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Standard Operating Procedure 17: Data Summary and Analysis

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Standard Operating Procedure 17: Data Summary and Analysis

Data Sets

The wetlands monitoring protocol for Cuyahoga Valley National Park generates five data sets:

1. The rapidly-assessed wetland data set (i.e., rapid set) includes 250 randomly sampled wetlands from the reference frame.
2. The intensively-assessed, randomly-selected wetlands (i.e., intensive set) includes 60 wetlands in 10 watersheds selected using a two-stage GRTS sampling method.
3. The intensively-assessed wetlands that were subjectively selected as “sentinel” sites. In most cases, the sentinel set is not treated as an entire data set. Rather analyses are typically applied to individual wetlands, which are referred to by the name of the wetland (e.g., Pleasant Valley set).
4. Water depth data (i.e., water depth data set), whether manually- or digitally-collected, are associated with the intensively-assessed wetlands and allow for the calculation of hydrological signatures.
5. Water chemistry data (pH, conductivity, dissolved oxygen, temperature = water quality data set), are also associated with the intensively-assessed wetlands. These data are collected simultaneously, but less frequently than water depth data.

Rapidly-Assessed Wetland Data Set

The rapidly-assessed data set provides an estimate of wetland condition across the entire park. The raw Ohio Rapid Assessment Methods (ORAM) scores can be used, or the scores can be converted to condition categories for analysis (Table 4.1). The large sample size may also offer the opportunity for numerous post-hoc analyses using factors such as watersheds, management areas, wetland type, etc. For an even more granular view, ORAM submetrics may be examined using similar factors described above. The ORAM is a qualitative analysis so subtle changes will be easily overlooked by examining averages. Instead, we plan to evaluate each wetland individually using frequency analyses and graphical illustration. If scores start changing for many wetlands, we will examine possible variables more carefully to determine why they might be changing and which we may be responsible for.

Intensively-Assessed Wetland Data Sets

First-Order Calculation of VIBI Metrics

For all species, in VIBI-emergent, VIBI-shrub, and VIBI-forest communities, relative abundance as cover for herbaceous species (Eq. 1) and density for woody species (Eq. 2) are calculated at the monitoring site level. From these three metrics, all subsequent submetrics and the VIBI score are derived. The VIBI is calculated by summing the 10 submetric scores (Table 17.1), yielding a potential score of between 0 and 100 (Mack and Gara 2015). Scores relate to a Wetland Aquatic Life Use and Antidegradation Category (OAC 3745-1-54) similar to the ORAM.

Herbaceous vegetation

1. Cover class values (0 to 10) are converted to the midpoint for that cover class to estimate percent cover for each herbaceous and shrub species. (e.g. Cover class 5 is 5-10%, which would be

recoded to 0.075 (7.5%)) The mean relative cover for all plant species in the vascular plant survey are calculated by summing the cover midpoints for each species ($\sum Cover_{species}$) and dividing by the total cover (summed) for all species at the site ($\sum Cover_{AllSpecies}$), bryophytes included.

$$\text{Eq. 1: Relative cover} = \frac{\sum Cover_{species}}{\sum Cover_{AllSpecies}}$$

Woody vegetation

- Density is calculated for all woody plant species (# stems/hectare) in the plot. Density is used to calculate relative dominance. and the pole timber density calculations require that relative density is known for tree species in the size 10-15 cm, 15-20 cm, and 20-25 cm size classes.

$$\text{Eq. 2: Relative Density} = \frac{\sum Stems_{species}}{\sum Stems_{AllSpecies}}$$

- Mean relative frequency for a woody plant is calculated as the number of dbh size classes the species occurs in divided by the total number of all dbh size classes (12).

Eq. 3: Relative frequency =

$$\frac{Number_{dbhclasses}}{Number_{allclasses}}$$

Description and Second-Order Calculation of Submetrics

Using the first-order metrics described above (relative frequency, relative cover, and relative density), a total of 17 submetrics can be calculated. The VIBI-emergent, VIBI-shrub, and VIBI-forest scores each use 10 of these 17 metrics (Table 17.1). Submetric calculations are described below and the VIBI-type that uses each submetric is shown in parentheses.

Table 17.1. Eighteen metrics are associated with the Vegetation Index of Biotic Integrity (VIBI) for emergent, shrub, and forested wetlands. Each specific VIBI consists of ten individual metrics.

