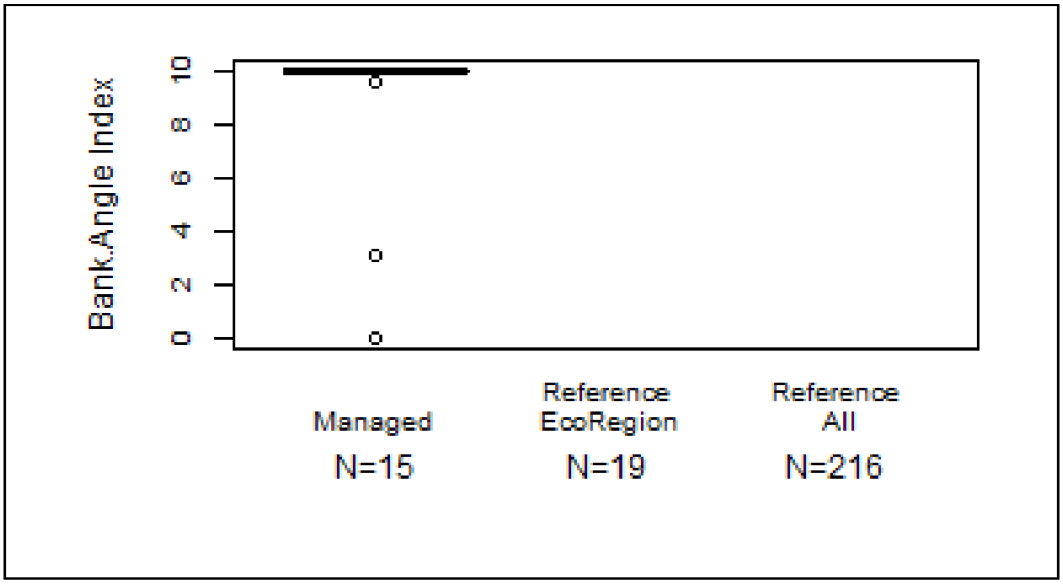

Figure 10. Bank Angle Index values across the OWEB - MFJD. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

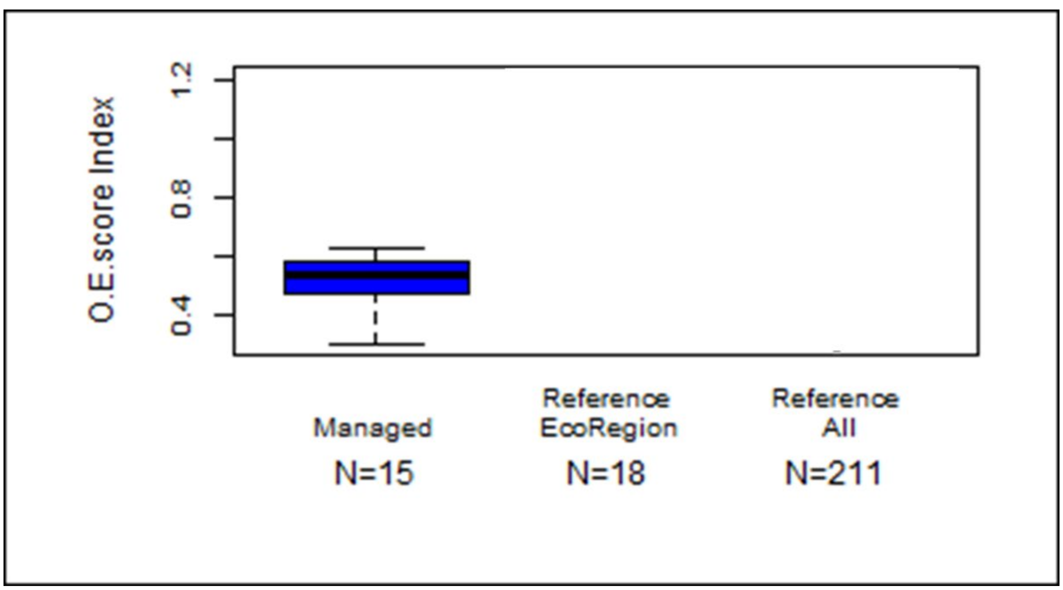

Figure 11. O/E Macroinvertebrate score Index values across the OWEB - MFJD. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area. Data represented in this figure include samples collected through 2019.

Table 3. Summary of Index Scores-- OWEB - MFJD; N=sample size, p-value=significance (0.1), sd=standard deviation, ci=95% confidence interval. Macroinvertebrate (O.E.) data represented in this table include samples collected through 2019. Because the drainage area of these sites on the M.F. John Day River are larger than our reference reaches, we do not feel that our models can correctly predict status. Therefore, statistical tests comparing status at MFJD sites to reference sites are were not conducted.

InterestArea	Metric	Indexscore	N	pvalue	sd	ci
Managed	Overall	21.16	15	NA	4.88	2.22
Reference Local	Overall	NA	<3	NA	NA	NA
Reference Eco Region	Overall	54.36	19	NA	15.92	6.34
Reference All	Overall	52.18	214	NA	16.55	1.87
Managed	Residual.Pool.Depth	0.1	15	NA	0.28	0.13
Reference Local	Residual.Pool.Depth	NA	<3	NA	NA	NA
Reference Eco Region	Residual.Pool.Depth	6.7	19	NA	2.19	0.87
Reference All	Residual.Pool.Depth	5.44	216	NA	2.45	0.28
Managed	Pool.Percent	9.38	15	NA	1.55	0.7
Reference Local	Pool.Percent	NA	<3	NA	NA	NA
Reference Eco Region	Pool.Percent	5.69	19	NA	2.23	0.89
Reference All	Pool.Percent	4.87	216	NA	2.58	0.29
Managed	Median.Substrate	0.89	15	NA	2.66	1.21
Reference Local	Median.Substrate	NA	<3	NA	NA	NA
Reference Eco Region	Median.Substrate	5.36	19	NA	2.15	0.86
Reference All	Median.Substrate	5.59	216	NA	2.54	0.29
Managed	Pool.Fines	1.02	15	NA	2.82	1.28
Reference Local	Pool.Fines	NA	<3	NA	NA	NA
Reference Eco Region	Pool.Fines	5.63	19	NA	2.42	0.96
Reference All	Pool.Fines	5.49	214	NA	2.46	0.28
Managed	Wood.Frequency	0.88	15	NA	1.49	0.68
Reference Local	Wood.Frequency	NA	<3	NA	NA	NA
Reference Eco Region	Wood.Frequency	6.91	19	NA	2.36	0.94
Reference All	Wood.Frequency	6.61	216	NA	2.4	0.27
Managed	Bank.Angle	8.85	15	NA	3.02	1.37
Reference Local	Bank.Angle	NA	<3	NA	NA	NA
Reference Eco Region	Bank.Angle	4.2	19	NA	2.26	0.9
Reference All	Bank.Angle	5.44	216	NA	2.57	0.29
Managed	O.E.score	0.52	15	NA	0.09	0.04
Reference Local	O.E.score	NA	<3	NA	NA	NA
Reference Eco Region	O.E.score	0.9	18	NA	0.12	0.05
Reference All	O.E.score	0.95	211	NA	0.14	0.02

Table 4 .Trend in stream habitat attributes across the Middle Fork John Day River sites including: Overall_Index score, O.E. (Observed/Expected macroinvertebrate score), VegStab (bank stability), UnCutPct (percent undercut banks), LWFrq (large wood frequency), Bank Angle, PTFines6 (percent fines in pool tails), D50 (median substrate size), RPD (residual pool depth), and PoolPct (percent pools). Refer to page 5 of methods (Heading: 'Summary Tables') for further explanation. Time1 = mean during first visit; Time2 = mean value for last visit; Percent Change = Percent change in the mean values between the first and last visit; Sample size = number of observations with repeat visits; Negative Number = Number of sites where actual measurement was lower on last visit; Positive Number = Number of sites where actual measurement was higher in last visit; None Number = Number of sites where last visit and first visit values were equal; P-value = Significance test; Desired Direction = direction of change in the mean, which can be either + or -; Actual Change = actual direction of change in the mean, which can be either +, -, or not significant (NS). Macroinvertebrate (O.E.) data represented in this table include samples collected through 2019.

Metric	Time1 Value	Time2 Value	Percent Change	Sample Size	Negative Number	Positive Number	None Number	P-value	Desired Direction	Actual Change
Overall_Index	19.38	21.41	10.5	15	10	3	2	0.504	+	NS
O.E.	0.47	0.58	24.2	15	3	12	0	0.006	+	+
VegStab	88.42	89.62	1.4	15	8	5	2	0.807	+	NS
UnCutPct	15.57	16.22	4.2	15	8	7	0	0.955	+	NS
LWFrq	15.58	28.84	85.1	15	5	8	2	0.753	+	NS
BankAngle	134.67	133.8	-0.6	15	7	8	0	0.69	-	NS
PTFines6	2.61	18.97	627.9	15	3	12	0	0.011	-	+
D50	0.0692	0.0838	21	15	4	11	0	0.009	+	+
RPD	0.58	0.52	-10.4	15	7	8	0	0.733	+	NS
PoolPct	44.06	50.99	15.7	15	6	9	0	0.256	+	NS

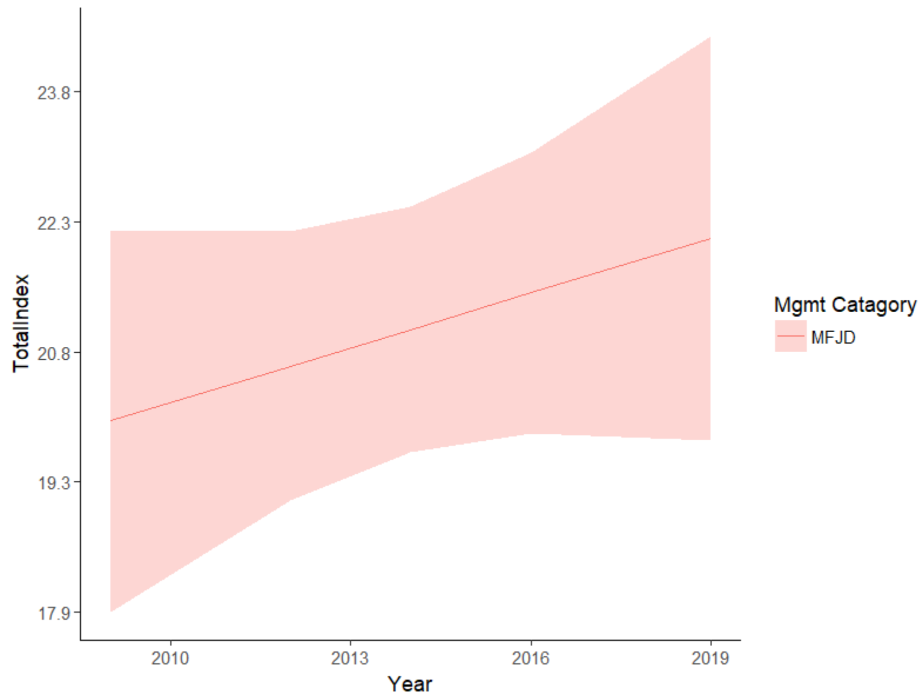

Figure 12. Modeled trend in Overall Index values (labeled TotalIndex) across the OWEB – MFJD as a solid line. Shaded portion represents the 90% confidence interval.

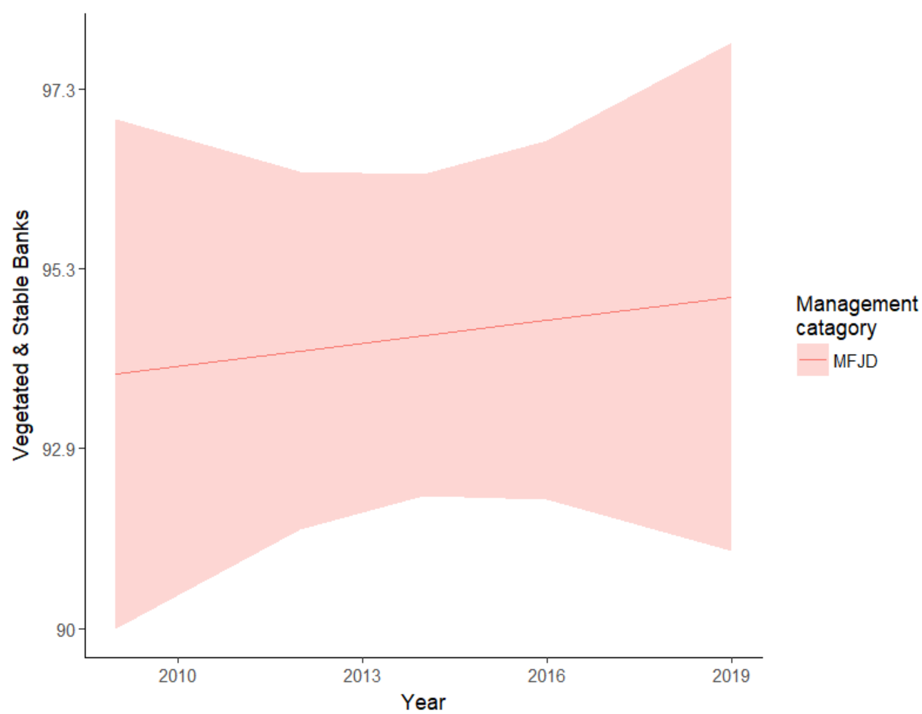

Figure 13. Modeled trend in Vegetative Bank Stability across the OWEB – MFJD as a solid line. Shaded portion represents the 90% confidence interval.

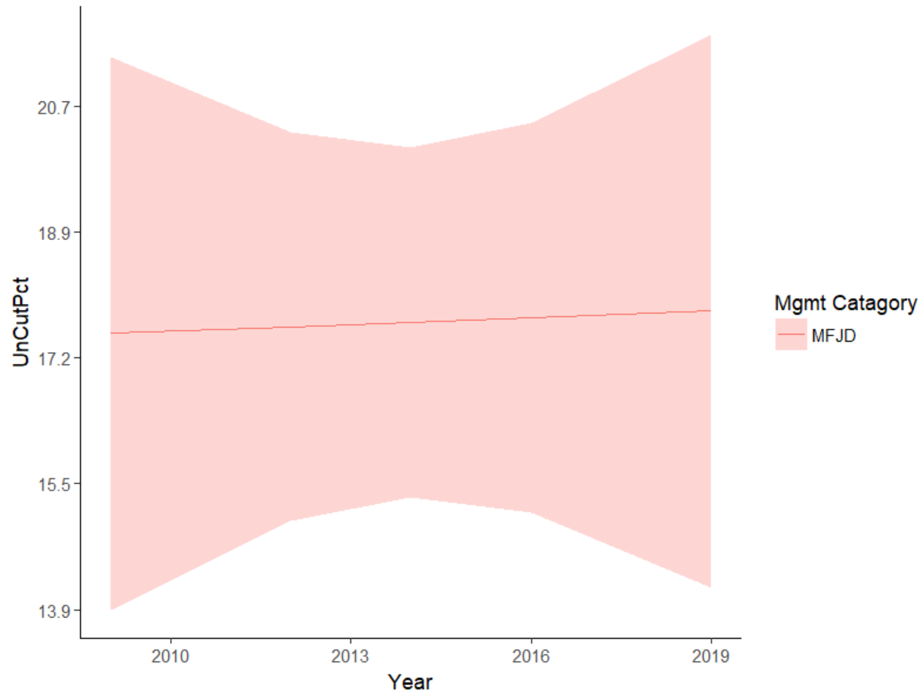

Figure 14. Modeled trend in Undercut Percent across the OWEB – MFJD as a solid line. Shaded portion represents the 90% confidence interval.

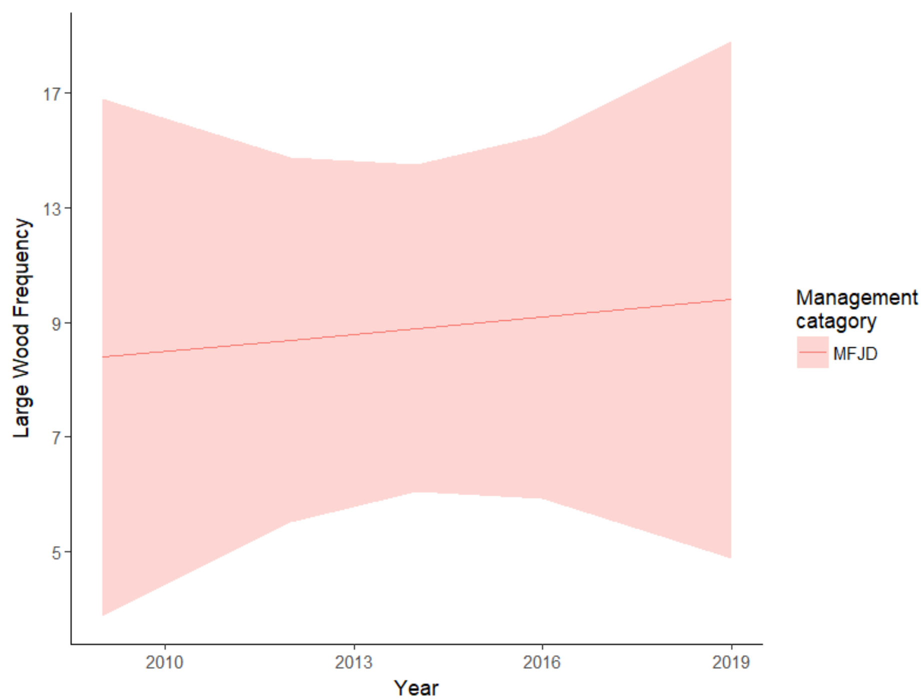

Figure 15. Modeled trend in Large Wood Frequency across the OWEB – MFJD as a solid line. Shaded portion represents the 90% confidence interval.

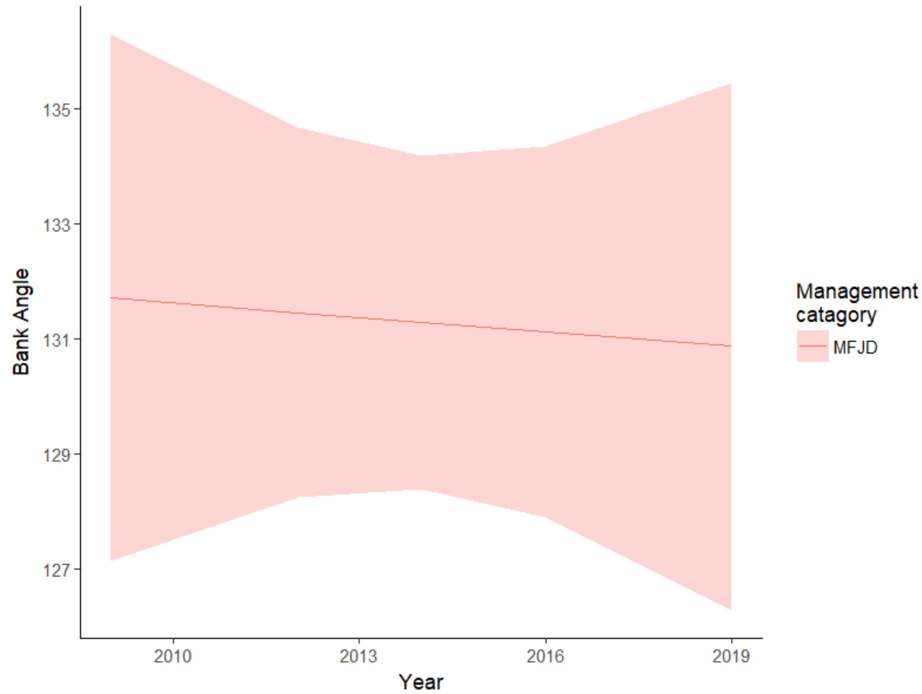

Figure 16. Modeled trend in Bank Angle across the OWEB – MFJD as a solid line. Shaded portion represents the 90% confidence interval.

