Standard Operating Procedure (SOP) #20

Data Analysis and Reporting

Version 1.01 (June 29, 2021)

Change History

New Version #	Revision Date	Author	Changes Made	Reasons for Change	Previous Version #
1.01	6/29/2021	Kim Weisenborn, Amanda McCutcheon	Updated to NRR formatting; renumbered SOP from #22 to #20, minor text updates	Formatting needed to be applied; some SOPs were removed or renumbered within the protocol, text updates for clarification	1.0

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, changes made, and reason for the change along with the new version number.

Purpose

This SOP covers general considerations regarding statistical analysis of water quality data and general reporting guidelines. Statistical analysis of water quality data must account for the nature of the data. The primary factors affecting choice of statistical tests are data censoring, seasonality, and sampling design. Data censoring is a limitation of measurement preventing values from being known, such as a detection limit. While such considerations dictate use of certain approaches, new developments in statistical analysis should always be considered. This SOP concentrates on marine data and will be amended following analysis of stream and standing waters. The reporting guidelines below reflect current practices by I&M and NPS.

Trend Analysis

No trend analysis is conducted for instances where more than 50% of the data are censored (after Weissinger 2018). The non-parametric Mann-Kendall Tau is used to assess trend in nutrients, chlorophyll, and turbidity when 50% or less of the data is censored. The seasonal Mann-Kendall test is applied to censored parameters displaying seasonality. Trends in non-censored parameters are analyzed by linear mixed model (VanLeeuwen et al. 1996). Data analysis is completed using the latest version of R (R Core Team 2017). Mann-Kendall tests are evaluated using the EnvStats

package for R (Millard 2013). Mixed models will be evaluated with the *lmerTest* package (Kuznetsova et al. 2016) or appropriate replacement as new, more efficient packages are developed.

Measurements from a series of water samples or sonde readings taken at an individual site within minutes of each other are assumed to be normally distributed around the true value of the parameter, as the parameter should not change appreciably over the short time required to take multiple samples or readings (but see censoring below). Variation in sample values should be most influenced by external factors. The water quality parameters at Ofu lagoon and the Tutuila marine area are analyzed separately. At Ofu lagoon where the water is shallow, nutrient samples are only collected at the surface. For this reason, depth is not included as a factor in the mixed model trend analyses for Ofu, and bottom and surface samples are not compared for correlation analysis.

Data censoring occurs when there is a limit to the values a parameter may display or be detected. Here nutrients, chlorophyll, and turbidity have the potential to be censored. Non-detection of a nutrient analyte means the value is less than the instrumental detection limit, but does not necessarily mean there is none present, even though that could be the case. Any distribution of values can also be censored; for example, an otherwise normal distribution where one tail is truncated by the detection limit. Censored data are therefore non-parametric by definition and are analyzed with non-parametric methods (Helsel and Hirsch 2002, see below). Data censoring is evaluated for nutrients, turbidity, and chlorophyll. The value of the detection limit is used for censored replicates in the calculation of mean parameter values, by site.

The non-parametric, rank-based Mann-Kendall Tau scores parameter values as higher or lower than a median, without assessing the magnitude of departure. Kendall tests are robust when outliers, missing data, or censoring are present (Helsel and Hirsch 2002). Kendall tests are not adjusted for the possibility of serial correlation here when datasets are less than 10 years in length. The seasonal Kendall test compares values within user-defined time-intervals such as months or quarters. Results are calculated for each time-interval and aggregated site (Helsel and Hirsch 2002). Thus, samples taken in the first annual quarter are compared only to other first-quarter samples. Trends within time intervals are combined to evaluate overall trend.

Seasonality is assessed for parameters prior to performing linear mixed model tests to determine if seasonal factors should be included in the model. Seasonality is evaluated using the multiple linear regression model function *lm* in R. Data are averaged to summarize the area and quarter. Wet and dry seasons were defined November through April (wet season for Hawaii and American Samoa, dry season for Guam) and May through October (dry season for Hawaii and American Samoa, wet season for Guam). Two models are considered: change over time and the effect of calendar-year quarters (q1, q2, q3), and change over time and the effect of the wet and dry seasons.

For marine data these models are applied to two datasets: mean values calculated by lumping surface and near-bottom data at a site, and mean values of surface data only, with the exception of the Ofu unit at NPSA. In total, four tests for seasonality are performed for each location (all depths wet/dry seasons, all depths quarters, surface only wet/dry seasons, and surface only quarters), except at Ofu, where only the two surface data tests were performed. It is necessary to exclude a time-interval, e.g.

“q4” and “dry”, in tests as these serve as references for the model. Thus, four tests for seasonality are performed for each parameter. Season is included in models only when strong evidence of seasonality was suggested, i.e. having three significant tests.

The linear mixed model allows for effects to be divided into fixed factors that impact the mean structure (e.g. depth, season, or quarter) and random factors that impact the variance structure (site and year). Variance was estimated by restricted maximum likelihood (REML), which is appropriate for unbalanced data such as split-panel design (Piepho and Ogutu 2002). Error for the random factors were partitioned into different sources of variation (site-to-site, year-to-year, and site-level estimates) (Starcevich 2013). The model is run using the *lmer* function in the *lmerTest* package (Kuznetsova et al. 2016) in R (R Core Team 2017) using R Studio. For marine data, the model includes fixed factors for time (WYEAR), depth, and seasonal factors when deemed appropriate by the seasonality analysis (Quarter or Season). The effect of site differences and random year-to-year variation is accounted for by including Station_ID and Year as random factors in the model.

Output of the *lmer* function includes effect estimates and t-statistics for each fixed factor in the model and for the interaction between the time component WYEAR and depth. Full output of the linear mixed model displays the slope of the effect of the factor and the standard error for that value. Full output also displays the intercept estimate and its statistical significance, indicating if the slope of the factor is significantly different from zero. For marine data, an interaction term “Time: Depth” was included in models. Such factors were included in models to account for the effect of these factors, and obtain model estimates better than a simple linear model, but individually these factors are not ecologically important and are not presented. The factor “Depth” tests for a difference between surface and bottom measurements. Additionally, *p*-values are estimated using Satterthwaite’s approximations (Kuznetsova et al. 2016). Effect estimates are not given for random factors, which are considered unobserved variables (Bates 2010, Bates et al. 2014).

Reporting

- A short internal communique may be issued to parks when an important trend or acute event is discovered.
- Annual briefs are issued to parks to summarize newly certified data. All certified data, including data newly certified, is presented in briefs with time-series graphs. A list of important results is presented, but the brief does not contain statistical analyses or in-depth interpretations.
- Trend reports are issued about every five years. Trend reports are externally reviewed NPS Natural Resource Reports (NRR)

Literature Cited

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