VIBI-Emergent	VIBI-Forest	VIBI-Shrub
Percent sensitive	Percent sensitive	Percent sensitive
Percent tolerant	Percent tolerant	Percent tolerant
FQAI score	FQAI score	FQAI score
Carex	Shade	Carex
Hydrophyte, native	Seedless Vascular Plants	Hydrophyte, native
Dicot, native	Percent hydrophyte	Dicot, native
Shrub, native, wetland	Pole timber density	Shrub, native, wetland
Annual/Perennial Ratio	Subcanopy IV	Subcanopy IV
Percent invasive graminoid	Canopy IV	Seedless Vascular Plants
Biomass	Percent bryophyte	Percent bryophyte

1. *Carex* spp. (*carex*): Number of species in the genus *Carex*. The *Carex* metric is calculated by counting the number of species in the genus *Carex*. (VIBI-E1, VIBI-SH1)
2. *Native dicot* spp. (*dicot*): Number of native dicot (dicotyledon) species. The dicot metric is calculated by counting the number of native, dicotyledon (dicot) species using the nativity and group codes. Only dicotyledon species are counted; monocot (monocotyledon), gymnosperm, or seedless vascular plant (fern, fern allies) are excluded. (VIBI-E2, VIBI-SH2)
3. *Native, wetland shrub* spp. (*shrub*): The shrub metric is calculated by counting the number of native, wetland (FACW, OBL) woody species that have a "shrub" lifeform using the codes for nativity, wetland status, and lifeform. (VIBI-E3, VIBI-SH3)
4. *Hydrophyte* spp. (*hydrophyte*): The hydrophyte metric is calculated by counting the number of native vascular plant species that have a FACW or OBL wetland indicator status using the wetland and nativity codes. (VIBI-E4, VIBI-SH4)
5. *Ratio of annual to perennial* spp. (*A/P*): The annual/perennial (A/P) metric is calculated by dividing the number of annual species by the number of non-woody perennial species using the codes for reproductive habit (annual, perennial, biennial, woody). Biennial species are excluded from calculation. (VIBI-E5)
6. *FQAI score*: The Floristic Quality Assessment Index score calculated using the following equation and the coefficients in Andreas et al. (2004). $I = 3 \sum (CC_i) / \sqrt{N_{all} \text{ species}}$ where I = the FQAI score, CC_i = the coefficient of conservatism of plant species i, and $N_{all} \text{ species}$ = the total number of species both native and nonnative (Fennessy et al. 1998a, 1998b; Lopez and Fennessy 2002). (VIBI-E6, VIBI-SH5, VIBI-F1, VIBI-FQ)
7. *Relative cover tolerant plant* spp. (*% tolerant*): The %tolerant metric is calculated by summing the relative cover values of all species, including adventive species, with Coefficients of Conservatism of 0, 1, and 2 using the coefficients in Andreas et al. (2004). (VIBI-E7, VIBI-SH6, VIBI-F2)
8. *Relative cover of sensitive plant* spp. (*% sensitive*): The %sensitive metric is calculated by summing the relative cover values of plants in herb and shrub strata with Coefficients of Conservatism of 6, 7, 8, 9 and 10 using the coefficients in Andreas et al. (2004). The relative cover of buttonbush (*Cephalanthus occidentalis*) is deducted from the sum of relative cover values of species with C of C's of 6 to 10. (VIBI-E8, VIBI-SH7, VIBI-F3)
9. *Relative cover of invasive graminoid* spp. (*% invgram*): The %invasive graminoid metric is calculated by summing the relative cover values of reed canary grass (*Phalaris arundinacea*),

cattails (*Typha angustifolia*, *T. latifolia*, *T. x glauca*), and giant reed (*Phragmites australis*). (VIBI-E9)

