**2011-2015 CHaMP Metric Status and Trend**

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**3/10/2016**

**Introduction**

Five years of CHaMP sampling have been completed, and we here present a summary of analysis methodology and select example results for status and trend at the watershed spatial scale. We necessarily cannot present here status and trend results for all metrics, in all CHaMP watersheds, at all spatial scales. Complete results are available at <https://isemp.egnyte.com/dl/USOtBj9AIJ>. Requests for status and trend estimates for additional metrics, and/or spatial domains not included, may be made to South Fork Research (contact Matt Nahorniak at matt@southforkresearch.org).

**Methods**

CHaMP sampling designs incorporate spatially balanced, stratified random sampling, where (in most CHaMP watersheds) strata are defined as combinations of valley class (source, transport, or depositional) and ownership type (public or private). Within each stratum, equally probable, spatially balanced sampling is done. Sample inclusion probability may vary across the different strata.

Spatial balance in sample design is achieved via use of a Generalized Random Tessellation Stratified (GRTS) sample selection algorithm (Stevens and Olsen, 2004). In sampling of a spatial resource, sample points very close to each other tend to be more alike (spatially correlated), thus there is limited additional information content added to a sample when, for example, a 2nd sample point occurs very close to an existing sample point. A spatially balanced sample tends to spread out the sample points more uniformly across space, increasing the amount of independent information present in each individual sample point. GRTS sampling, specifically, provides a spatially balanced sample while also maintaining the robust sample properties of simple random sampling. The spsurvey package (Kincaid and Olsen, 2013) for the R statistical programming language is used to analyze status and trend for GRTS sampling performed by CHaMP. Spsurvey elegantly incorporate sample design into the analysis, and properly accounts for the GRTS sampling design and spatial autocorrelation estimates in the variance estimates.

For CHaMP data analysis, we define status as the distribution of a CHaMP metric over a specified spatial domain and time range. For spatial domain, we here present selected results at the watershed level. However, status can also be defined at sub watershed levels (HUC5 within a watershed, individual tributary creeks, etc.) or across multiple watersheds (i.e. the entire interior Columbia basin covered by CHaMP sampling). Time ranges considered may include individual years, as well as time averaged status over each year completed thus far in CHaMP sampling (2011-2015). When estimating status over multiple years, we first average the metric of interest at the site level to obtain a single average response at each site over the time period of interest, then analyze the data using spsurvey using the single average response for each site.

Trend is defined as the average of site level linear trend over time, for a give metric, over a specified spatial domain. Currently we have five years of data. For sites sampled annually, we typically have five visit year measurements – one for each year. For three year rotating panel sites, we have either one or two visit year measurements per sites. For all sites that contain more than one visit year, we can estimate a linear trend by regressing the metric as measured at each site against time (in years). Note that, at the site level, there is high uncertainty in a trend estimate made from a regression of either 2 or 4 data points. These individual site level trend estimates are then analyzed using spsurvey, just as is done for status, as described above, to estimate a distribution of trends across the spatial domain of interest.

Extreme caution should be applied when interpreting estimates of trend, given that only five years of data are available. Small year to year differences may show up as trends, but in reality these “trends” may only reflect short term aberrations year to year, rather than long term linear changes. With only five years’ of data, it is not possible to distinguish short term year-year aberrations from long term trends. Thus, any statistically significant trend observed to date should merely be interpreted as a significant difference across the five years sampled thus far, and should not be interpreted as a likely indication of future trends or used to predict future status. After a full nine years’ worth of CHaMP sampling have been completed, we will have a significantly better ability to distinguish long term trends from year-year aberrations.

**Results**

Example results for the five year average status and trend, for selected CHaMP metrics in the Wenatchee watershed, are shown in Table 1. Non-zero trends (likely to be year-year aberrations rather than long term linear trends) are highlighted in blue. Results for all watersheds are included at cm.org.