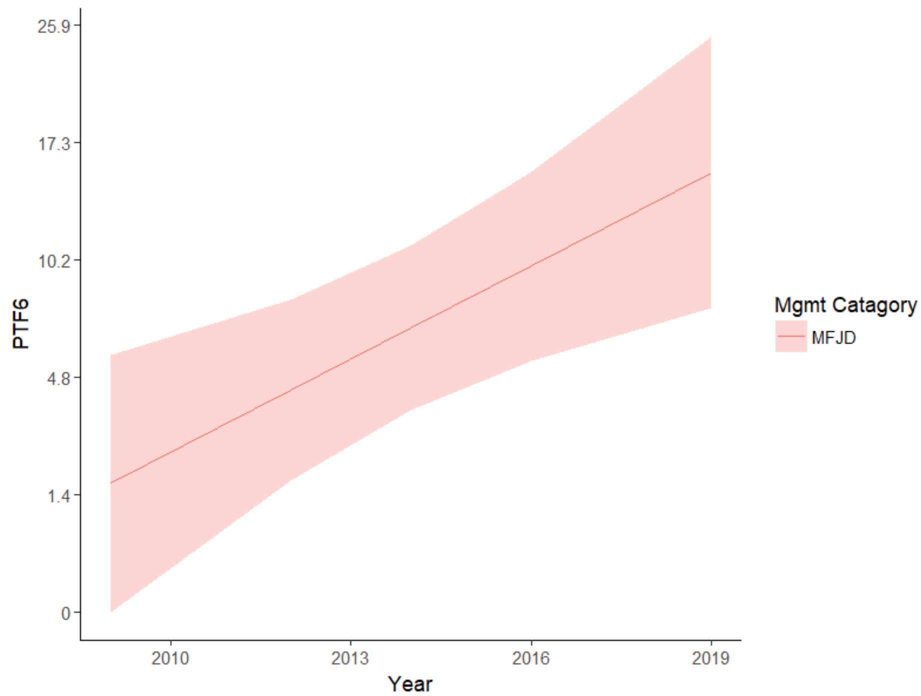

Figure 17. Modeled trend in Pool Tail Fines >6mm across the OWEB – MFJD as a solid line. Shaded portion represents the 90% confidence interval.

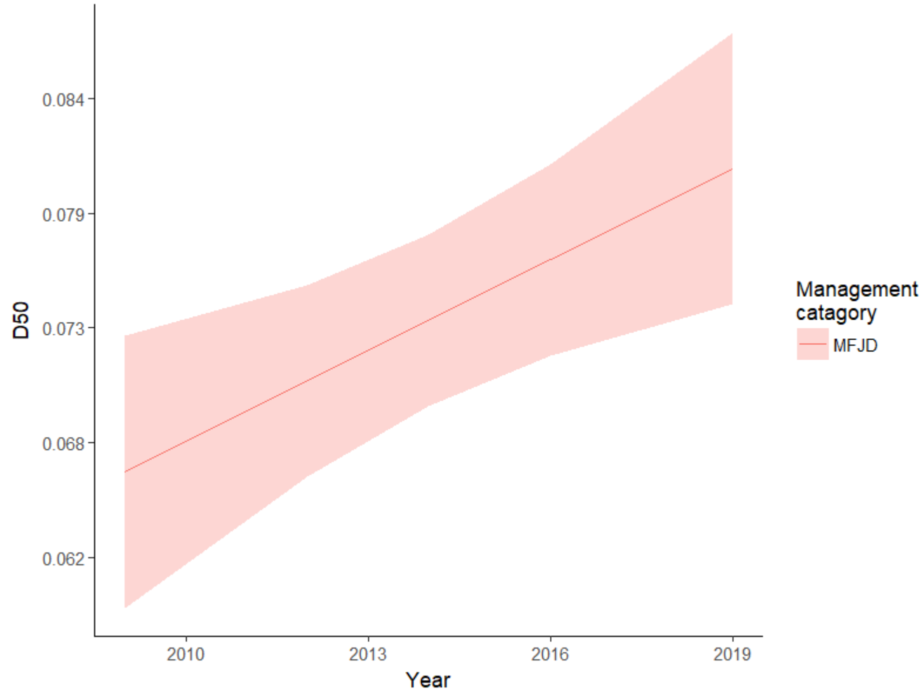

Figure 18. Modeled trend in Median Particle Size across the OWEB – MFJD as a solid line. Shaded portion represents the 90% confidence interval.

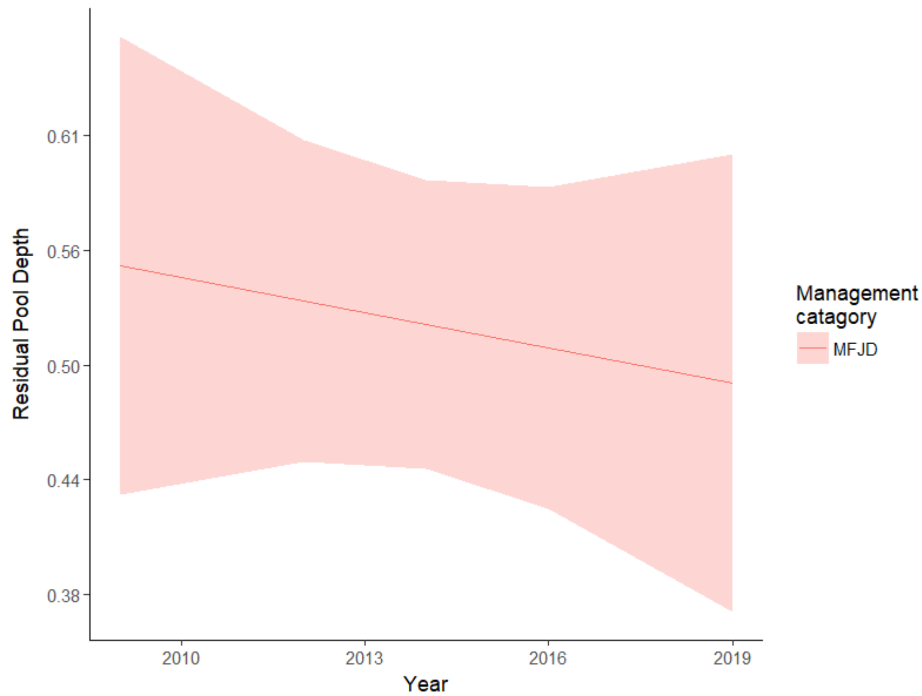

Figure 19. Modeled trend in Residual Pool Depth across the OWEB – MFJD as a solid line. Shaded portion represents the 90% confidence interval.

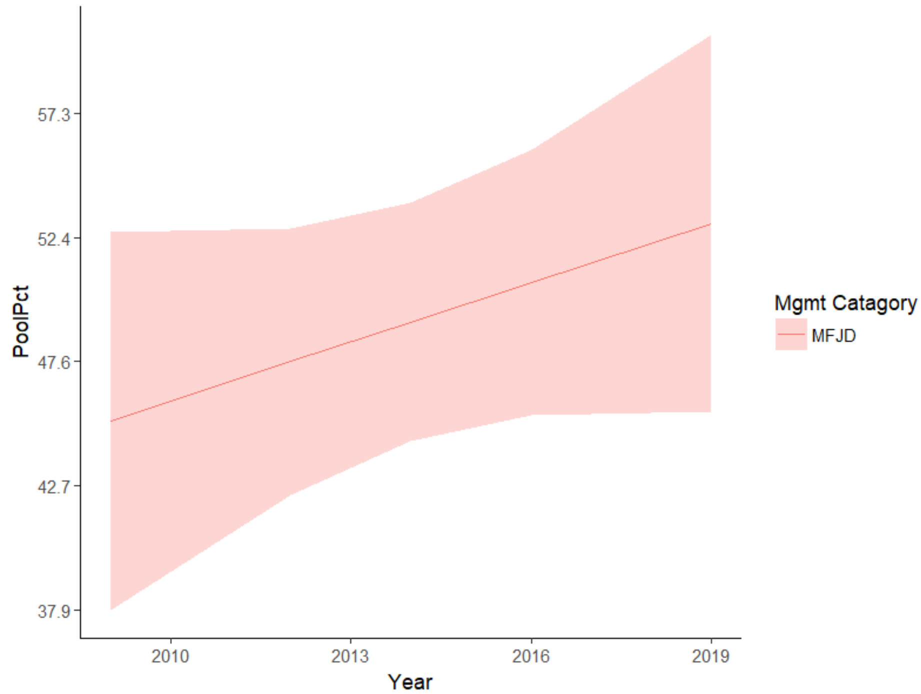

Figure 20. Modeled trend in Pool Percent across the OWEB – MFJD as a solid line. Shaded portion represents the 90% confidence interval.

Table 5: P-values for significance tests of year covariates included in regression models used to describe variation in stream measurements. P-values represent the significance of trends in measured stream metrics observed in data collected by the PIBO program since 2001 (with observations made with support by OWEB occurring since 2009). Response variables (i.e., observations of stream metrics) were modeled separately for three groups of sites. P-values for managed sites on the Middle Fork John Day River (MFJD) report the significance of temporal trends at randomly distributed (i.e., integrator) sites identified as "managed sites" in the survey design of the PIBO program. P-values for reference sites that occur in the same ecoregion (EcoRegion reference) as managed sites on the Forest report the significance of temporal trends across this sub-set of randomly distributed reference (i.e., integrator) sites in the Columbia River Basin. P-values for all reference sites that occur throughout the Columbia River Basin (All reference) report the significance of temporal trends across of randomly distributed reference (i.e., integrator) sites in the Columbia River Basin. Statistical significance evaluated for alpha = 0.1, and indicated in the table with "*".

Metric	**M.F. John Day River**	**EcoRegion reference**	**All reference**
Overall Index	0.154	NA	NA
Vegetated & Stable Banks	0.431	NA	NA
% Undercut Banks	0.921	NA	NA
Large Wood Frequency	0.691	NA	NA
Bank Angle	0.803	NA	NA
PTF <6 mm	0.011*	NA	NA
D50	0.003*	NA	NA
Residual Pool Depth	0.363	NA	NA
% Pool	0.104*	NA	NA

Results

Camp and Lick Creeks Status

We resampled 10 sites on Camp and Lick Creeks which were originally sampled in 2008 and again in 2014 (Figure 3). The 10 sites were significantly lower for the overall Index Score when compared to the PIBO reference sites within the Eco Region and the Columbia River Basin. These 10 sites were also significantly lower for 4 of the 6 other metrics that are contained in the overall Index Score. Both median substrate size and pooltail fines >6mm were larger than expected given the stream size, but only pooltail fines >6mm were significantly greater than reference sites. Pool percent, residual pool depth, large wood frequency, and bank angle were all significantly lower than at reference sites. These 10 sites were also significantly lower for the macroinvertebrate metric (O/E) (Table 6).

Camp and Lick Creeks Trend

PIBO conducted two separate analyses of trend using the data from the 10 sites see methods. Traditionally, PIBO has used the data from the first and last visit to evaluate trend at sites. These data are analyzed in their raw, untransformed state using a Wilcoxon signed rank test, a nonparametric statistical test for differences in two samples (see methods section). Results from this analysis are presented in Table 7 below. The 10 sites were trending significantly in the desired direction for 3 of 8 metrics, large wood frequency, residual pool depth, and pool percent. This trend is also observed in the regression model, see below. Two metrics were trending in an undesirable direction (pooltail fines and median substrate size, Table 7), also consistent with the regression model (see below). This analysis provides a clear picture of conditions during the most recent sampling, relative to initial conditions, and provides unaltered estimates of metric averages that can be used for further reporting and documentation if needed.

As PIBO has now completed three sample visits at sites on Camp and Lick creeks, the above analysis of trend potentially lacks power to assess trend as only data from first and last samples are used. Further, the above analysis does not lend itself to graphical displays of trends. Therefore, PIBO also used a linear modeling framework to evaluate trend at these 10 sites through time. Additionally, this analysis is conducted for the PIBO reference network, including a subset of the local ecoregion (see methods section). This analytical method shows that reference conditions are not static. However, this results section will speak to these changes only in regard to changes in conditions at Camp and Lick creek sites. Across the Camp and Lick creek sites, there were statistically significant trends in pooltail fines, median particle size, wood frequency, residual pool depth, and pool percent (Table 8). Each of these metrics showed a similar level of significance and the same trend direction as in the Wilcoxon sign rank test (Tables 7 & 8). Both residual pool depth and pool percent are trending upward in the in Camp and Lick creek sites, nearing reference conditions (Figures 44 & 45). For both pool metrics, there was no trend at reference sites. Large wood frequency at Camp and Lick creek sites was also trending upwards, as was observed for both eco-regional and all reference sites. However, the rate of change is considerably steeper in the managed sites (Figure 40). Median particle size was trending downward. Although this is often considered the wrong trend direction, the very high starting point shows this trend getting closer to all reference conditions (Figure 43). Further, the eco-regions median particle size also decreased, although at a slower rate. Pooltail fines >6mm trended upwards, a direction often considered undesirable, but once again this change is moving a very distant measure closer to reference (Figure 42). The trend of pooltail fines shows this metric has caught up with reference sites.

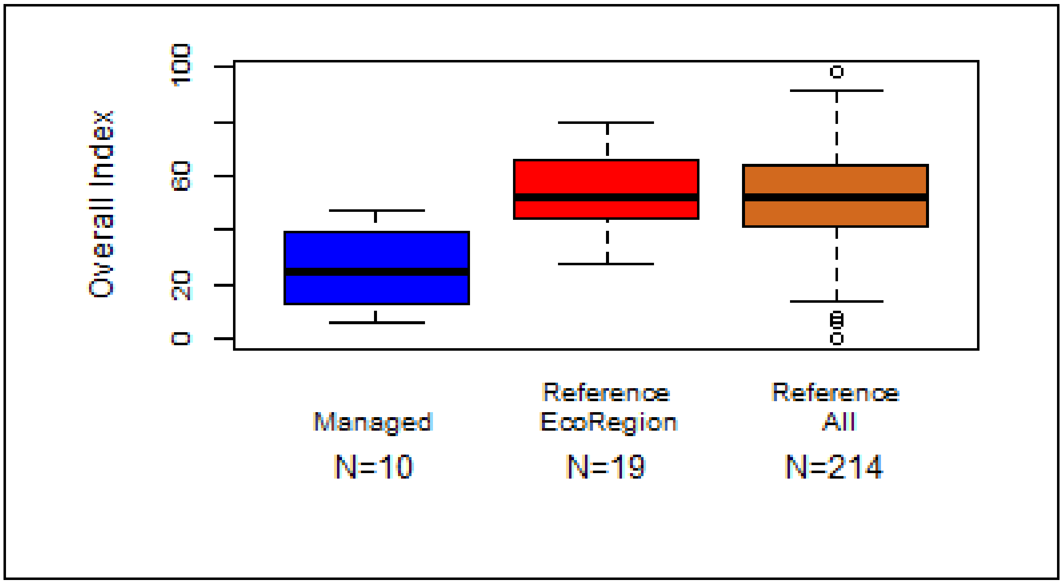

Figure 21. Overall Index values across Camp and Lick creeks. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

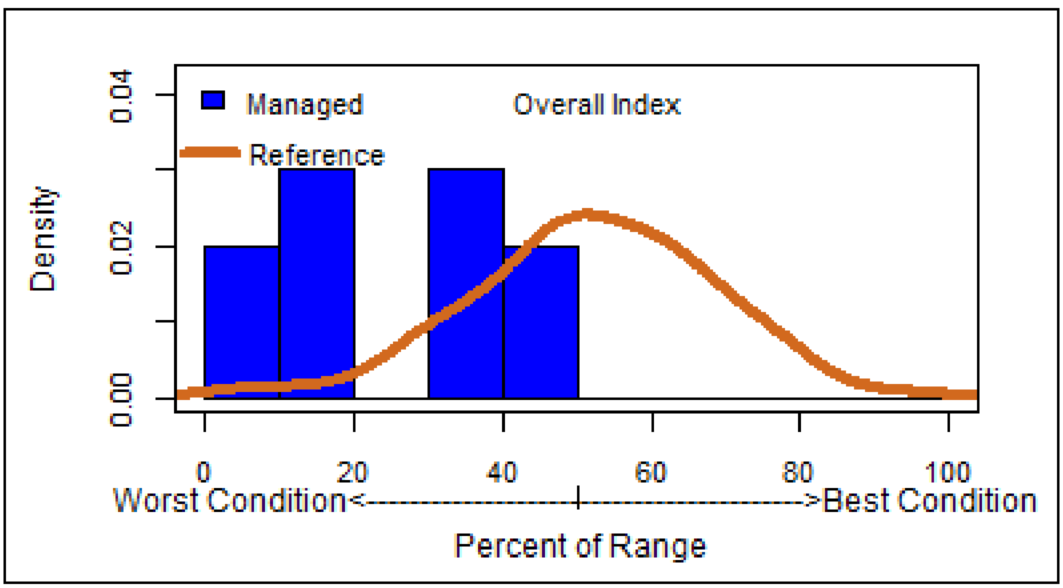

Figure 22. Overall Index values across Camp and Lick creeks. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches.

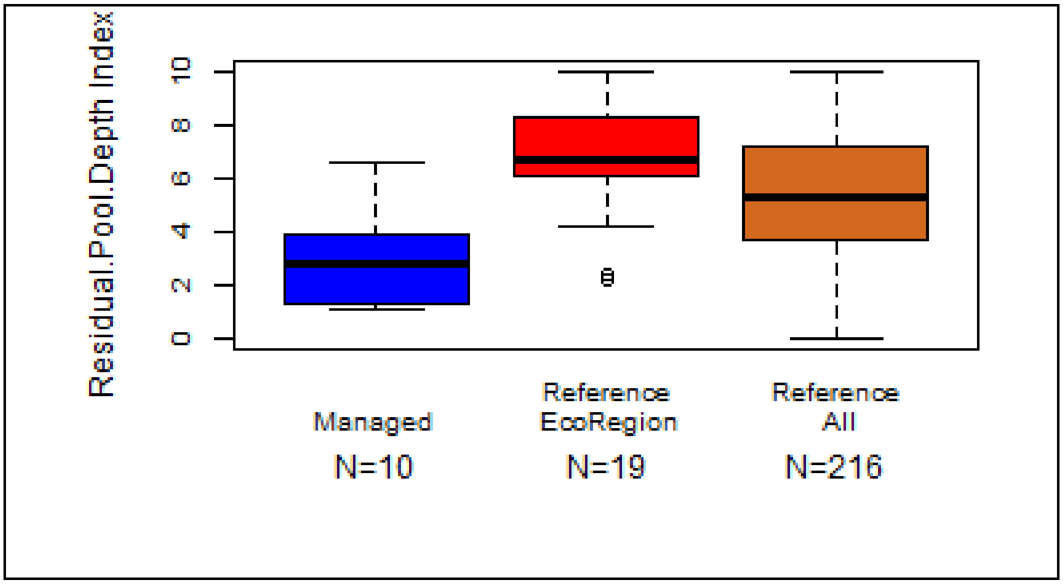

Figure 23. Residual Pool Depth Index values across Camp and Lick creeks. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

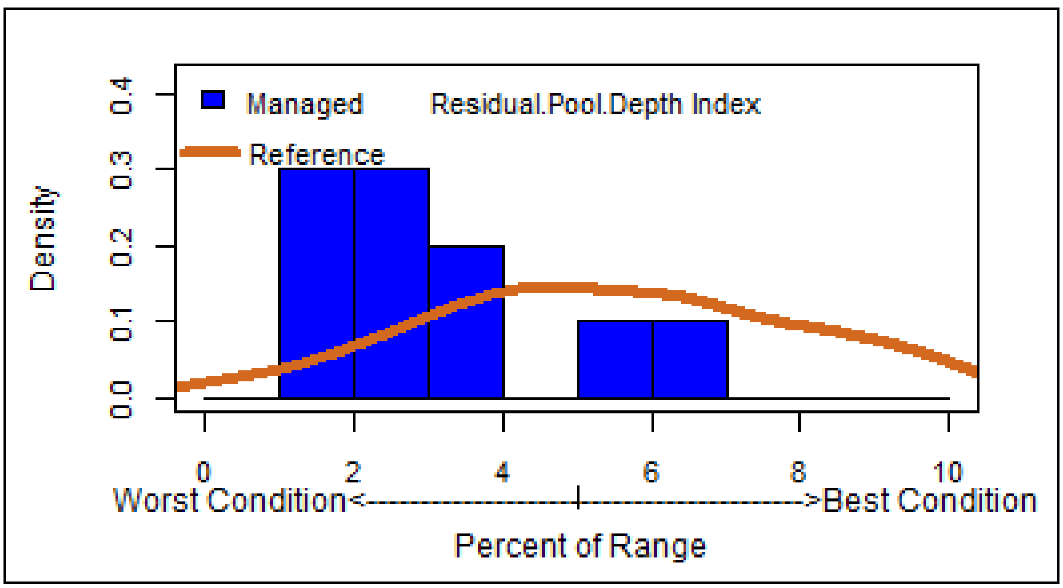

Figure 24. Residual Pool Depth Index values across Camp and Lick creeks. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches.