10. *Standing biomass (biomass)*: The biomass metric is calculated by averaging the grams per square meter of standing biomass samples (usually 8) collected in intensive modules. (VIBI-E10)
11. *Native shade spp. (shade)*: The shade metric is calculated by counting the number of native species that have shade or facultative shade (partial) tolerance status using the shade and nativity codes. Tree (canopy species) and adventives are excluded. Small trees (subcanopy species) and shrubs are included (Codes for these are provided in the "shade" column). (VIBI-F4)
12. *Seedless vascular plant (SVP) spp.* The SVP metric is calculated by counting the number of seedless vascular plants (ferns and fern allies) using the group code. (VIBI-SH8, VIBI-F5)
13. *Relative cover of shade tolerant hydrophyte spp. (% hydrophyte)*: The %hydrophyte metric is calculated by summing the relative cover value (as calculated above) for native, shade and partial shade hydrophytic plant species (FACW and OBL) in the herb and shrub strata using the nativity and indicator status codes. (VIBI-F6)
14. *Relative cover of bryophytes (% bryophyte)*: The bryophyte metric is calculated by summing the relative cover values for all bryophyte species (all moss species plus the aquatic liverworts *Riccia* and *Ricciocarpos*). When completing Field Data Sheet 1, the cover of mosses and aquatic liverworts, individually or in the aggregate, should be recorded. Mosses do not need to be identified to any level beyond moss ("true" mosses or Musci of Division Bryophyta), or can be recorded as Moss #1, Moss #2, etc. All cover values assigned to mosses or aquatic liverworts are summed into an aggregate bryophyte "species" and the relative cover of bryophytes calculated as described above. (VIBI-SH9, VIBI-F7)
15. *Relative density of small trees (pole timber)*: The pole timber metric is calculated by summing the relative density of tree species in the 10-15 cm, 15-20 cm and 20-25 cm size classes. Relative density of a tree species is calculated by dividing the number of stems counted for that species on Field Data Sheet 2 (woody stem) by the total number of stems of all species counted. (VIBI-F8)
16. *Importance of native shade subcanopy spp (subcanopy IV)*: Importance value is the average of relative size class frequency, relative density, and relative basal area. The subcanopy importance value (IV) metric is calculated by summing the average importance value of native shade tolerant subcanopy species (shrubs and small trees) plus the average importance value of native facultative shade subcanopy (shrubs and small trees) species using the nativity, lifeform, and shade tolerance codes. Subcanopy trees are coded as "small trees" and are tree species which at maturity do not reach the canopy of the forest, e.g. *Carpinus caroliniana*. (VIBI-SH10, VIBI-F9)

17. *Importance canopy spp (canopy IV)*: Canopy tree species are species which at maturity will inhabit the upper canopy of the forest even if at the time of sampling they are growing in the subcanopy. The canopy importance value (IV) metric is calculated by averaging the importance values of native canopy (tree) species using the nativity and lifeform codes. (*VIBI-F10*)
18. *Cover-weighted C of C*: The relative cover for each vascular plant species recorded within the plot is multiplied with the C of C assignment for that species. The value is summed for all species present in the VIBI plot. (*VIBI-FQ*)

Statistical Tests

Our use of reference sites as providing information on “best attainable condition” for management planning or comparison to wetlands included in the intensive data set is still prospective at this point.

With this protocol, obtaining estimates for means and variances or computing confidence intervals is not straight-forward, because sampling occurs in two stages, and there is a variance associated with each stage. Numerous statistical texts describe this issue. Lohr (1999) discusses this under “two-stage cluster sampling”. Thompson (2002) discusses this under “multistage design”. Perhaps the most useful reference for actually calculating the necessary parameters is Elzinga et al. (2001), which describes in detail and with an example how to calculate means, variances, and confidence intervals from two-stage sampling (their Appendix 9). This publication is available at no charge from the BLM (<http://www.blm.gov/nstc/library/pdf/MeasAndMon.pdf>).

Such calculations will provide estimates of means and variances for each of the three strata. Such information will often be what is desired, as combining estimates over the strata will result in greater overall variability and uncertainty. If, however, it is desired to obtain ‘park-wide’ estimates, one may estimate the mean and variance of the total population as with any stratified design (see, for example, Thompson 2002).

Change Detection

Analyses for community change detection should begin with the relatively simple approaches described below (exploratory analyses, parameter estimation and control charts) and progress to more complicated analyses when biologically important changes seem to be occurring and the simpler analyses do not yield all the necessary information.

Exploratory data analyses such as scatter plots, frequency histograms and box plots (see Elzinga et al. 2001 for some examples) are simple to construct and easy to understand. These should always be the first step in any analysis. These will help detect biologically important change, suggest other important statistical tests, assess the assumptions on which various statistical tests are based, and screen for outliers.

Confidence intervals usually supply the most useful information about the location of a particular parameter. Confidence intervals of 90 or 95% are common. The percentage should depend upon the amount of uncertainty one is willing to accept relative to the need for a precise interval.

Ordination could be employed either as an exploratory analysis with only a single year (or panel) of data, or to make comparisons after several years of data are obtained. PC-ORD (McCune and Grace 2002) is the recommended software for conducting ordinations, although other applications are available. Nonmetric multidimensional scaling (NMS; Kruskal 1964, Mather 1976) is recommended over other ordination techniques because it has less restrictive assumptions. Habitat variables may also be included in a second matrix (first matrix is the species data), and the correlation of each habitat variable with each ordination axis determined.