**Table 1. Status and trend estimates for selected CHaMP metrics in the Wenatchee watershed. Full results are available at** [**https://isemp.egnyte.com/dl/USOtBj9AIJ**](https://isemp.egnyte.com/dl/USOtBj9AIJ)**.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Metric** | **N** | **Status** | | | **Trend** | | |
| **Mean** | **95% LCB** | **95% UCB** | **Trend** | **95% LCB** | **95% UCB** |
| Alkalinity | 55 | 58.05 | 49.62 | 66.49 | -0.90 | -8.44 | 6.64 |
| Bankfull Depth Avg | 52 | 0.48 | 0.41 | 0.56 | 0.02 | -0.01 | 0.04 |
| Bankfull Width Avg | 51 | 12.41 | 9.62 | 15.20 | 0.67 | -0.29 | 1.62 |
| Discharge | 54 | 1.63 | 1.24 | 2.03 | -0.12 | -0.48 | 0.24 |
| Fast NonTurbulent Percent | 52 | 13.69 | 9.54 | 17.84 | -0.79 | -1.64 | 0.07 |
| Fish Cover: Artificial | 52 | 0.21 | 0.02 | 0.41 | 0.02 | -0.02 | 0.05 |
| Gradient | 52 | 2.66 | 2.05 | 3.28 | 0.03 | -0.01 | 0.07 |
| Large Wood Frequency: Bankfull | 52 | 33.29 | 27.06 | 39.52 | 0.84 | -2.23 | 3.91 |
| Large Wood Frequency: Wetted | 52 | 19.80 | 16.42 | 23.18 | 0.41 | -1.51 | 2.33 |
| Residual Pool Depth | 50 | 0.49 | 0.37 | 0.60 | 0.00 | -0.03 | 0.04 |
| Sinuosity | 52 | 1.23 | 1.18 | 1.28 | 0.01 | 0.00 | 0.01 |
| Slow Water Frequency | 52 | 3.86 | 2.73 | 4.98 | 0.33 | 0.19 | 0.47 |
| Slow Water Percent | 52 | 29.66 | 24.92 | 34.41 | 0.93 | -1.43 | 3.29 |
| Substrate < 2mm | 48 | 17.93 | 13.84 | 22.03 | -0.31 | -2.83 | 2.22 |
| Substrate < 6mm | 48 | 29.89 | 22.30 | 37.49 | -1.70 | -7.86 | 4.47 |
| Substrate Est: Boulders | 52 | 10.15 | 7.32 | 12.97 | -0.48 | -1.63 | 0.68 |
| Substrate Est: Coarse and Fine Gravel | 52 | 40.73 | 36.35 | 45.12 | -1.02 | -4.04 | 2.00 |
| Substrate Est: Cobbles | 52 | 22.21 | 18.09 | 26.33 | 0.52 | -1.05 | 2.09 |
| Substrate Est: Sand and Fines | 52 | 25.48 | 20.85 | 30.12 | 0.96 | -2.84 | 4.76 |
| Substrate: D50 | 55 | 45.25 | 35.10 | 55.40 | -0.05 | -4.17 | 4.07 |
| Substrate: D84 | 55 | 124.55 | 100.32 | 148.79 | 2.75 | -4.12 | 9.62 |
| Thalweg Depth Avg | 52 | 0.41 | 0.33 | 0.48 | -0.01 | -0.02 | -0.01 |
| Thalweg Site Length | 52 | 263.98 | 220.68 | 307.27 | 4.08 | -0.46 | 8.62 |
| Wetted Depth SD | 52 | 0.17 | 0.14 | 0.20 | -0.01 | -0.01 | 0.00 |
| Fish Cover: Aquatic Vegetation | 48 | 0.86 | 0.51 | 1.22 | 0.07 | -0.45 | 0.59 |
| Percent Undercut by Area | 48 | 1.75 | 0.78 | 2.73 | 0.18 | -0.46 | 0.82 |
| Substrate: Embeddedness Avg | 46 | 9.27 | 6.25 | 12.28 | 0.95 | -0.28 | 2.17 |
| Substrate: Embeddedness SD | 46 | 10.37 | 7.96 | 12.77 | 0.24 | -1.07 | 1.54 |
| Percent Undercut by Length | 44 | 4.87 | 2.32 | 7.43 | 0.60 | 0.02 | 1.18 |

Results in Table 1 for status represent the five year average status for each CHaMP metric at within the Wenatchee watershed.

Results are also summarized for individual years, and within individual watersheds. Detailed results for Large Wood Frequency, Wetted, by year and by watershed (for select watersheds) are displayed by Table 2. Complete results for key CHaMP metrics, covering individual years, the average status and trend from 2011-2015, in all CHaMP watersheds, are available at <https://isemp.egnyte.com/dl/USOtBj9AIJ>.

**Table 2. Detailed Summary for Large Wood Frequency: Wetted, in selected watersheds. Full results are available at** <https://isemp.egnyte.com/dl/USOtBj9AIJ>**.**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Population** | **Year** | **N** | **Status** | | | **Trend** | | |
| **Mean** | **95% LCB** | **95% UCB** | **Trend** | **95% LCB** | **95% UCB** |
| Entiat | 2011 | 66 | 29.3 | 18.8 | 39.8 |  |  |  |
| 2012 | 51 | 19.8 | 13.0 | 26.6 |  |  |  |
| 2013 | 66 | 35.3 | 26.9 | 43.7 |  |  |  |
| 2014 | 45 | 13.5 | 9.9 | 17.0 |  |  |  |
| 2015 | 49 | 16.4 | 13.1 | 19.8 |  |  |  |
| Avg. of all Years | 103 | 26.7 | 22.4 | 30.9 | 2.77 | -0.80 | 6.35 |
| Methow | 2011 | 22 | 6.4 | 3.5 | 9.3 |  |  |  |
| 2012 | 17 | 9.1 | -0.1 | 18.4 |  |  |  |
| 2013 | 24 | 7.0 | 4.5 | 9.6 |  |  |  |
| 2014 | 20 | 5.2 | 3.2 | 7.2 |  |  |  |
| 2015 | 21 | 6.4 | 3.6 | 9.2 |  |  |  |
| Avg. of all Years | 43 | 7.9 | 5.0 | 10.8 | -1.00 | -2.88 | 0.88 |
| Tucannon | 2011 | 19 | 17.8 | 10.8 | 24.9 |  |  |  |
| 2012 | 25 | 28.5 | 17.9 | 39.1 |  |  |  |
| 2013 | 28 | 14.9 | 10.3 | 19.5 |  |  |  |
| 2014 | 21 | 17.2 | 11.2 | 23.2 |  |  |  |
| 2015 | 17 | 28.0 | 17.2 | 38.9 |  |  |  |
| Avg. of all Years | 47 | 20.6 | 16.3 | 24.9 | -0.51 | -1.94 | 0.92 |
| Wenatchee | 2011 | 23 | 20.6 | 14.3 | 26.9 |  |  |  |
| 2012 | 21 | 12.6 | 8.8 | 16.3 |  |  |  |
| 2013 | 21 | 26.1 | 18.2 | 34.0 |  |  |  |
| 2014 | 17 | 10.8 | 7.5 | 14.1 |  |  |  |
| 2015 | 19 | 12.0 | 8.3 | 15.6 |  |  |  |
| Avg. of all Years | 52 | 19.8 | 16.4 | 23.2 | 0.41 | -1.51 | 2.33 |