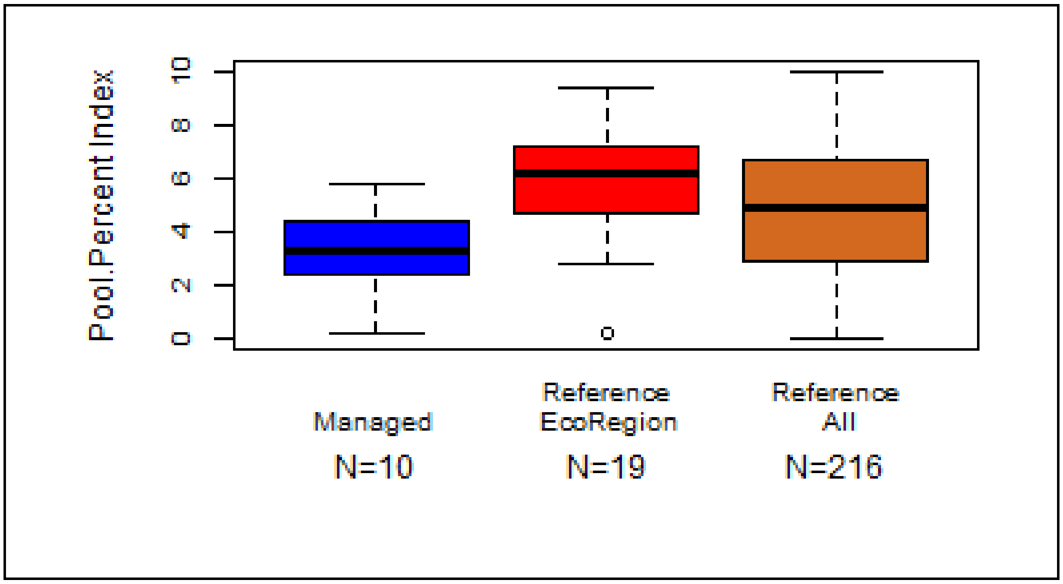

Figure 25. Pool Percent Index values across Camp and Lick creeks. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

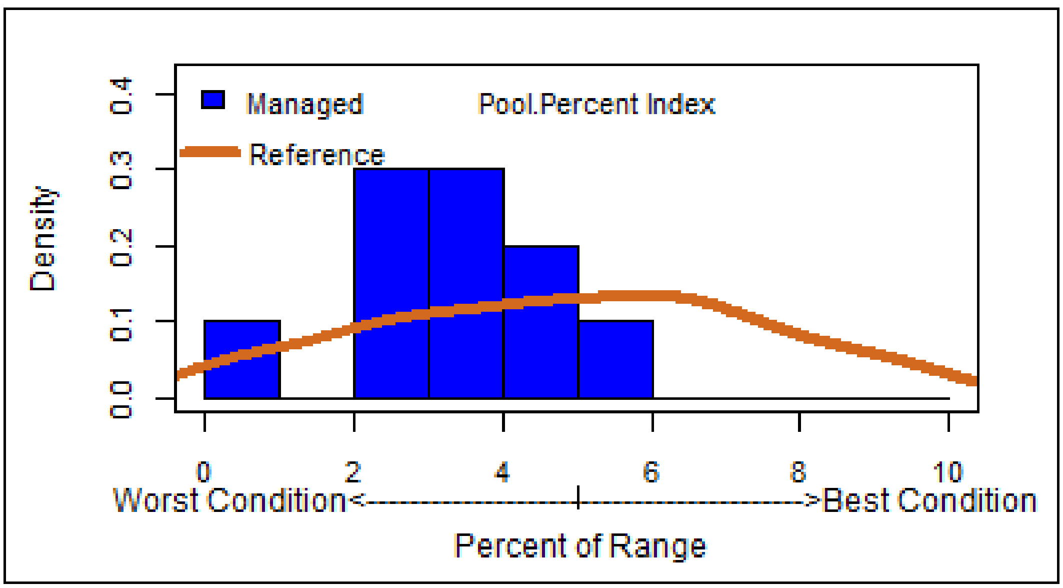

Figure 26. Pool Percent Index values across Camp and Lick creeks. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches.

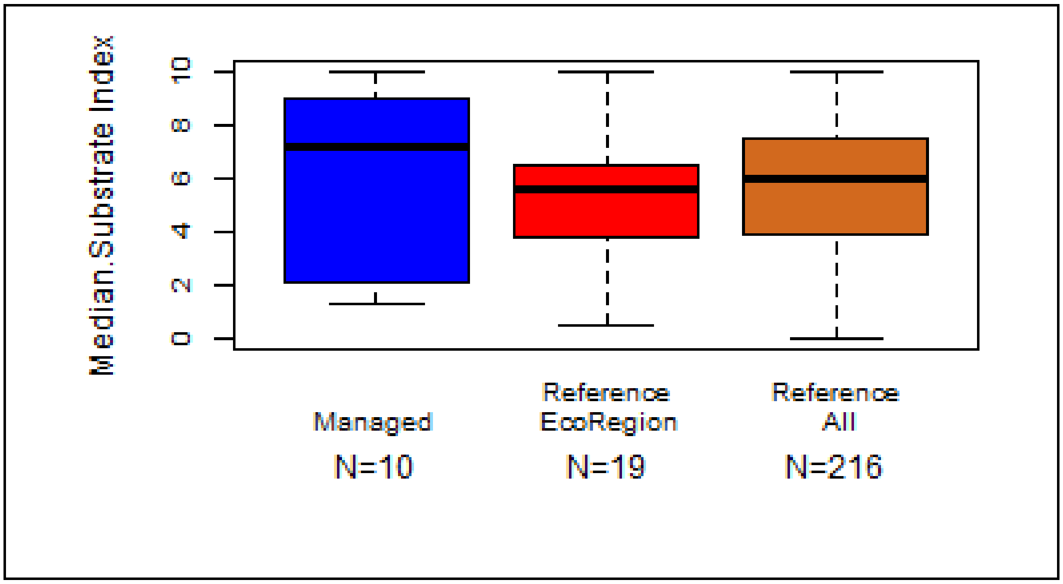

Figure 27. Median substrate Index values across Camp and Lick creeks. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

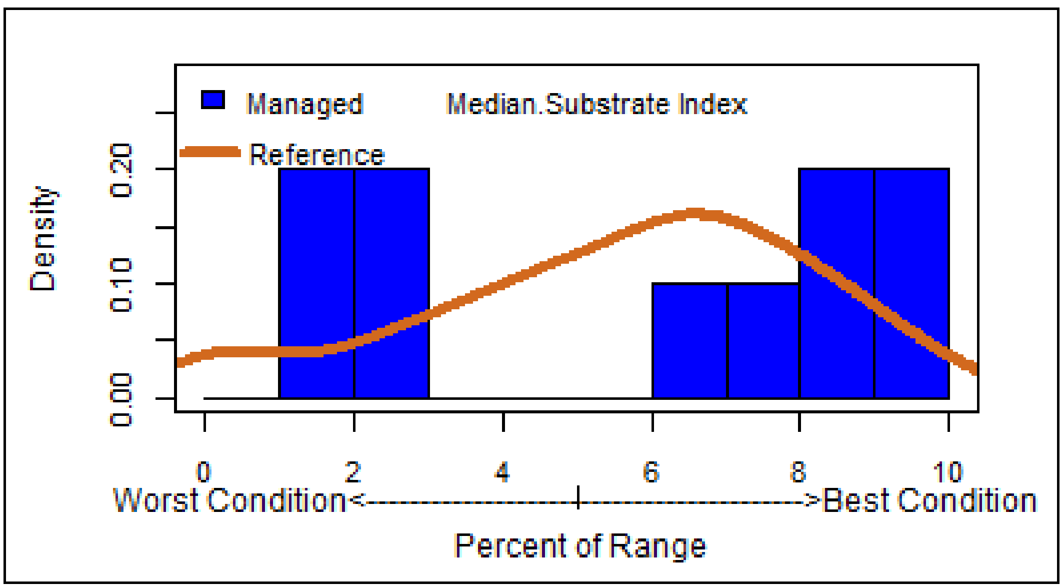

Figure 28. Median substrate Index values across Camp and Lick creeks. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches.

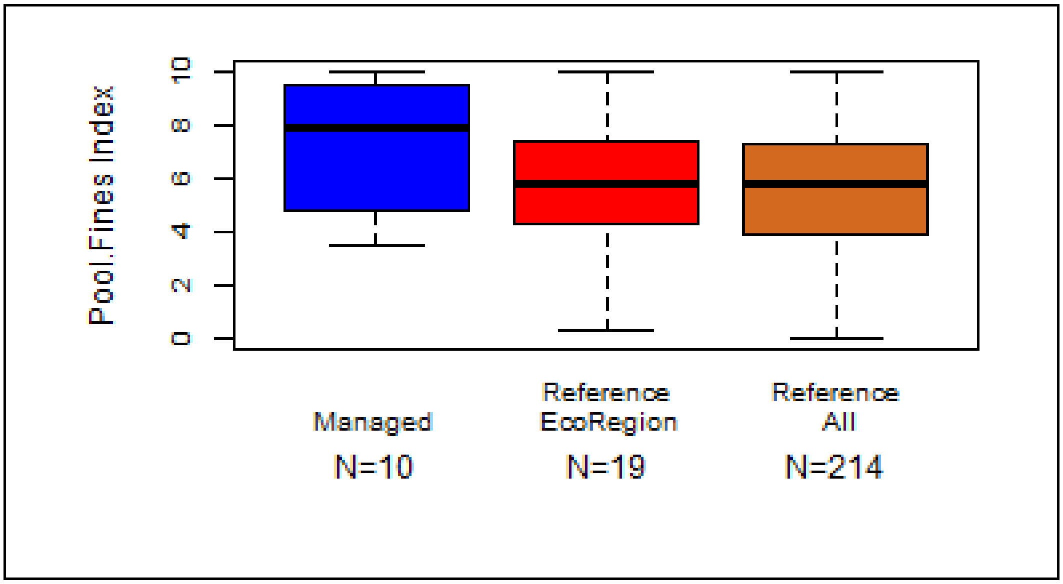

Figure 29. Pool Fines < 6 mm Index values across Camp and Lick creeks. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

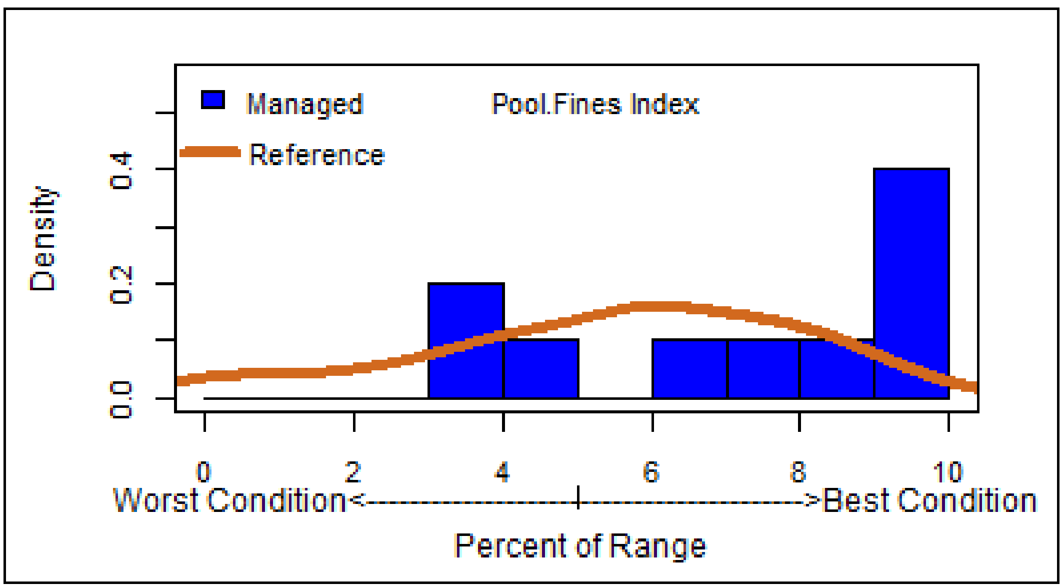

Figure 30. Pool Fines < 6 mm Index values across Camp and Lick creeks. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches.

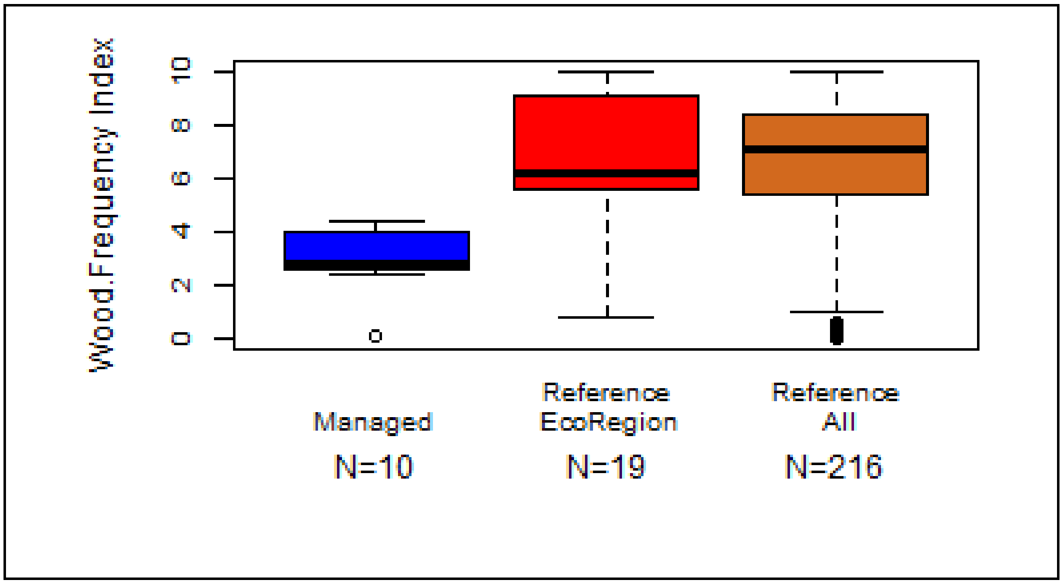

Figure 31. Wood Frequency Index values across Camp and Lick creeks. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

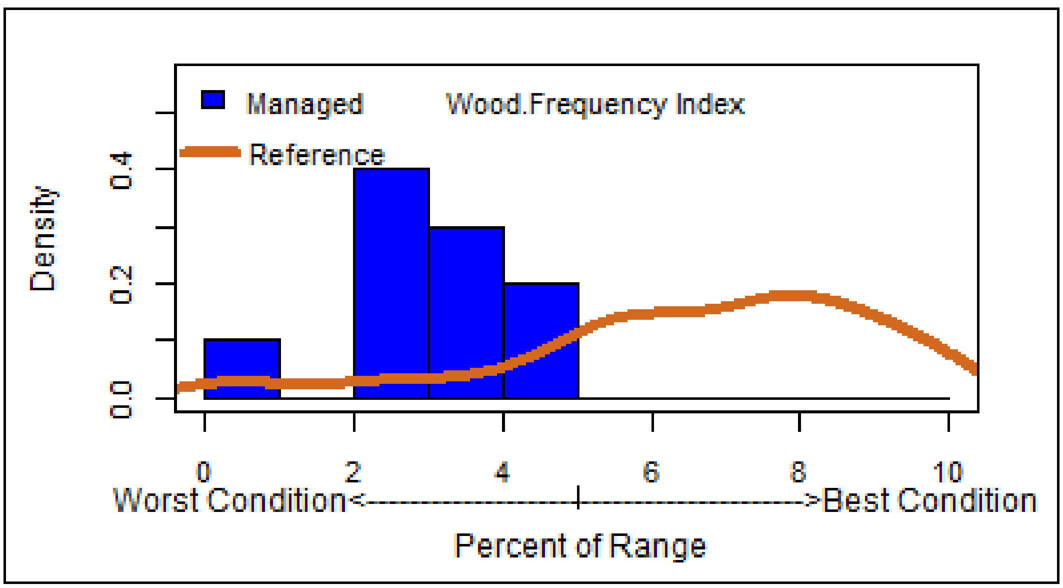

Figure 32. Wood Frequency Index values across Camp and Lick creeks. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches.