The Multi-Response Permutation Procedure (MRPP) may be used as a nonparametric method to test for differences between groups (Zimmerman et al. 1985, McCune and Grace 2002). The MRPP is similar to the two sample t-test and the one-way analysis of variance F-test and it can be shown to be functionally identical to these tests. An important advantage of MRPP is that it does not assume the data are from a normal population, or that there are homogeneous variances. MRPP analyses can be conducted with PC-ORD software.

Regression analyses represent an obvious method for analyzing long-term trends. The most informative approach to a regression analysis is likely to be estimation of regression parameters (e.g., the slope, which is indicative of the rate of change), rather than simple determination of statistical significance (because P-values are dependent on sample size).

Analysis of variance (ANOVA) could also be used for these data. A repeated measures design would be appropriate given that the same plots are sampled over time. Factor levels could represent different watersheds or be based upon ORAM, VIBI or LDI scores, allowing for many different comparisons of interest.

Other approaches: Given the great diversity of data that will be collected with this ecosystem-level protocol, many other analytical methods could be applied. Management concerns and thus questions of interest are likely to change over time. Thus, it is important to keep in mind that other approaches not mentioned here may be useful in the future.

Water Depth Data Set

Water level data collected from groundwater wells at Wetlands of Management Concern are graphed relative to the date of collection to produce a hydrograph (Figure 17.1). Precipitation data can be viewed with the water level data to get a better sense of the recharge and retention cycles in response to rain (Figure 17.2).

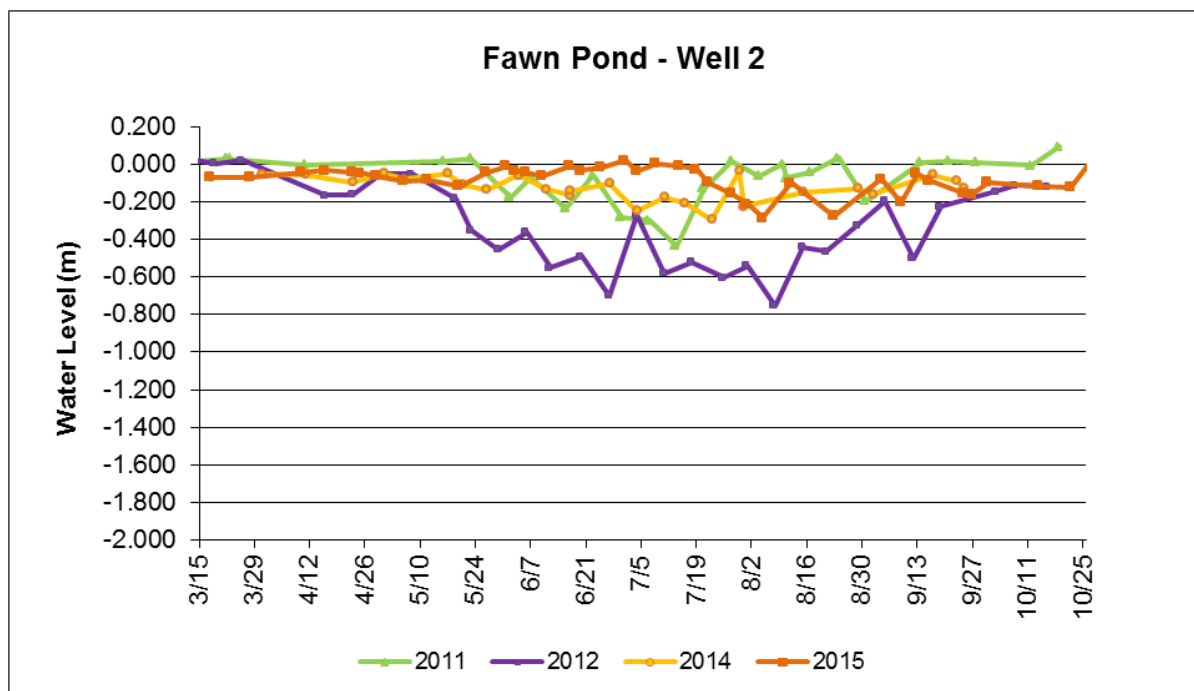


Figure 17.1. Annual hydrological data for Fawn Pond, Well 3 from 2009-2015.