In addition to results in tabular form, plots showing status by year, by watershed, for each of the selected key CHaMP metrics, are included at <https://isemp.egnyte.com/dl/USOtBj9AIJ>. These plots include, for each metric, estimates of the mean by year, as well as 95% confidence intervals for the mean. Examples include here include Large Wood Frequency: Wetted (Figure 1) and Substrate: D50 (Figure 2).

**Variance Decomposition**

In addition to status and trend estimation, a variance decomposition analysis has been updated to estimate the relative magnitude of the various variance components that sum up to the total amount of variance observed in each CHaMP metric. Variance components assumed for the model are as follows:

* σ2y: Year-Year (common across all sites in all valley classes in all watersheds)
* σ2w: Watershed-Watershed variance
* σ2vc: Valley-Class to Valley Class variance
* σ2s: Site-Site variance
* σ2e: Measurement Error (Independent for all sites, all measurements, all years)

The lmer function in R is used to estimate components of variance. Inverse probability bootstrapping (IPB), a technique developed within CHaMP is used to account for design weights in the original sampling plan. IPB sampling is a methodology developed specifically to support CHaMP data analysis (manuscript is currently in review).

Measurement noise is assessed via a subsample of CHaMP sites that are re-visited more than once in a given season. Differences in within year, within site responses are taken as measurement noise, and may be due to crew-crew variability or error, but may also reflect real variability, reflective of changes that occur within a sampling season. However, given that year-year variance components tend to be small, it is reasonable to assume that within year temporal components of variability are also small, and thus regarding within year variation as measurement noise is likely a reasonable assumption.

The variance decomposition is serves several purposes. First, it highlights which metrics, if any, have problematically high measurement noise relative to overall variance. Such metrics are typically addressed via improved sampling procedures or metric modification. In addition, the variance decomposition provides insight into how to any necessary modifications to the sampling design are to be done. For example, we observe that typical year-year variation is a small component of the overall variance. This suggests that less additional information is gained by sampling sites annually, as might be gained by sampling more total sights, but sampling then less often, given a consistent total sampling effort.

Results for the updated variance decomposition are provided by Figure 3.

In general, the amount of measurement noise, relative to other sources of variation, is low, and consistent with that observed in this analysis in prior years. Large wood volume in wetted fast turbulent water is where the highest amount of noise is observed. This may be due to compounding errors in not only the volume of wood measured, but in the visit-visit variability in the assessment of reach type (which may vary with discharge, and not therefore be purely measurement error be real variability). Even at this highest level of measurement noise, the impact on precision of estimates at watershed, or other multi-site spatial scale ups, is minimal. Measurement noise tends to be minimized at larger samples sizes, while signal strengths are increased.

**Summary**

Complete status and trend results are not presented here; instead, example results are provided, as well as explanations of status and trend calculations are being done. Complete results in both tabular and graphical form are available at <https://isemp.egnyte.com/dl/USOtBj9AIJ>.

**References**

1. Stevens Jr DL, and Olsen AR (2004). Spatially balanced sampling of natural resources. J Am Stat Assoc, 99:465, 262-278, DOI: 0.1198/016214504000000250.
2. Kincaid TM, Olsen AR (2013). Spsurvey: spatial survey design and analysis. R package version 2.6. URL: <http://www.epa.gov/nheerl/arm/>.

**Figure Captions**

Figure 1. Estimated mean Large Wood Frequency: Wetted (1/m), by watershed x year. Black lines indicates 95% confidence intervals for the mean.

Figure 2. Estimated Substrate D50: Median Pebble Size (mm) by watershed x year. Black lines indicates 95% confidence intervals for the mean.

Figure 3. Relative components of variance for selected CHaMP metrics, sorted from lowest to highest relative measurement noise