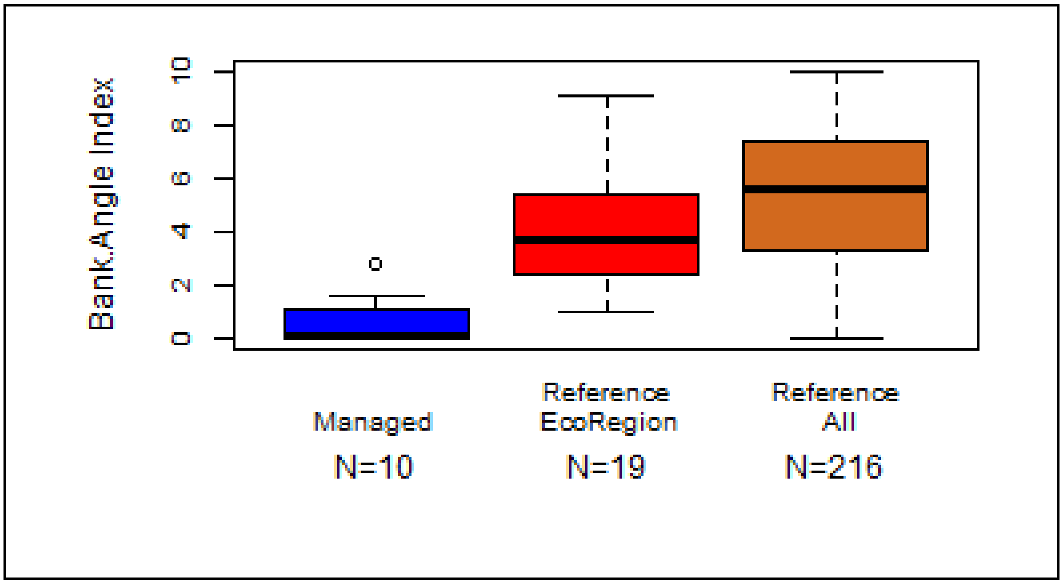

Figure 33. Bank Angle Index values across Camp and Lick creeks. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

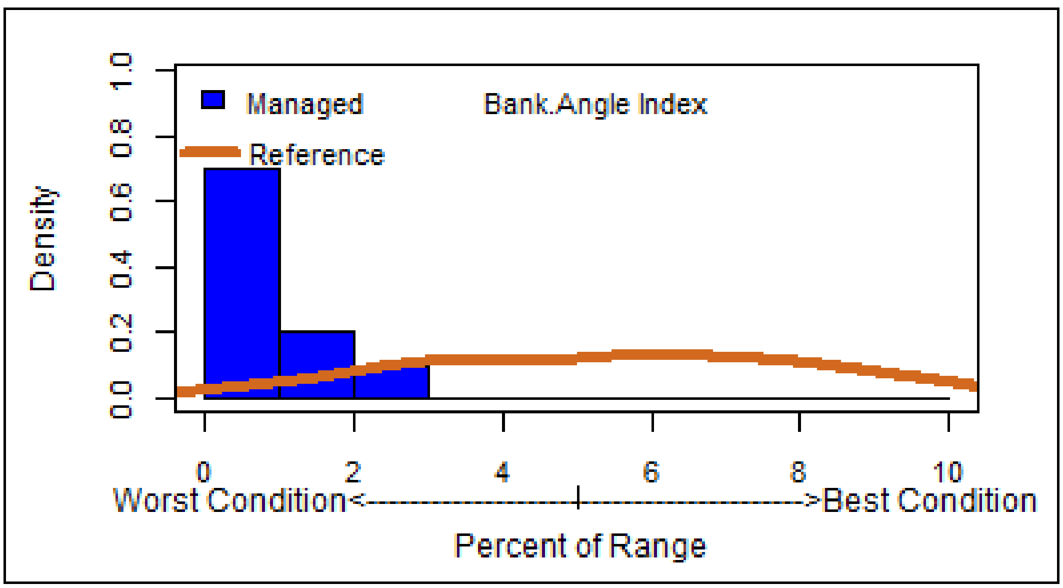

Figure 34. Bank Angle Index values across Camp and Lick creeks. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches.

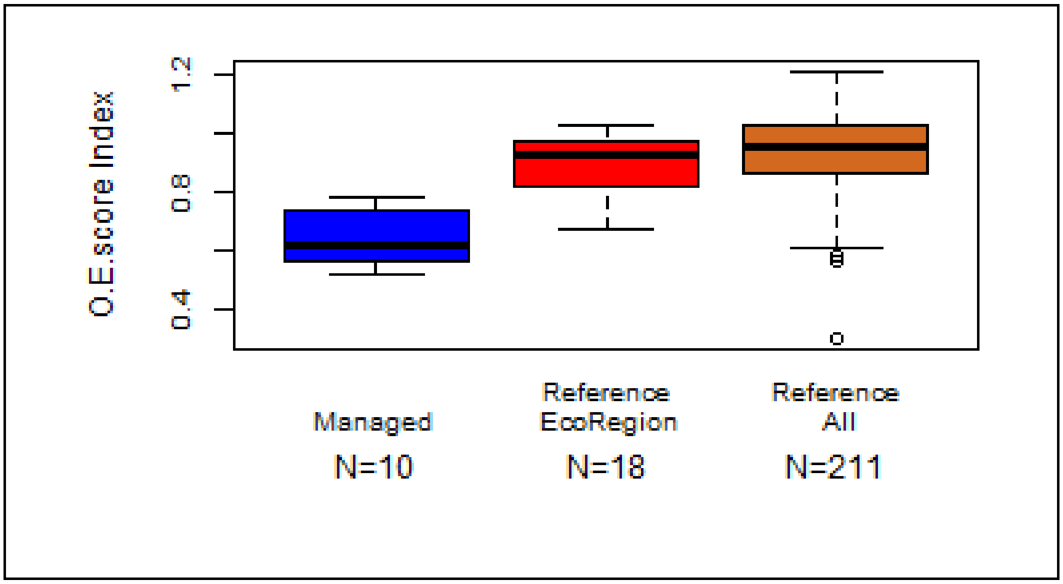

Figure 15. O/E Macroinvertebrate score Index values across the Camp and Lick creeks. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

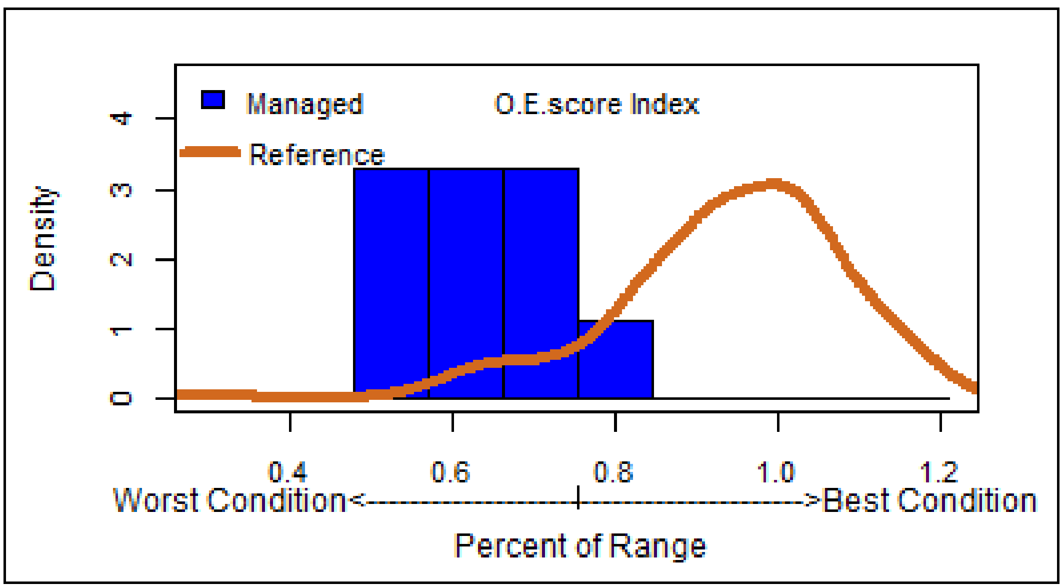

Figure 16. O/E Macroinvertebrate score Index values across the Camp and Lick creeks. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches. This includes macroinvertebrates samples collected through 2019.

Table 6. Summary of Index Scores—Camp and Lick creeks; N=sample size, p-value=significance (0.1), sd=standard deviation, ci=95% confidence interval. Data represented in this figure include samples collected through 2019.

InterestArea	Metric	Indexscore	N	pvalue	sd	ci
Managed	Overall	25.34	10	NA	15.48	8.98
Reference Local	Overall	NA	<3	NA	NA	NA
Reference Eco Region	Overall	54.36	19	p<0.01	15.92	6.34
Reference All	Overall	52.18	214	p<0.01	16.55	1.87
Managed	Residual.Pool.Depth	3.04	10	NA	1.87	1.08
Reference Local	Residual.Pool.Depth	NA	<3	NA	NA	NA
Reference Eco Region	Residual.Pool.Depth	6.7	19	p<0.01	2.19	0.87
Reference All	Residual.Pool.Depth	5.44	216	p<0.01	2.45	0.28
Managed	Pool.Percent	3.27	10	NA	1.6	0.93
Reference Local	Pool.Percent	NA	<3	NA	NA	NA
Reference Eco Region	Pool.Percent	5.69	19	p<0.01	2.23	0.89
Reference All	Pool.Percent	4.87	216	0.012	2.58	0.29
Managed	Median.Substrate	5.98	10	NA	3.61	2.09
Reference Local	Median.Substrate	NA	<3	NA	NA	NA
Reference Eco Region	Median.Substrate	5.36	19	0.627	2.15	0.86
Reference All	Median.Substrate	5.59	216	0.745	2.54	0.29
Managed	Pool.Fines	7.28	10	NA	2.57	1.49
Reference Local	Pool.Fines	NA	<3	NA	NA	NA
Reference Eco Region	Pool.Fines	5.63	19	0.111	2.42	0.96
Reference All	Pool.Fines	5.49	214	0.058	2.46	0.28
Managed	Wood.Frequency	2.97	10	NA	1.27	0.74
Reference Local	Wood.Frequency	NA	<3	NA	NA	NA
Reference Eco Region	Wood.Frequency	6.91	19	p<0.01	2.36	0.94
Reference All	Wood.Frequency	6.61	216	p<0.01	2.4	0.27
Managed	Bank.Angle	0.62	10	NA	0.94	0.54
Reference Local	Bank.Angle	NA	<3	NA	NA	NA
Reference Eco Region	Bank.Angle	4.2	19	p<0.01	2.26	0.9
Reference All	Bank.Angle	5.44	216	p<0.01	2.57	0.29
Managed	O.E.score	0.64	10	NA	0.09	0.05
Reference Local	O.E.score	NA	<3	NA	NA	NA
Reference Eco Region	O.E.score	0.9	18	p<0.01	0.12	0.05
Reference All	O.E.score	0.95	210	p<0.01	0.14	0.02

Trend: Comparison of First and Last Sample Dates for Camp and Lick creeks

Table 7 .Trend in stream habitat attributes across Camp and Lick creeks including: Overall_Index score, O.E. (Observed/Expected macroinvertebrate score), VegStab (bank stability), UnCutPct (percent undercut banks), LWFrq (large wood frequency), Bank Angle, PTFines6 (percent fines in pool tails), D50 (median substrate size), RPD (residual pool depth), and PoolPct (percent pools). Refer to page 5 of methods (Heading: 'Summary Tables') for further explanation. Time1 = mean during first visit; Time2 = mean value for last visit; Percent Change = Percent change in the mean values between the first and last visit; Sample size = number of observations with repeat visits; Negative Number = Number of sites where actual measurement was lower on last visit; Positive Number = Number of sites where actual measurement was higher in last visit; None Number = Number of sites where last visit and first visit values were equal; P-value = Significance test; Desired Direction = direction of change in the mean, which can be either + or -; Actual Change = actual direction of change in the mean, which can be either +, -, or not significant (NS). Macroinvertebrate (O.E.) data represented in this table include samples collected through 2019.

Metric	Time1 Value	Time2 Value	Percent Change	Sample Size	Negative Number	Positive Number	None Number	P-value	Desired Direction	Actual Change
Overall_Index	21.42	26.98	26	10	2	8	0	0.139	+	NS
O.E.	0.71	0.65	-9.1	10	5	5	0	0.646	+	NS
VegStab	85.26	84.35	-1.1	10	6	4	0	0.959	+	NS
UnCutPct	10.64	8.26	-22.4	10	7	3	0	0.285	+	NS
LWFrq	51.54	152.14	195.2	10	3	7	0	0.028	+	+
BankAngle	135.8	139.8	2.9	10	4	6	0	0.444	-	NS
PTFines6	2.64	28.57	981.8	10	1	9	0	0.028	-	+
D50	0.0818	0.0694	-15.1	10	7	3	0	0.093	+	-
RPD	0.24	0.3	24.2	10	2	8	0	0.017	+	+
PoolPct	29.32	42.93	46.4	10	2	8	0	0.028	+	+

Trend: Linear Modeling of Trends in Habitat Metrics for Camp and Lick creeks

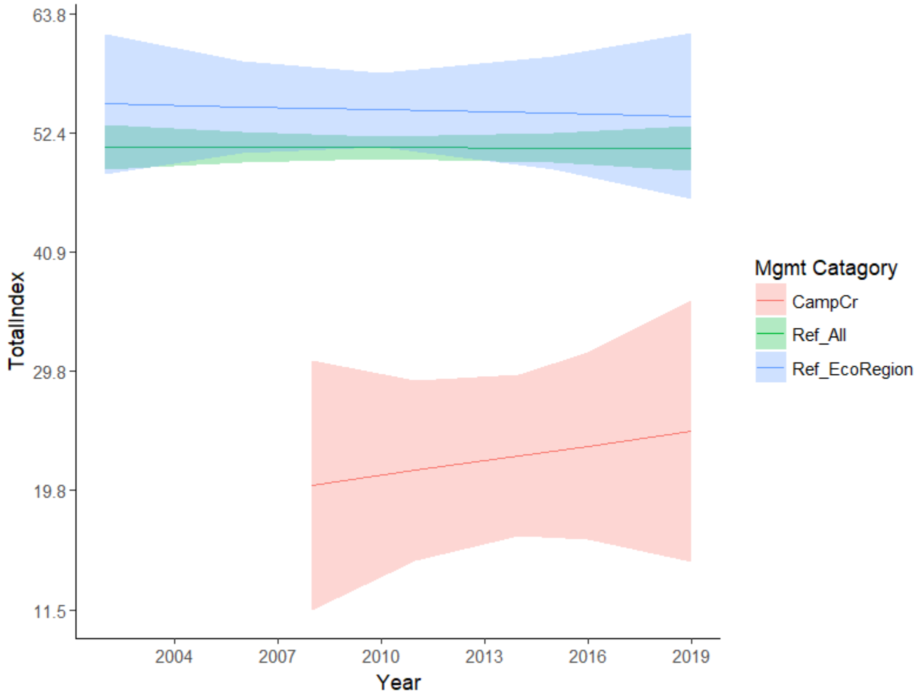

Figure 37. Modeled trend in Overall Index Score (labeled TotalIndex) across Camp and Lick creeks (CampCr) as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

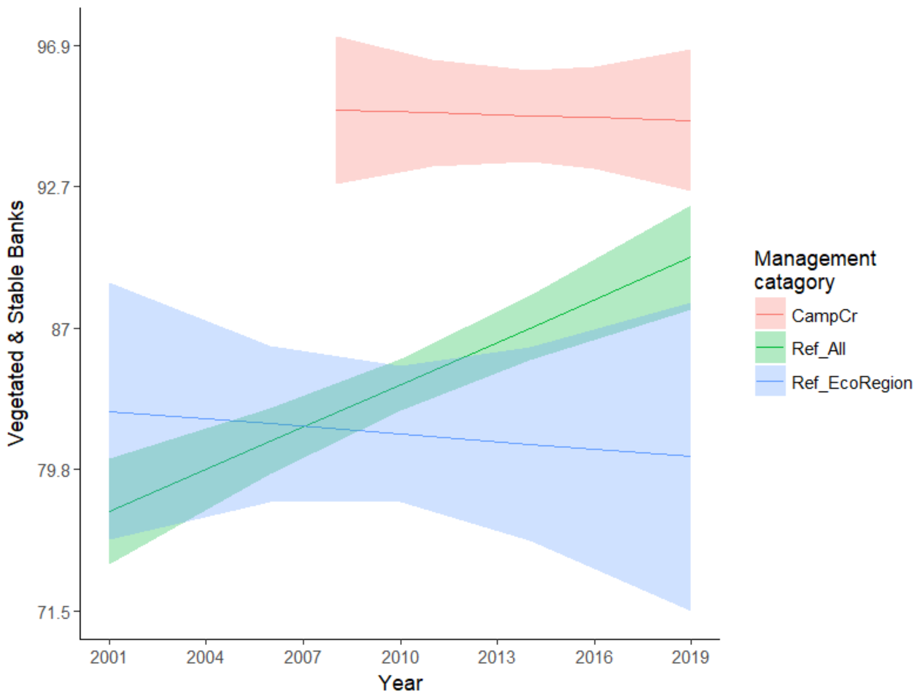

Figure 38. Modeled trend in Vegetative Bank Stability across Camp and Lick creeks (CampCr) as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

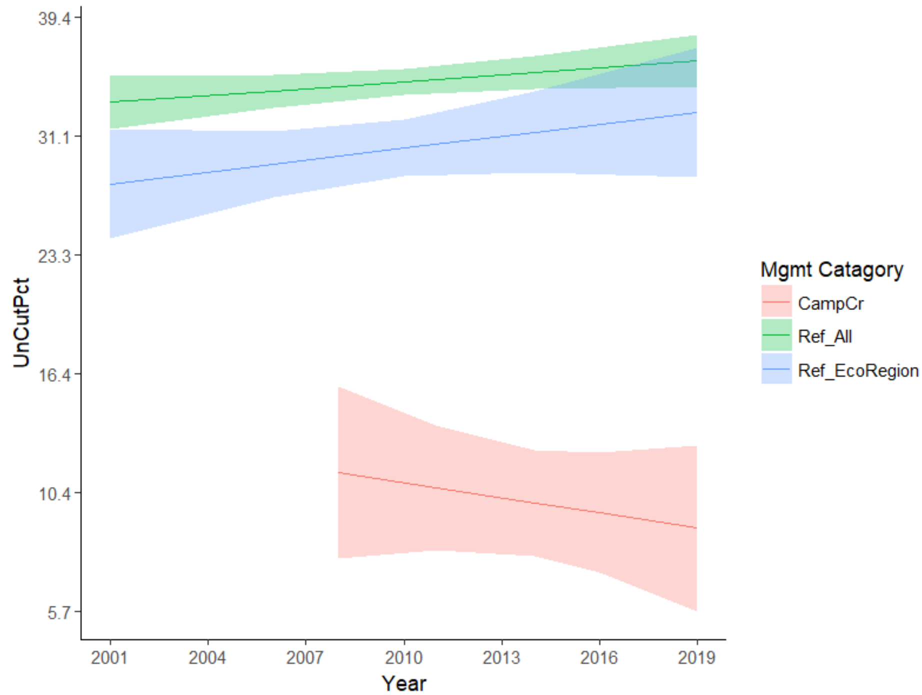

Figure 39. Modeled trend in Undercut Percent across Camp and Lick creeks (CampCr) as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

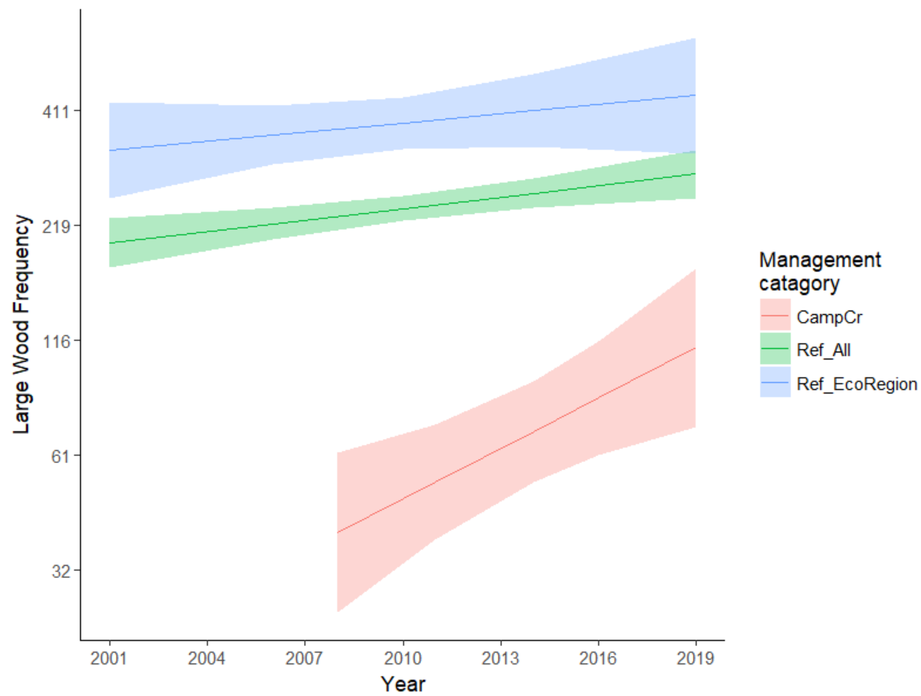

Figure 40. Modeled trend in Large Wood Frequency across Camp and Lick creeks (CampCr) as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