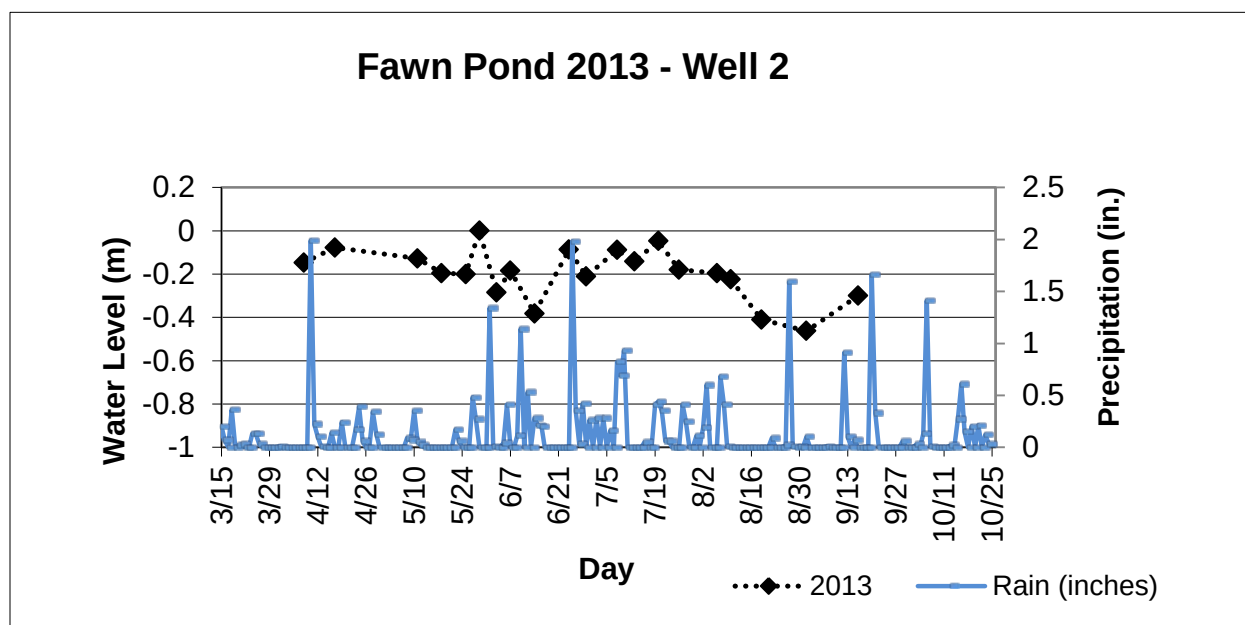


Figure 17.2. Rainfall data plotted against water level data at one shallow groundwater wells (Fawn Pond 2013).

Water Quality Data Set

The Mann-Kendall test for trend is commonly used in water quality analyses. The Mann-Kendall test can be conducted with “Time Trends” software, freely available at <http://www.niwa.co.nz/our-science/freshwater/tools/time-trends>. Other analysis tools in the TimeTrends software package can also be used.

Caveats of Statistical Tests

Before any statistical tests are conducted, data should be examined for assumptions (when applicable) such as normality and homoscedasticity (homogeneity of variances). If raw data are not normally distributed, a transformation should be considered. A $\log_{10}$ transformation will often make a data set more normal, but one should not assume such a transformation will always work. Other transformations are possible (see Kutner et al. 2005). After transformations, the distributions of the transformed data should always be examined. A formal test for normality is available and other tests can be used to evaluate other statistical assumptions, such as Bartlett’s test for the existence of homoscedasticity (Sokal and Rohlf 1995).

One must be cautious in the interpretation of P -values from multiple tests conducted on the same data set. When more than one statistical test is conducted from the same data set, the probability of the Type I error is no longer equal to the P -value specified in any given test. P -values can be corrected for multiple comparisons (e.g., the sequential Bonferroni technique, Rice 1989), albeit at a loss of statistical power (Nakagawa 2004). The more multiple comparisons made and corrected for in this way, the lower the chance of obtaining any ‘significant’ result. There is much debate over the appropriate method of dealing with the uncertainty of Type I errors in the context of multiple comparisons (e.g., Perneger 1998, Cabin and Mitchell 2000, Moran 2003); the best strategy is to make as few multiple comparisons (i.e., report as few P -values) as possible and to remember that the primary goal of these analyses is to detect changes before it is too late to react efficiently to undesirable changes.

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