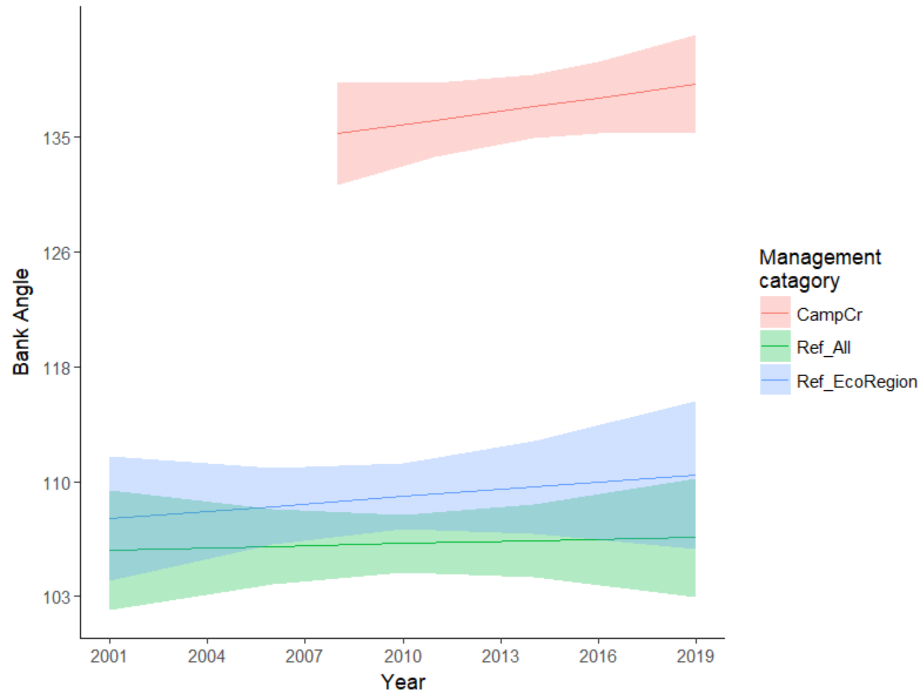

Figure 41. Modeled trend in Bank Angle across Camp and Lick creeks (CampCr) as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

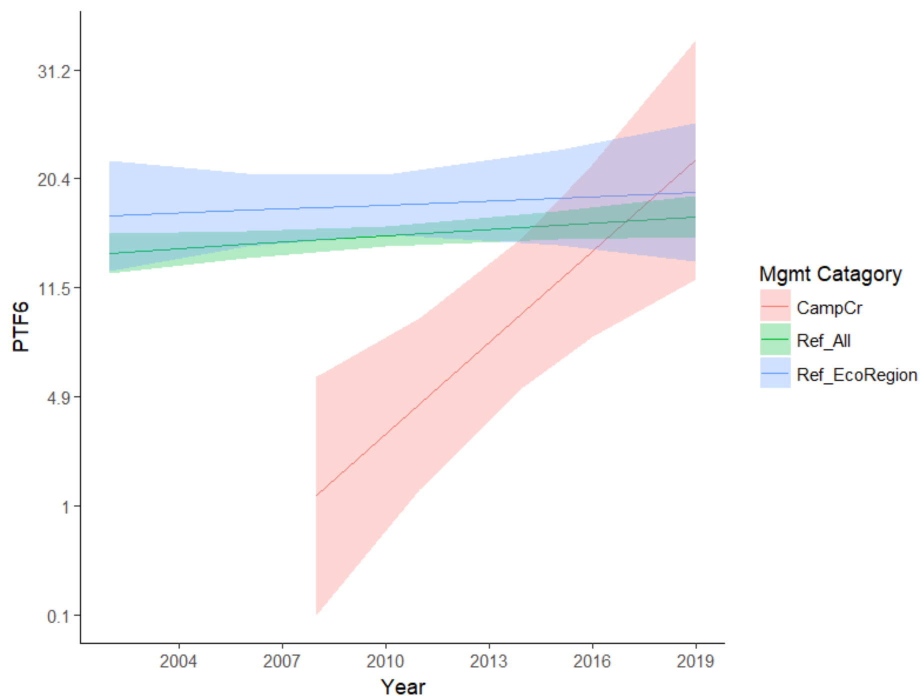

Figure 42. Modeled trend in Pooltail Fines >6mm across Camp and Lick creeks (CampCr) as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

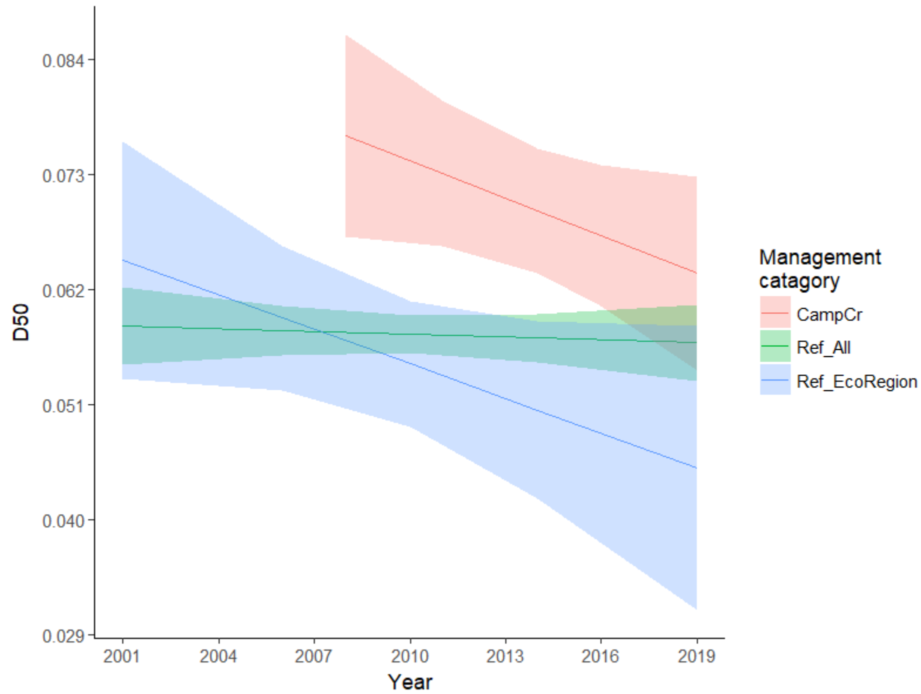

Figure 43. Modeled trend in Median Particle Size across Camp and Lick creeks (CampCr) as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

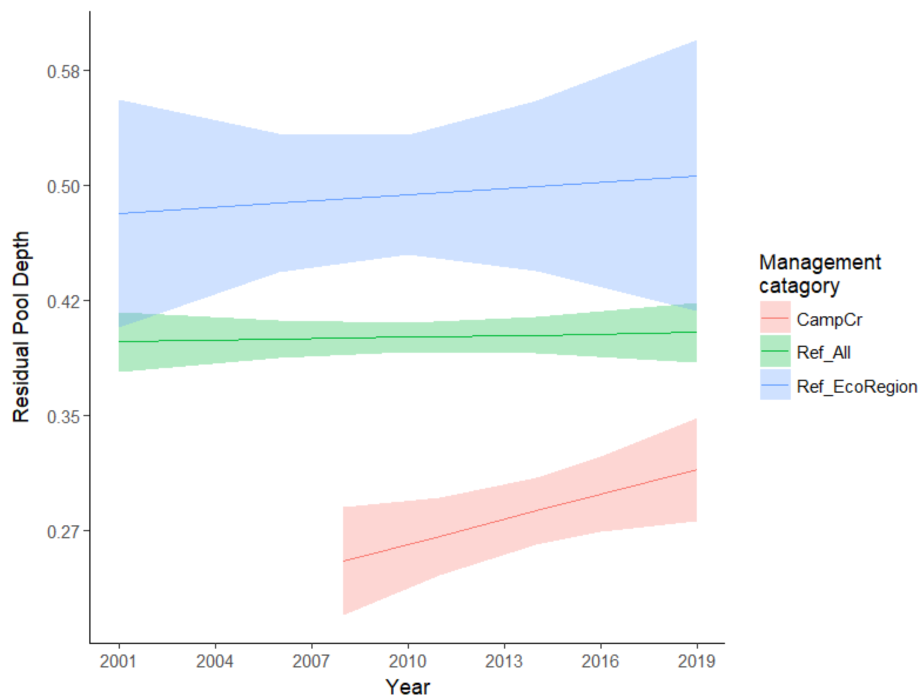

Figure 44. Modeled trend in Residual Pool Depth across Camp and Lick creeks (CampCr) as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

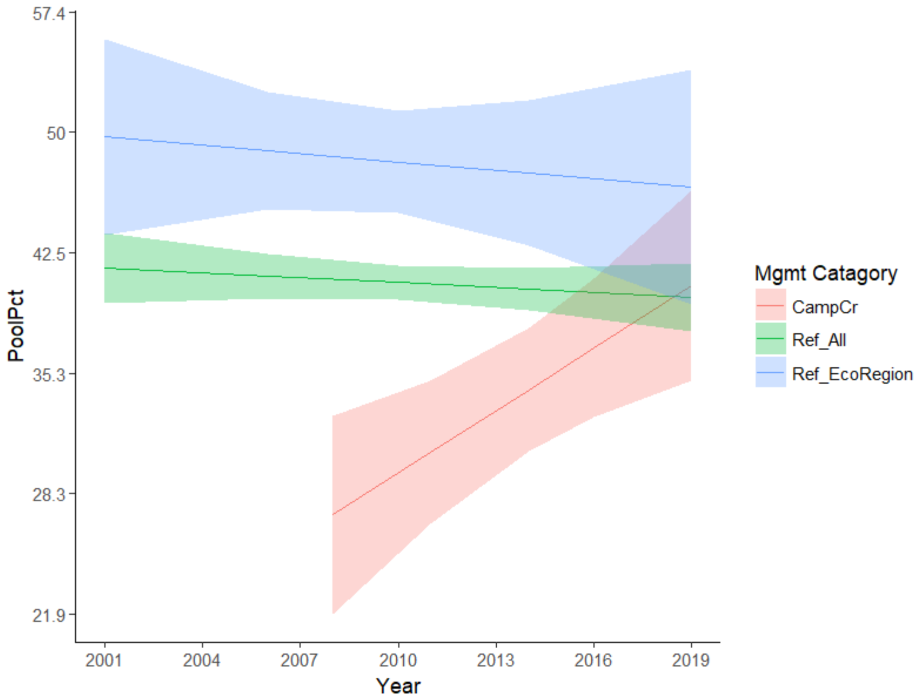

Figure 45. Modeled trend in Pool Percent across Camp and Lick creeks (CampCr) as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

Table 8: P-values for significance tests of year covariates included in regression models used to describe variation in stream measurements. P-values represent the significance of trends in measured stream metrics observed in data collected by the PIBO program since 2001 (with observations made with support by OWEB occurring since 2008). Response variables (i.e., observations of stream metrics) were modeled separately for three groups of sites. P-values for managed sites on Camp and Lick creeks, tributaries to the Middle Fork John Day River (Camp) report the significance of temporal trends at randomly distributed (i.e., integrator) sites identified as "managed sites" in the survey design of the PIBO program. P-values for reference sites that occur in the same ecoregion (EcoRegion reference) as managed sites on the Forest report the significance of temporal trends across this sub-set of randomly distributed reference (i.e., integrator) sites in the Columbia River Basin. P-values for all reference sites that occur throughout the Columbia River Basin (All reference) report the significance of temporal trends across of randomly distributed reference (i.e., integrator) sites in the Columbia River Basin. For more details on the description of site classifications, see accompanying report. Statistical significance is indicated by a "*" and is evaluated for alpha = 0.1.

Metric	**Camp**	**EcoRegion reference**	**All reference**
Overall Index	0.529	0.808	0.932
Vegetated & Stable Banks	0.873	0.773	<0.001*
% Undercut Banks	0.396	0.166	0.024*
Large Wood Frequency	0.009*	0.029*	<0.001*
Bank Angle	0.276	0.395	0.836
PTF <6 mm	0.006*	0.576	0.013*
D50	0.104*	0.105*	0.556
Residual Pool Depth	0.07*	0.565	0.546
% Pool	0.018*	0.615	0.229

Middle Fork John Day IMW – tributaries monitored by PIBO MP

Site selection

Sites included in this section include the Camp & Lick Creek sites from the previous analysis and all other PIBO sites in the Middle Fork John Day River hydrologic unit (Appendix A). This excludes those sites directly on the Middle Fork of the John Day River, as the stream size precludes effective comparison to the PIBO reference network. This adds twelve additional sites to the Camp/Lick group for this IMW analysis. Of these 22 sites, 20 meet the criteria allowing for their inclusion in trend analyses.

Results

IMW Tributaries Status

The 22 sites, distributed across 10 streams, included in the analysis of status in the Middle Fork John Day HUC are listed in Appendix A. Overall, including the additional sites distributed across the M.F. John Day basin yielded similar results as when considering only the 10 sites Camp and Lick creeks in the analysis above. The 22 sites were significantly lower for the Overall Index Score when compared to the PIBO reference sites within the Eco Region and the Columbia River Basin (Figures 46 & 47). However, the mean Overall Index score for all sites in the Middle Fork John Day HUC (Table 9) is higher than the Camp/Lick group by itself (Table 6). These 22 sites were also significantly lower for 4 of the 6 other metrics that are contained in the Overall Index score. Pool percent, residual pool depth, large wood frequency, and bank angle were all significantly lower than at reference sites. In contrast, both median substrate size and pooltail fines >6mm were larger than expected given the stream size, but only pooltail fines >6mm were significantly greater than reference sites. These 22 sites were also significantly lower for the macro invertebrate metric (O/E) (Table 9).

IMW Tributaries Trend

PIBO conducted two separate analyses of trend using the data from the 20 sites (see methods). Traditionally, PIBO has used the data from the first and last visit to evaluate trend at sites. These data are analyzed in their raw, untransformed state using a Wilcoxon signed rank test, a nonparametric statistical test for differences in two samples (see methods section). Results from this analysis are presented in Table 10. The 20 sites were trending significantly in the desired direction for 1 of 8 metrics, large wood frequency. Of note, the positive tendency in pool percent was nearly significant when comparing the first and last sampling occasions, but not in the regression analysis. Although the reason for the difference is not entirely clear, it is likely driven by the use of observations between the first and last visit. In contrast, median substrate size was trending in an undesirable direction (Table 10). This significant trend was also observed with the regression model (see below). This analysis provides a clear picture of conditions during the most recent sampling, relative to initial conditions, and provides unaltered estimates of metric averages that can be used for further reporting and documentation if needed.

As PIBO has now completed three or more sample visits at sites in the MFJD tributaries, the above analysis of trend potentially lacks power to assess trend as only data from two samples are used. Further, the above analysis does not lend itself to graphical displays of trends. Therefore, PIBO also used a linear modeling framework to evaluate trend at these 20 sites through time. Additionally, this analysis is conducted for the PIBO reference network, including a subset of the local ecoregion (see methods section). While this analytical method shows that reference conditions are not static, this results section will speak to these changes only in regard to changes in condition at sites in the Middle Fork John Day HUC. In MFJD tributary sites, there were statistically significant trends in pooltail fines <6mm (Figure 67) and large wood frequency (Figure 65, Table 11). Both pooltail fines <6mm and large wood frequency trended significantly in the same trend as observed for the Wilcoxon sign rank test (Tables 10 & 11). In the regression analysis, median particle size was found to have a nearly significant trend in the same direction as the Wilcoxon sign rank test, where the trend was significant (Tables 10 & 11). Wood frequency was trending upwards, this is also the case in both eco-regional and all reference trends, and the rate of change is commensurate between MFJD tributaries and reference sites (Figure 65). Pooltail fines >6mm trended upwards, a direction often considered undesirable, but the amount of pooltail fines > 6mm at MFJD tributary sites was moving a very distant measure closer to that observed at reference sites (Figure 67). The trend of pooltail fines shows this metric has caught up with reference sites.

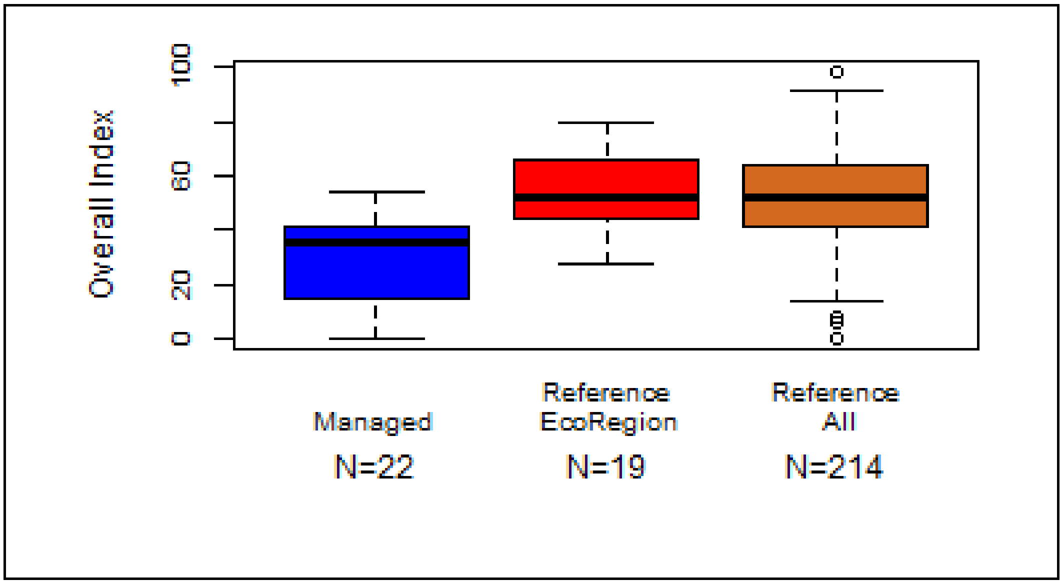

Figure 46. Overall Index values across the MFJD tributaries. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

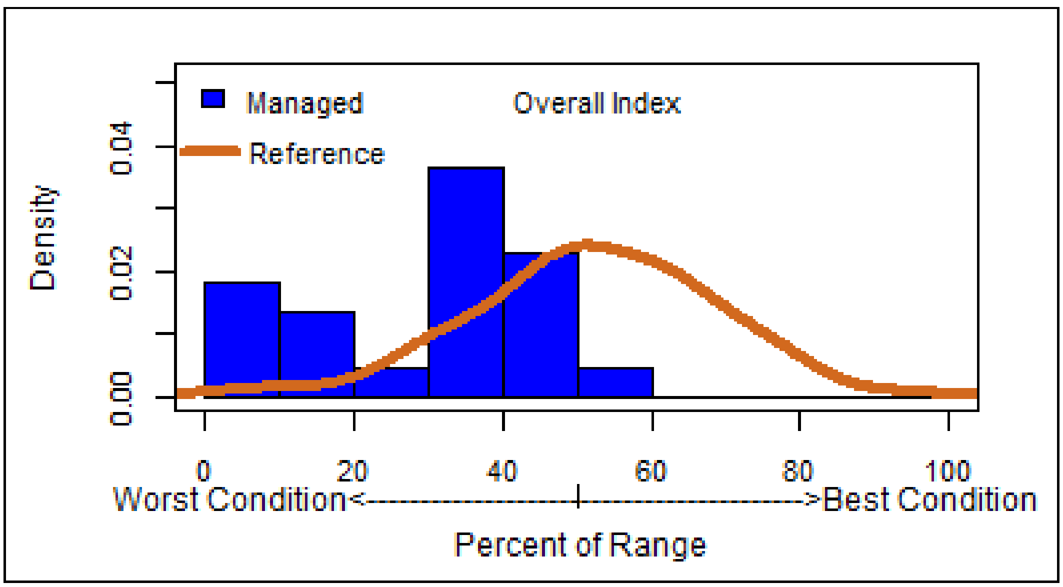

Figure 47. Overall Index values across the MFJD tributaries. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches.

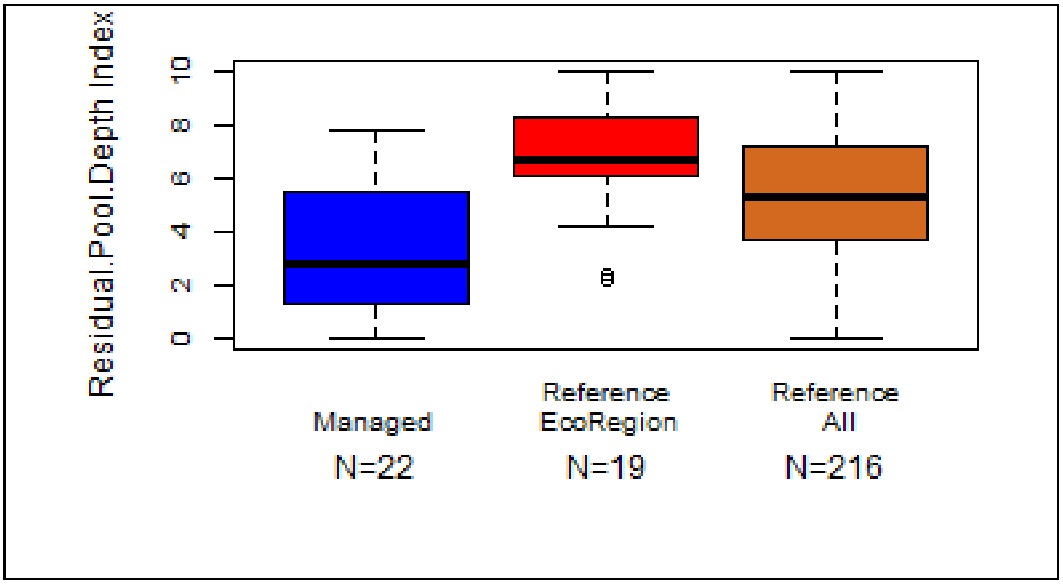

Figure 48. Residual Pool Depth Index values across the MFJD tributaries. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

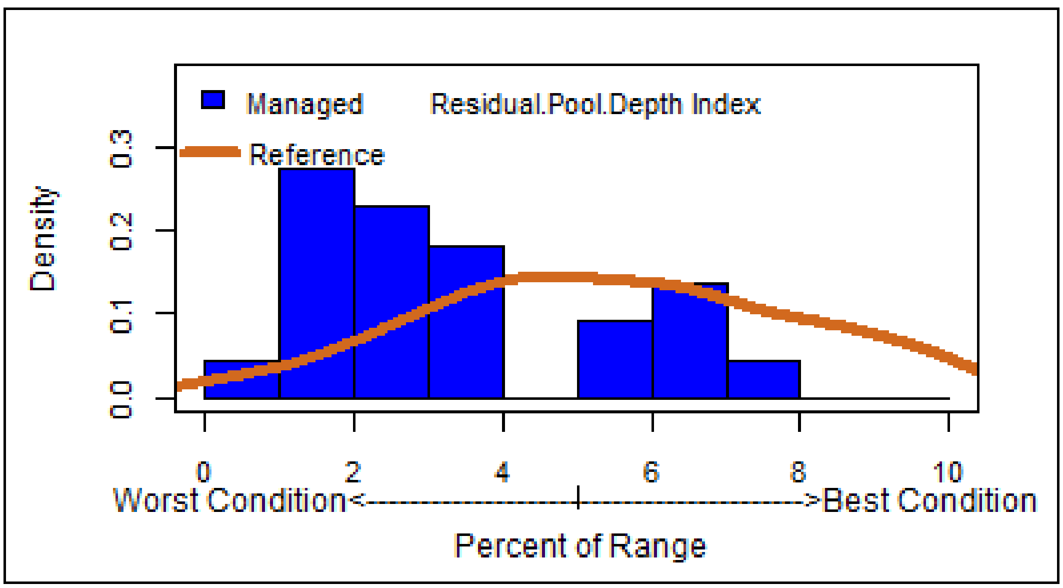

Figure 49. Residual Pool Depth Index values across the MFJD tributaries. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches.

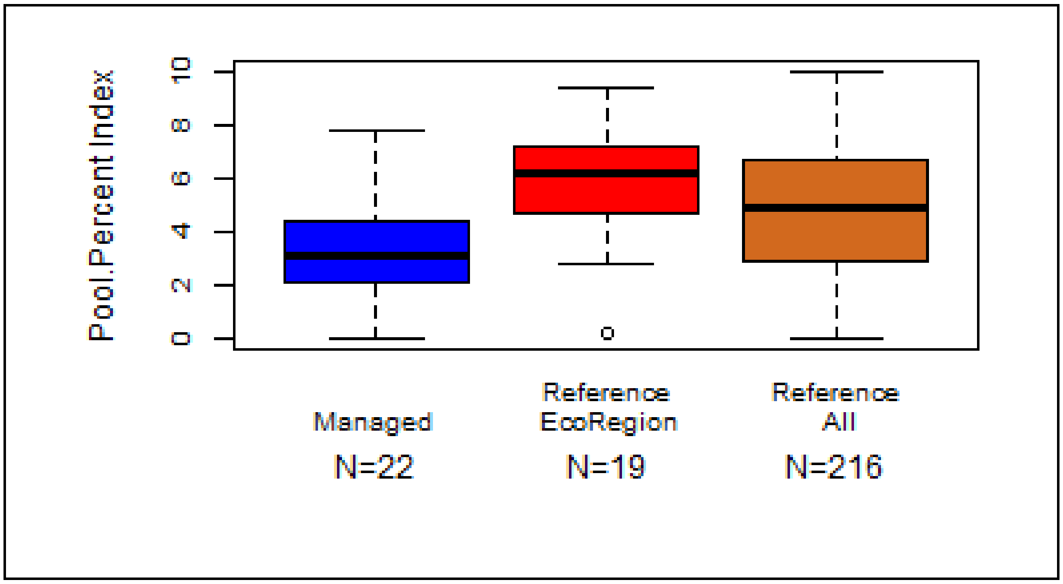

Figure 50. Pool Percent Index values across the MFJD tributaries. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

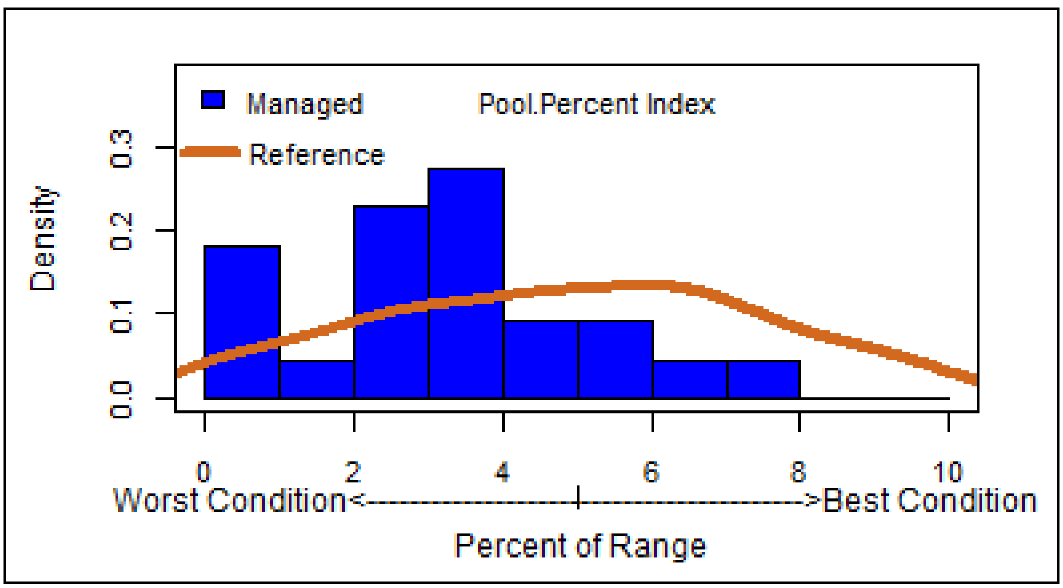

Figure 51. Pool Percent Index values across the MFJD tributaries. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches.

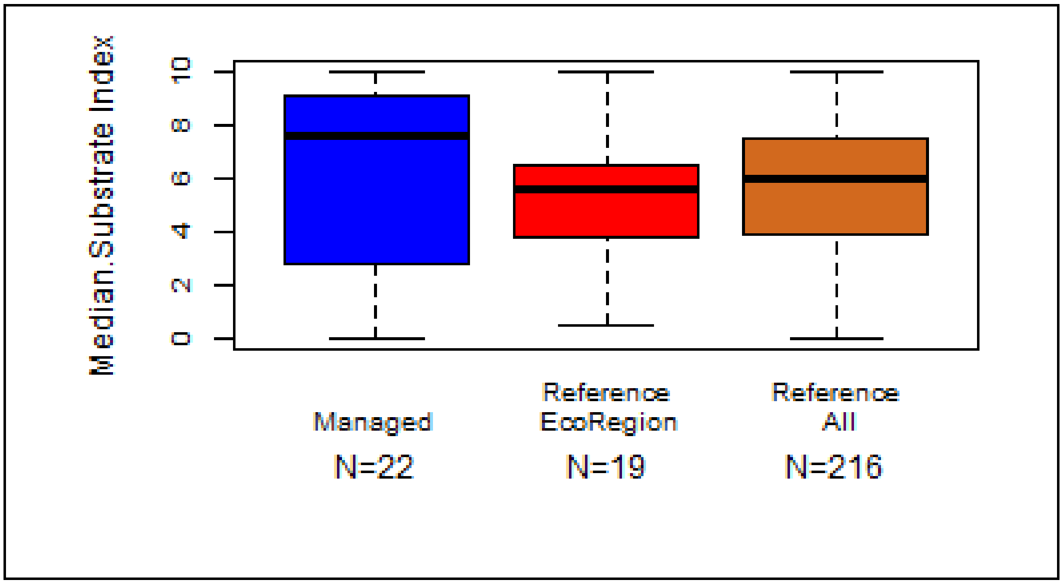

Figure 52. Median substrate Index values across the MFJD Tributaries. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

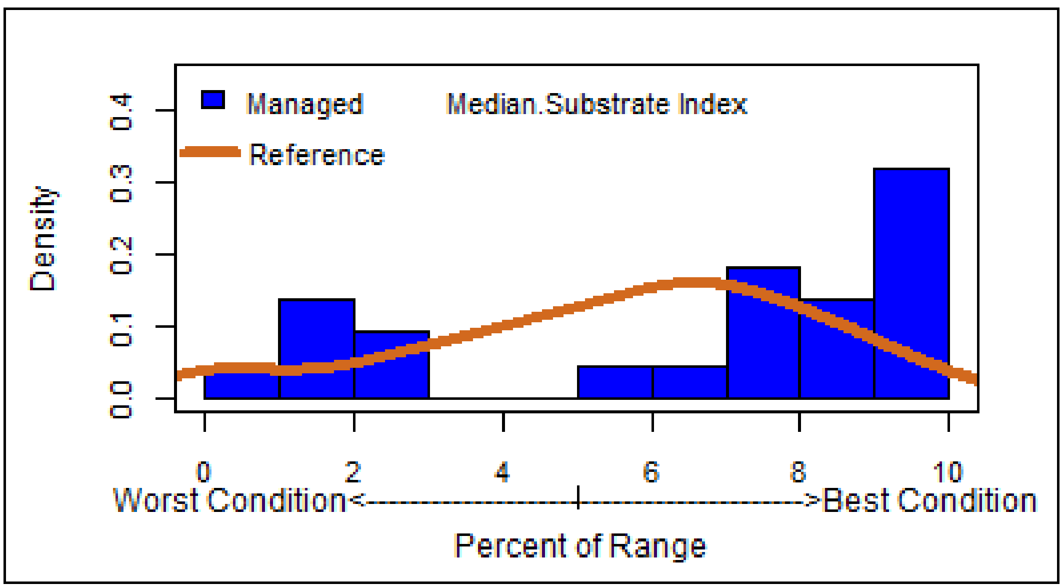

Figure 53. Median substrate Index values across the MFJD Tributaries. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches.

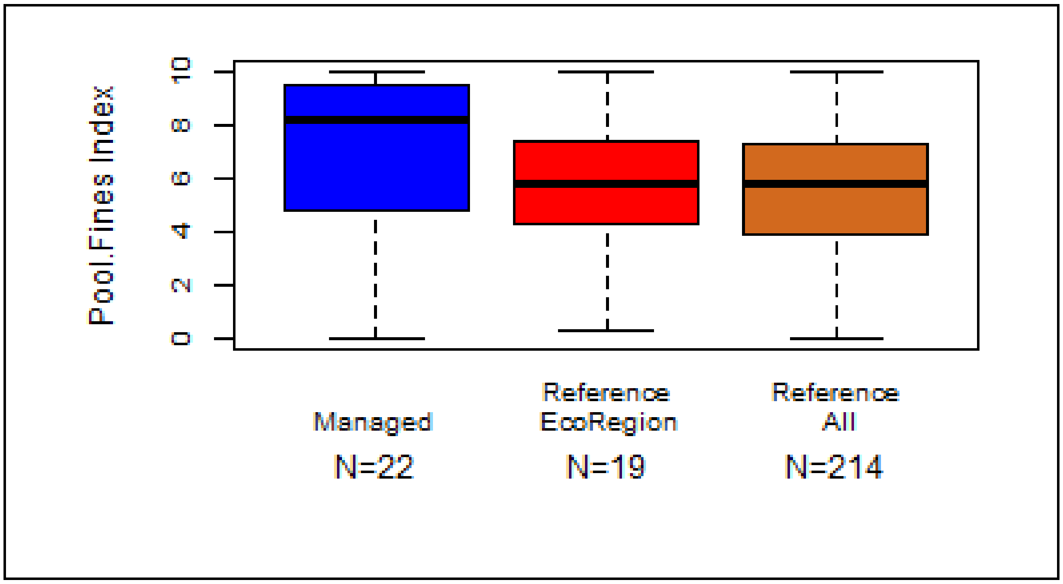

Figure 54. Pool Fines < 6 mm Index values across the MFJD Tributaries. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

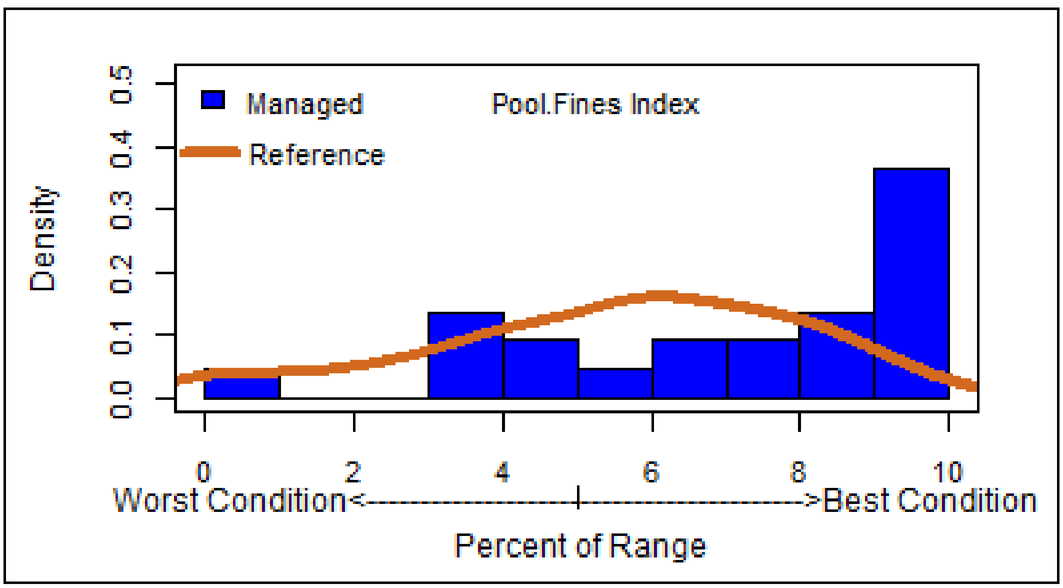

Figure 55. Pool Fines < 6 mm Index values across the MFJD Tributaries. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches.

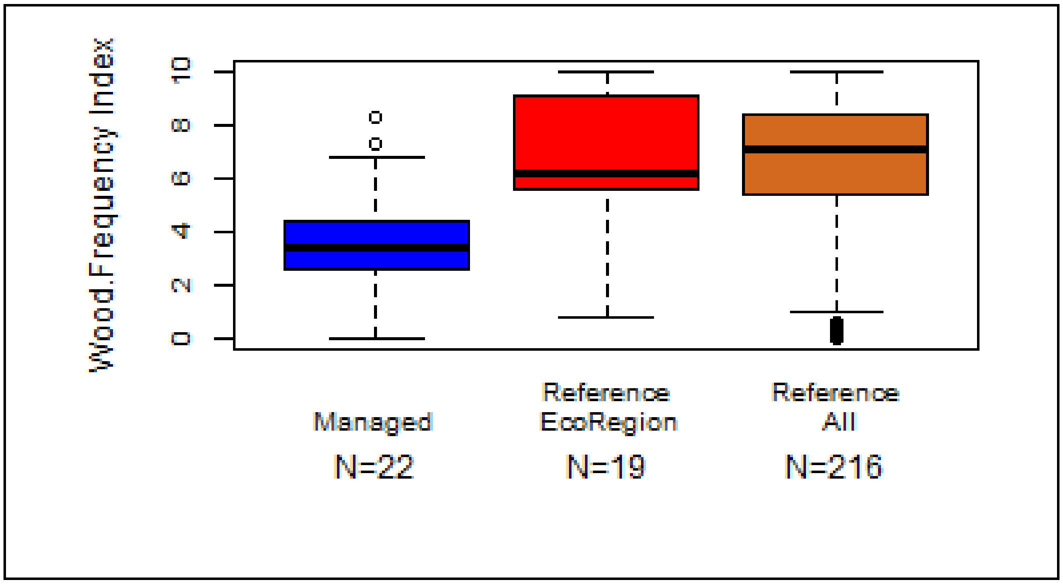

Figure 56. Wood Frequency Index values across the MFJD Tributaries. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

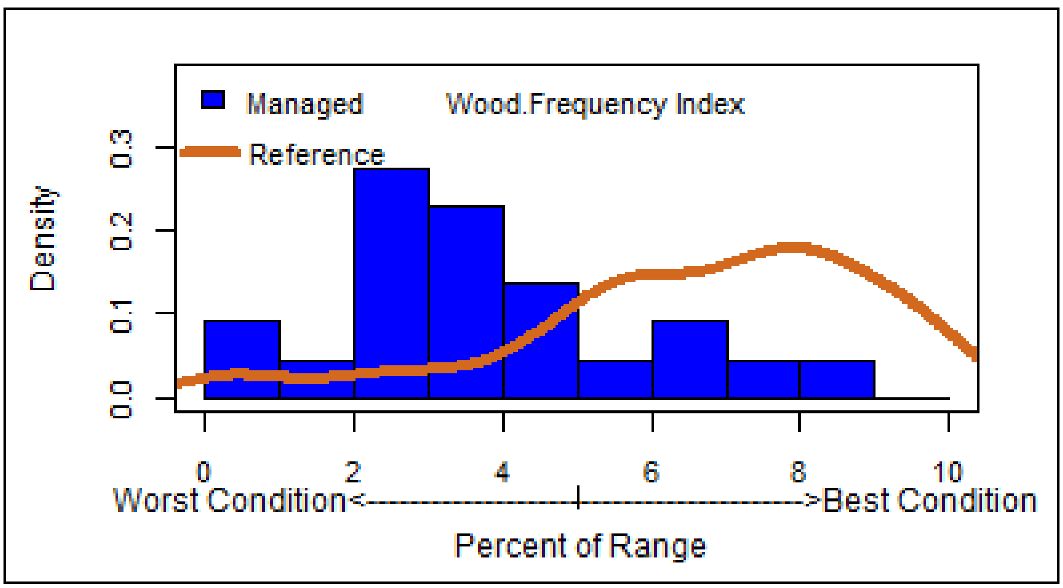

Figure 57. Wood Frequency Index values across the MFJD Tributaries. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches.

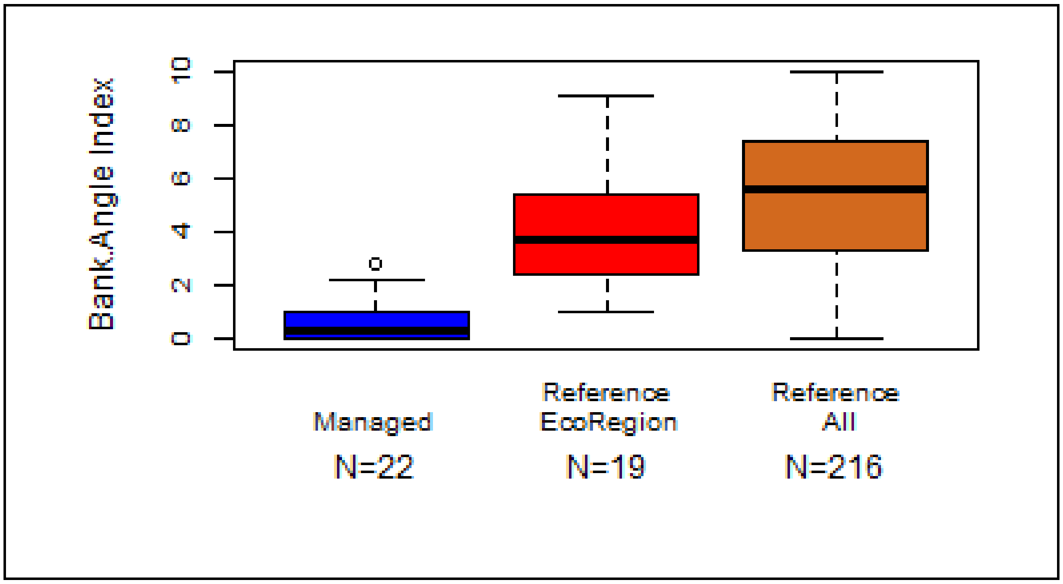

Figure 58. Bank Angle Index values across the MFJD Tributaries. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

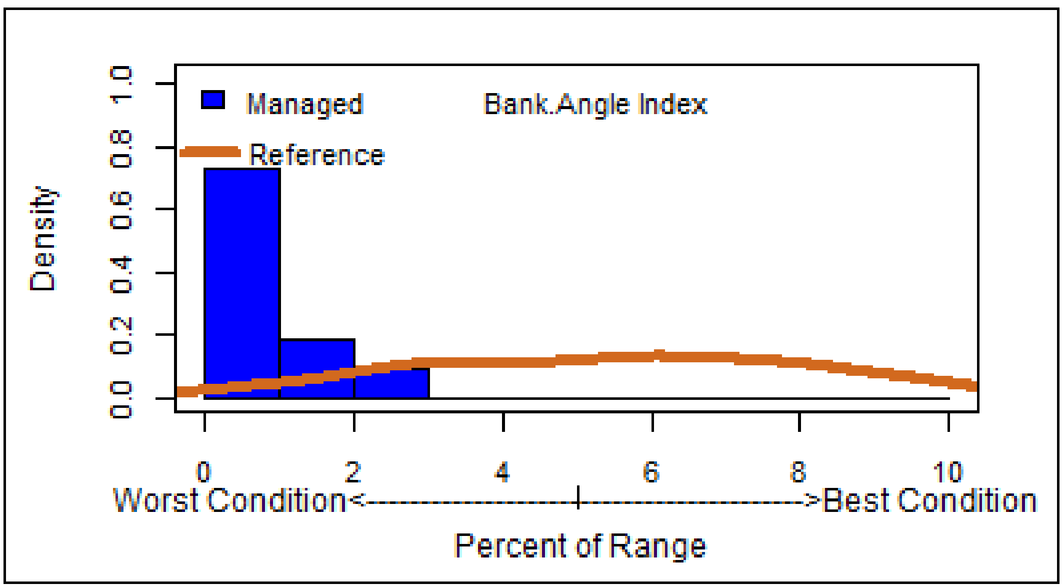

Figure 59. Bank Angle Index values across the MFJD Tributaries. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches.

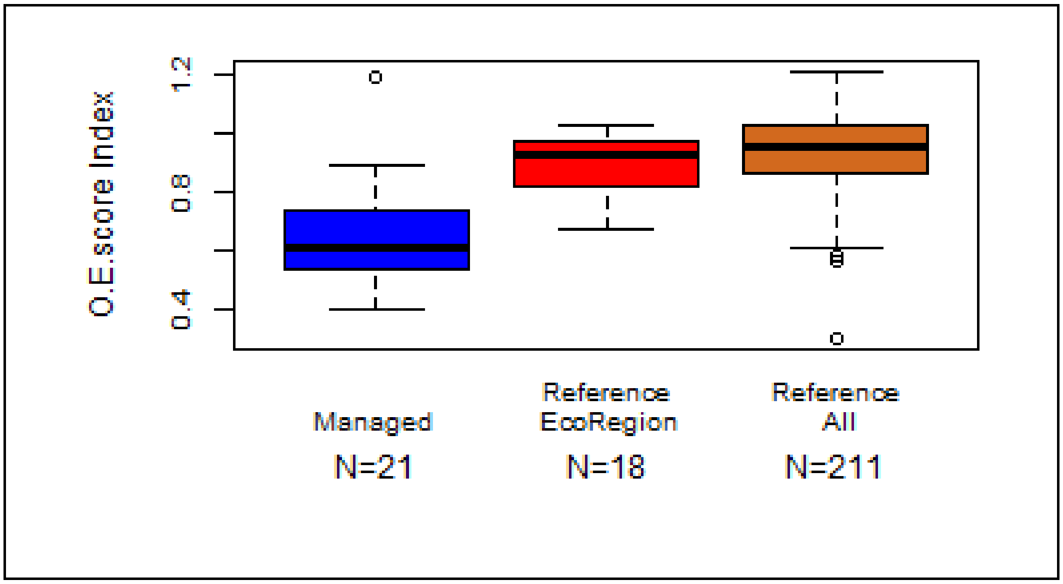

Figure 15. O/E Macroinvertebrate score Index values across the MFJD tributaries. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

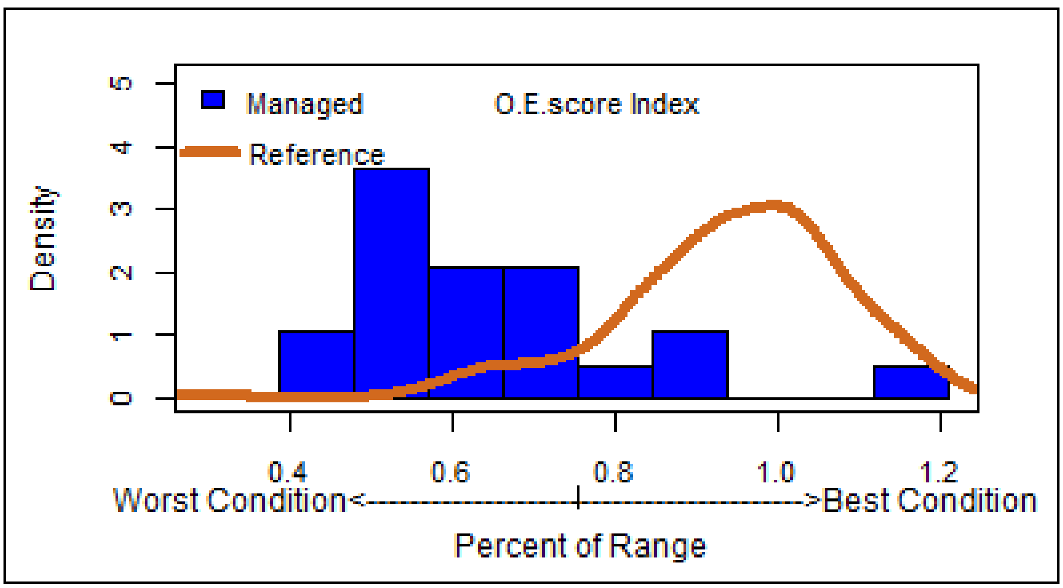

Figure 16. O/E Macroinvertebrate score Index values across the MFJD tributaries. Distribution of index values for managed reaches (histogram) compared to expected values at reference reaches (the line graph). Close matches between histogram height and line indicate conditions are similar at managed and reference reaches. This includes macroinvertebrate samples through 2019.

Table 9. Summary of Index Scores-- MFJD Tributaries; N=sample size, p-value=significance (0.1), sd=standard deviation, ci=95% confidence interval. Macroinvertebrate (O.E.) data represented in this table include samples collected through 2019.

InterestArea	Metric	Indexscore	N	pvalue	sd	ci
Managed	Overall	30.24	22	NA	16.16	5.93
Reference Local	Overall	NA	<3	NA	NA	NA
Reference Eco Region	Overall	54.36	19	p<0.01	15.92	6.34
Reference All	Overall	52.18	214	p<0.01	16.55	1.87
Managed	Residual.Pool.Depth	3.31	22	NA	2.23	0.82
Reference Local	Residual.Pool.Depth	NA	<3	NA	NA	NA
Reference Eco Region	Residual.Pool.Depth	6.7	19	p<0.01	2.19	0.87
Reference All	Residual.Pool.Depth	5.44	216	p<0.01	2.45	0.28
Managed	Pool.Percent	3.24	22	NA	2.07	0.76
Reference Local	Pool.Percent	NA	<3	NA	NA	NA
Reference Eco Region	Pool.Percent	5.69	19	p<0.01	2.23	0.89
Reference All	Pool.Percent	4.87	216	p<0.01	2.58	0.29
Managed	Median.Substrate	6.58	22	NA	3.41	1.25
Reference Local	Median.Substrate	NA	<3	NA	NA	NA
Reference Eco Region	Median.Substrate	5.36	19	0.173	2.15	0.86
Reference All	Median.Substrate	5.59	216	0.198	2.54	0.29
Managed	Pool.Fines	7.13	22	NA	2.82	1.03
Reference Local	Pool.Fines	NA	<3	NA	NA	NA
Reference Eco Region	Pool.Fines	5.63	19	0.073	2.42	0.96
Reference All	Pool.Fines	5.49	214	0.015	2.46	0.28
Managed	Wood.Frequency	3.68	22	NA	2.14	0.79
Reference Local	Wood.Frequency	NA	<3	NA	NA	NA
Reference Eco Region	Wood.Frequency	6.91	19	p<0.01	2.36	0.94
Reference All	Wood.Frequency	6.61	216	p<0.01	2.4	0.27
Managed	Bank.Angle	0.67	22	NA	0.79	0.29
Reference Local	Bank.Angle	NA	<3	NA	NA	NA
Reference Eco Region	Bank.Angle	4.2	19	p<0.01	2.26	0.9
Reference All	Bank.Angle	5.44	216	p<0.01	2.57	0.29
Managed	O.E.score	0.65	21	NA	0.18	0.07
Reference Local	O.E.score	NA	<3	NA	NA	NA
Reference Eco Region	O.E.score	0.9	18	p<0.01	0.12	0.05
Reference All	O.E.score	0.95	210	p<0.01	0.14	0.02

Trend: Comparison of First and Last Sample Dates for MFJD Tributaries

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Table 10 .Trend in stream habitat attributes across the MFJD tributaries including: Overall_Index score, O.E. (Observed/Expected macroinvertebrate score), VegStab (bank stability), UnCutPct (percent undercut banks), LWFrq (large wood frequency), Bank Angle, PTFines6 (percent fines in pool tails), D50 (median substrate size), RPD (residual pool depth), and PoolPct (percent pools). Refer to page 5 of methods (Heading: 'Summary Tables') for further explanation. Time1 = mean during first visit; Time2 = mean value for last visit; Percent Change = Percent change in the mean values between the first and last visit; Sample size = number of observations with repeat visits; Negative Number = Number of sites where actual measurement was lower on last visit; Positive Number = Number of sites where actual measurement was higher in last visit; None Number = Number of sites where last visit and first visit values were equal; P-value = Significance test; Desired Direction = direction of change in the mean, which can be either + or -; Actual Change = actual direction of change in the mean, which can be either +, -, or not significant (NS). Macroinvertebrate (O.E.) data represented in this table include samples collected through 2019

Metric	Time1 Value	Time2 Value	Percent Change	Sample Size	Negative Number	Positive Number	None Number	P-value	Desired Direction	Actual Change
Overall_Index	28.24	30.69	8.6	20	7	13	0	0.351	+	NS
O.E.	0.67	0.61	-9.7	20	12	8	0	0.313	+	NS
VegStab	84.98	82.83	-2.5	20	12	7	1	0.629	+	NS
UnCutPct	12.56	15.1	20.2	20	9	11	0	0.247	+	NS
LWFrq	96.04	161.2	67.8	20	5	15	0	0.008	+	+
BankAngle	133.5	131.2	-1.7	20	11	9	0	0.239	-	NS
PTFines6	7.2	23.62	228	20	8	12	0	0.126	-	NS
D50	0.069	0.0617	-10.6	20	14	6	0	0.067	+	-
RPD	0.23	0.25	6.1	20	7	13	0	0.179	+	NS
PoolPct	33.5	38.85	16	20	7	13	0	0.108	+	NS

Trend: Linear Modeling of Trends in Habitat Metrics for MFJD Tributaries

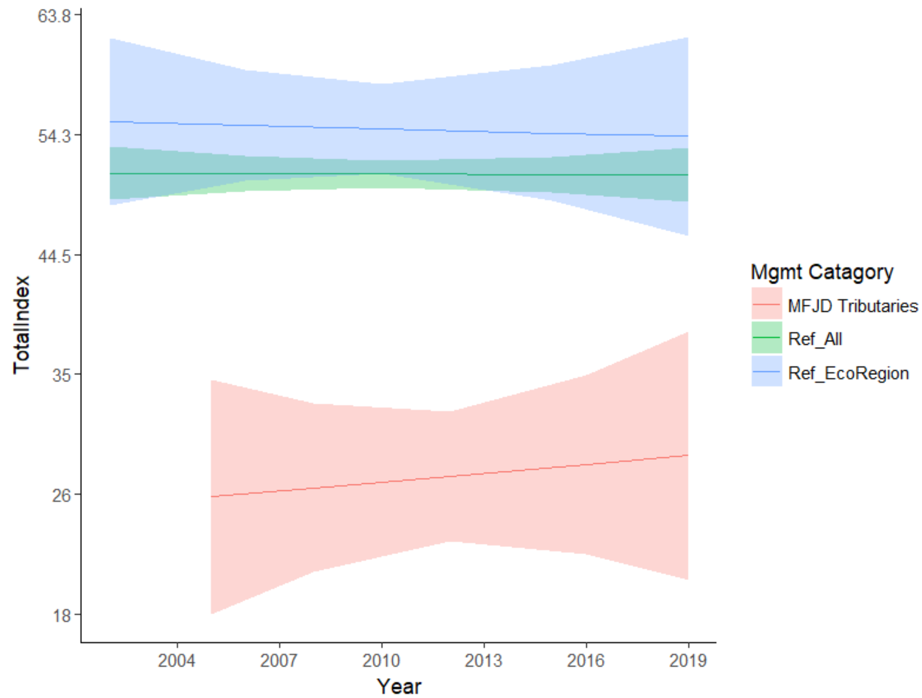

Figure 62. Modeled trend in Overall Index Score (labeled TotalIndex) across the MFJD tributaries as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

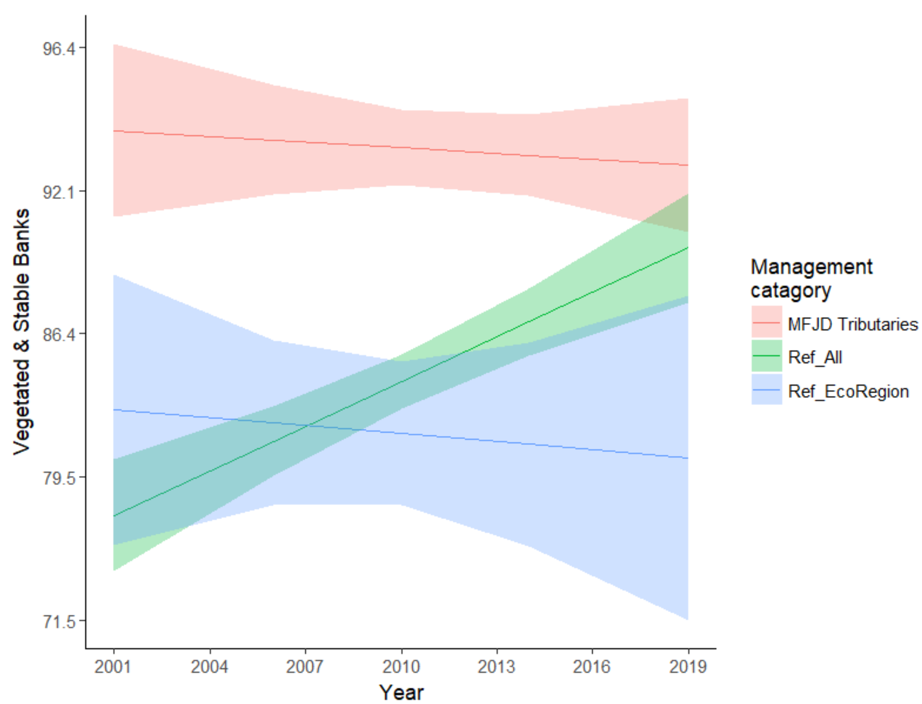

Figure 63. Modeled trend in Vegetative Bank Stability across the MFJD tributaries as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

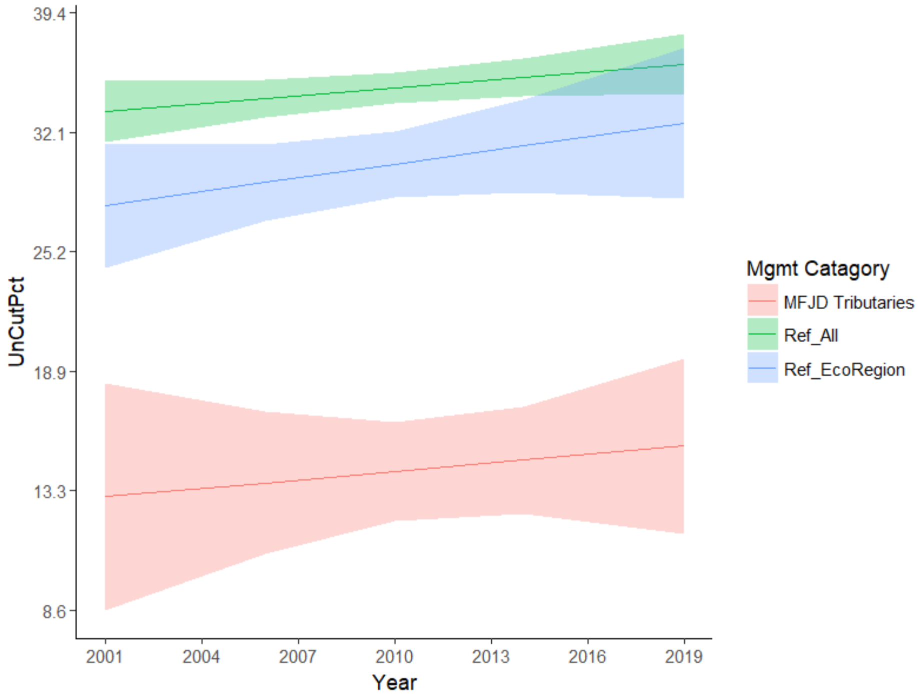

Figure 64. Modeled trend in Undercut Percent across the MFJD tributaries as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

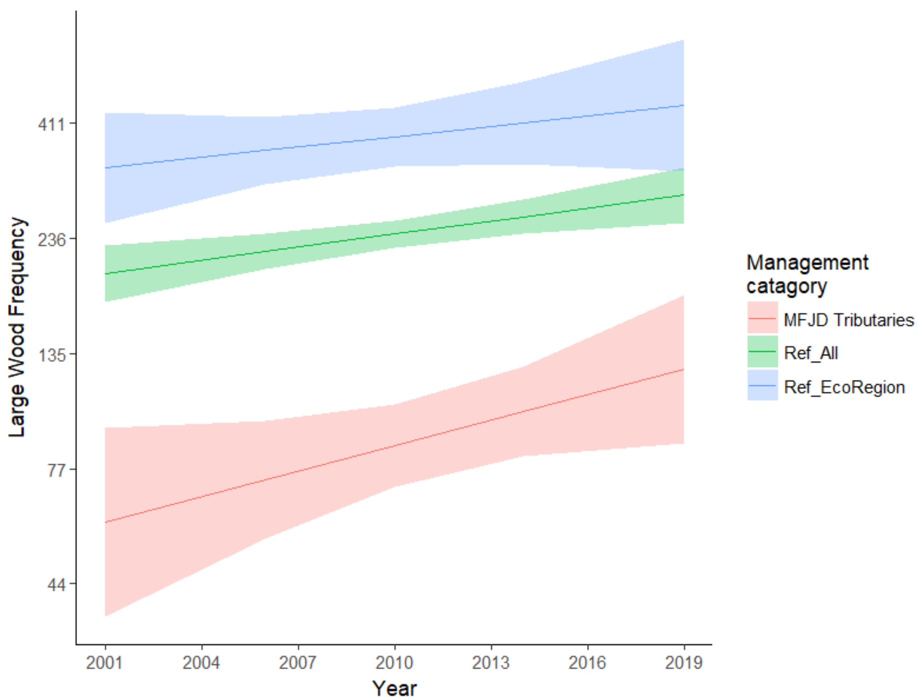

Figure 65. Modeled trend in Large Wood Frequency across the MFJD tributaries as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

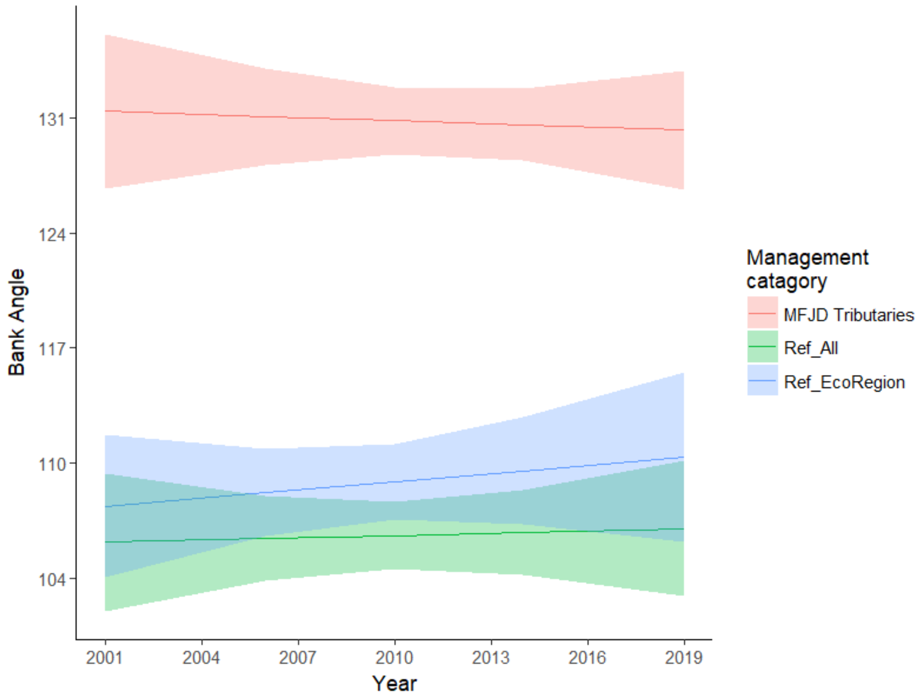

Figure 66. Modeled trend in Bank Angle across the MFJD tributaries as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

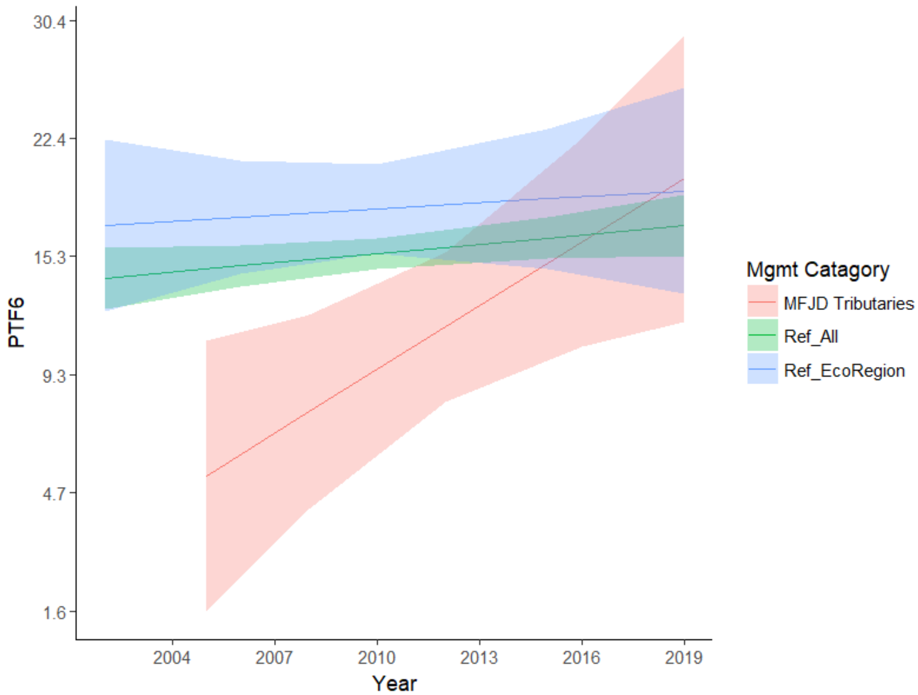

Figure 67. Modeled trend in Pooltail Fines >6mm across the MFJD tributaries as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

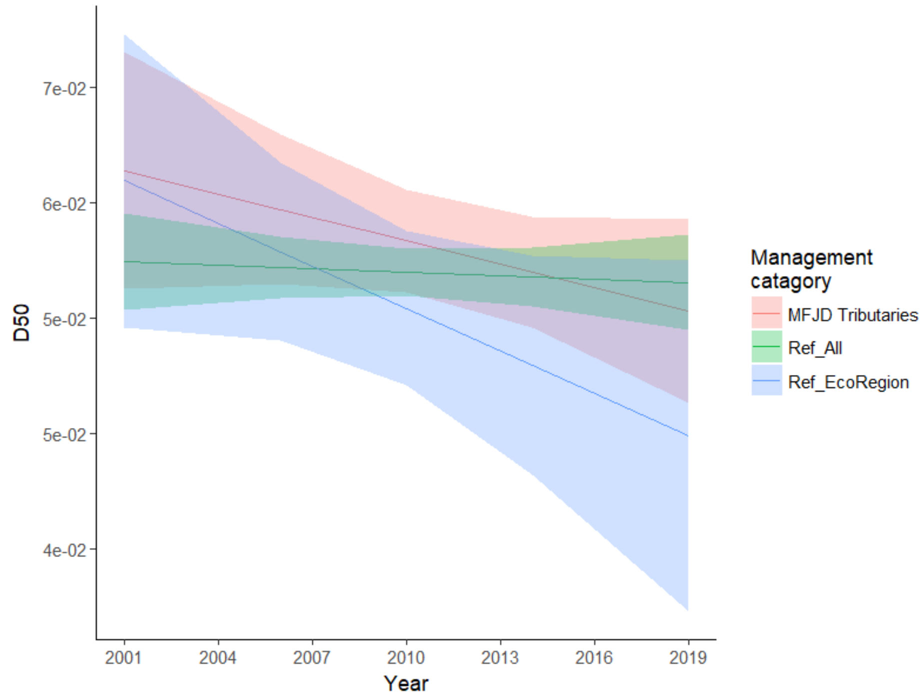

Figure 68. Modeled trend in Median Particle Size across the MFJD tributaries as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green

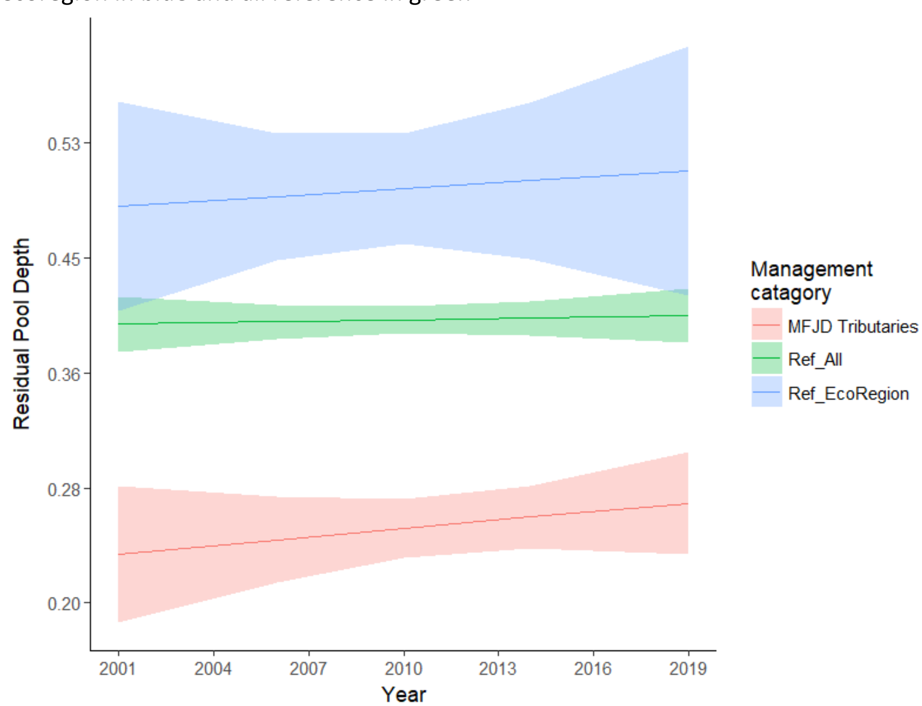

Figure 69. Modeled trend in Residual Pool Depth across the MFJD tributaries as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

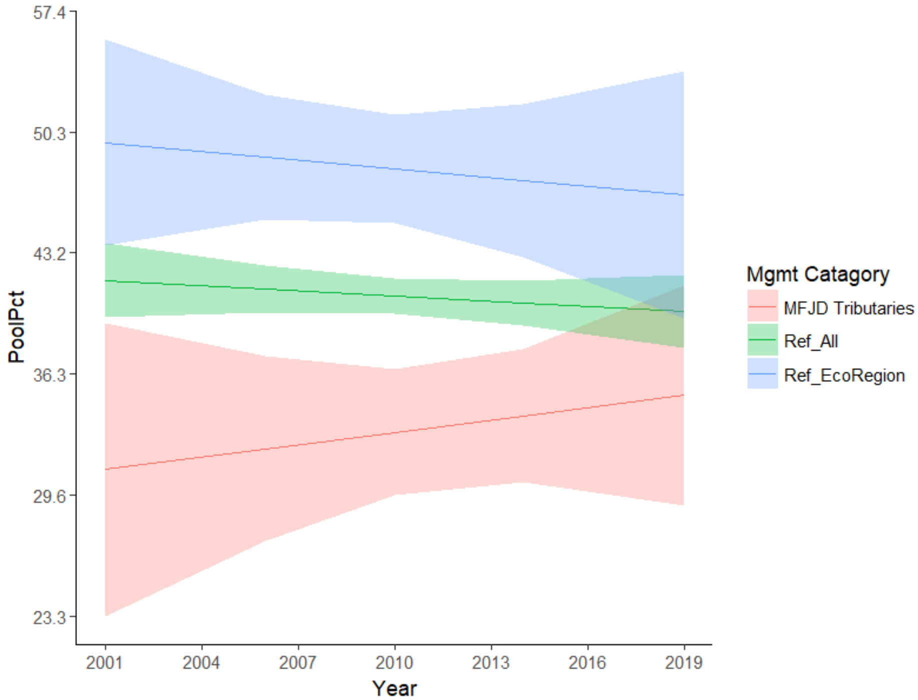

Figure 70. Modeled trend in Pool Percent across the MFJD tributaries as a solid red line. Shaded portion represents the 90% confidence interval. Modeled trend in reference sites are included for comparison with local ecoregion in blue and all reference in green.

Table 11: P-values for significance tests of year covariates included in regression models used to describe variation in stream measurements. P-values represent the significance of trends in measured stream metrics observed in data collected by the PIBO program since 2001 (with observations made with support by OWEB occurring since 2008). Response variables (i.e., observations of stream metrics) were modeled separately for three groups of sites. P-values for managed sites on MFJD tributaries report the significance of temporal trends at randomly distributed (i.e., integrator) sites identified as "managed sites" in the survey design of the PIBO program. P-values for reference sites that occur in the same ecoregion (EcoRegion reference) as managed sites on the Forest report the significance of temporal trends across this sub-set of randomly distributed reference (i.e., integrator) sites in the Columbia River Basin. P-values for all reference sites that occur throughout the Columbia River Basin (All reference) report the significance of temporal trends across of randomly distributed reference (i.e., integrator) sites in the Columbia River Basin. For more details on the description of site classifications, see accompanying report. Statistical significance is indicated with a "*" and is evaluated for alpha = 0.1.

Metric	**Camp**	**EcoRegion reference**	**All reference**
Overall Index	0.596	0.808	0.932
Vegetated & Stable Banks	0.653	0.773	<0.001*
% Undercut Banks	0.584	0.166	0.024*
Large Wood Frequency	0.038*	0.029*	<0.001*
Bank Angle	0.779	0.395	0.836
PTF <6 mm	0.024*	0.576	0.013*
D50	0.109	0.105	0.556
Residual Pool Depth	0.316	0.565	0.546
% Pool	0.564	0.615	0.229

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Appendix A

List of sites included in this report from within the Middle Fork of the John Day Intensively Monitored Watershed. The column *Included* will indicate why these sites are relevant to and in what section of the report these sites will be featured.

Site ID	Site Name	Included	Stream	Latitude	Longitude	First Sampled
1013	154-02-I	Watershed Site	Squaw	44.571842	-118.402566	2001
1014	154-03-I	Watershed Site	Vinegar	44.605140	-118.529685	2001
1016	154-07-I	Watershed Site	Bridge	44.585431	-118.509592	2001
1474	153-01-I	Watershed Site	S.F. Long	44.627600	-118.983274	2005
1479	153-05-I	Watershed Site	Slide	44.732699	-118.959509	2005
1480	153-17-I	Watershed Site	Indian	44.843803	-118.853947	2005
1551	153-02-I	Watershed Site	Long	44.677707	-118.953528	2005
1554	153-12-I	Watershed Site	Deadwood	44.766619	-118.791325	2005
1888	154-09-I	Watershed Site	Camp	44.653021	-118.826908	2006
1889	154-11-I	Watershed Site	Big Boulder	44.681811	-118.711309	2006
2033	154-02-R	Watershed Site	Olmstead	44.532692	-118.384713	2006
2636	518-01-I	Camp/Lick	Camp (C1)	44.688871	-118.797155	2008
2637	518-02-I	Camp/Lick	Camp (C2)	44.686667	-118.797258	2008
2638	518-03-I	Camp/Lick	Camp (C3)	44.671174	-118.802465	2008
2639	518-04-I	Camp/Lick	Camp (C6)	44.662188	-118.813261	2008
2640	518-05-I	Camp/Lick	Camp (C14)	44.644153	-118.837982	2008
2641	518-06-I	Camp/Lick	Camp (C18)	44.633394	-118.845772	2008
2642	518-07-I	Camp/Lick	Camp (C25)	44.595340	-118.872088	2008
2643	518-08-I	Camp/Lick	Camp (C28)	44.586149	-118.870718	2008
2644	518-09-I	Camp/Lick	Lick (L2)	44.660151	-118.807456	2008
2645	518-10-I	Camp/Lick	Lick (L4)	44.652811	-118.801694	2008
2858	522-01-I	Middle Fork Site	MFJDPIBO-001	44.682270	-118.767714	2009
2859	522-02-I	Middle Fork Site	MFJDPIBO-002	44.678132	-118.760634	2009
2860	522-03-I	Middle Fork Site	MFJDPIBO-003	44.675036	-118.748423	2009
2861	522-04-I	Middle Fork Site	MFJDPIBO-004	44.594695	-118.517027	2009
2862	522-05-I	Middle Fork Site	MFJDPIBO-005	44.592453	-118.513149	2009
2863	522-06-I	Middle Fork Site	MFJDPIBO-006	44.605452	-118.541614	2009
2864	522-07-I	Middle Fork Site	MFJDPIBO-007	44.653256	-118.680166	2009
2865	522-08-I	Middle Fork Site	MFJDPIBO-215	44.629923	-118.595841	2009
2866	522-20-I	Middle Fork Site	MFJDPIBO-102	44.658649	-118.684961	2009
2867	522-26-I	Middle Fork Site	MFJDPIBO-105	44.594340	-118.453240	2009
2869	522-12-I	Middle Fork Site	MFJDPIBO-115	44.621822	-118.581562	2009
2871	522-14-I	Middle Fork Site	MFJDPIBO-305	44.629634	-118.599551	2009
2872	522-15-I	Middle Fork Site	MFJDPIBO-308	44.760286	-118.866071	2009

2873	522-16-I	Middle Fork Site	MFJDPIBO-310	44.730557	-118.840090	2009
2874	522-17-I	Middle Fork Site	MFJDPIBO-312	44.693005	-118.798822	2009
3310	527-03-I	Watershed Site	W.F. Lick	44.605931	-118.790039	2012