

SOP 12 – Data Analysis and Annual Reporting

Version 1.0 (August, 2007)

The following table lists all changes that have been made to this Standard Operating Procedure since the original publication date. Any recommended or required changes added to the log must be complete and concise and promptly brought to the attention of the Project Leader. The Project Leader will review and incorporate all changes, officially complete the revision history log, and change the date and version number on the title page. For complete instructions, please refer to Instructions for Recording Revisions in SOP 13.

Revision History Log:

New Version #	Previous Version #	Revision Date	Author (full name, title, affiliation)	Location in Document and Description of Change	Reason for Change

The goals of estuarine monitoring within Northeast Region (NER) coastal parks are to:

- 1) determine whether nutrient loads to park estuaries are increasing over time, and
- 2) assess how estuarine natural resources are affected by changing nutrient inputs.

Two distinct monitoring protocols have been developed to achieve these goals, and the utility and interpretability of each is tightly linked to the other. Goal (1) is principally addressed by a separate protocol that prescribes monitoring of watershed characteristics which are used to model nutrient loading to NER coastal parks. The priority objective of this protocol is to address goal (2) by tracking estuarine response to nutrient enrichment. While this protocol is designed around the most universal indicators of estuarine responses to enrichment (and so to a certain extent provides information on the status of nutrient loading to these estuaries as well), interpretation of trends in results from this monitoring protocol are most useful when interpreted within the context of changing nutrient load to the NER estuaries.

Water Quality and Sediment Organic Carbon Reporting

There are three components for analysis and reporting of sediment and water-quality monitoring data. These are (1) the area-weighted spatial survey, (2) the trend station data, and (3) the continuous monitoring components. For the area-weighted assessment of condition, estuarine waters are treated as a continuous resource, and sampling stations are selected randomly from within hexagons of a randomly overlaid grid. Except for a small subset of the hexagons assigned with trend stations, sampling is re-randomized each year. This reduces the bias associated with deliberate station positioning. It also allows us to report area-weighted average values of condition for each estuary, and the proportion of each estuary falling into specific categories of

condition. The methods for this aspect of data analysis and reporting are addressed below in Area-Weighted Spatial Data. As a starting point for reporting of water-quality data from the spatial survey, data reduction should be performed so that the metrics listed in Table 20 are reported for each hexagon spatial element for each park. It must be noted that in two cases an additional stratum was required for a portion of the estuarine resource that was not well suited to this sampling strategy. At CACO, estuarine kettle holes are sampled as discrete units without the need for a grid of tessellated hexagons. They are sampled exhaustively with one station randomly positioned within each. At COLO, a stratum consisting of small tidal creeks is treated similarly. Each section of creek within NPS stewardship is small enough to be represented by a single station.

Table 20. Data to be included in the data report in tabular format and organized by park, stratum, and spatial element number (hexagon ID). Note that all variables are reported annually except for sediment organic carbon, which is only sampled every fifth year.

	Single value for station	Surface	Mid-depth	Bottom
Dissolved oxygen (mg l ⁻¹)		X	X	X
Dissolved oxygen (% saturation)		X	X	X
Chlorophyll <i>a</i> (µg l ⁻¹)		X		
Turbidity (NTU)		X	X	X
PAR Attenuation (K _d m ⁻¹)	X			
Temperature		X	X	X
Salinity		X	X	X
Sediment organic carbon (%)	X			

The second component of analysis and reporting is associated with trend stations. For NPS NER parks without pre-existing monitoring programs, 20% (six) of the hexagons are assigned trend stations. Parks with existing monitoring programs are evaluated individually to see if existing stations can be adopted as trend stations for this protocol (see sections on spatial sampling design). In some cases, the number of trend stations exceeds 20% at these parks. Trend stations are initially positioned randomly within their hexagons, but are not re-randomized each year. They are also monitored each week of the index period rather than just once. Trend stations serve three functions in this protocol:

- 1) Because positions of trend stations are not re-randomized each year, the influence of spatial variability is removed. Consequently, trend stations improve the ability to detect change (at these stations) over time.
- 2) Since trend stations are visited each week during the 4-week index period, they provide for the ability to evaluate temporal variability within the index period.
- 3) Trend stations contribute to the snap-shot assessment of condition generated by the spatial survey above.

The methods for analysis and reporting of trend station data are described later in this SOP.

The final component of data analysis is for the continuous monitoring stations. Since continuous stations are positioned subjectively within the parks, they do not contribute to an unbiased assessment of overall resource condition. Rather, continuous monitoring stations provide high-resolution information on temporal variability during the index period. These data provide insights into how well the spatial assessment and trend station data represent condition throughout the index period. Continuous (Index Period) Water-Quality Data describes the reporting requirement for these data.

Area-Weighted Spatial Data

Area-weighted water quality and benthic condition within each estuary is reported in two ways: 1) the mean condition and 2) the percent of the estuarine area exceeding threshold values for selected parameters. Estimation procedures for mean parameter values and variance are weighted by the estuarine area within the tessellated hexagon from which each sample is collected (Cochran 1977, Stevens and Olsen 2003). For parks with multiple sampling strata (ACAD, CACO, COLO), each stratum is evaluated individually and then also combined for a park-wide synopsis.

Note that, for this protocol, at least 6 of the hexagons from each park have been assigned as trend stations. Not only are these stations sampled every year, they are also sampled each week during the index period. For this component of the analysis, however, data are only used from the first date within the index period that a trend station is successfully sampled. This will help to prevent biasing the analysis and averaging out extreme events. The subsequent repeat visits to trend stations are used for examining changes within the index period.

Special consideration is necessary for the few parks with existing monitoring programs where multiple trend stations are positioned within a single hexagon. In these cases, area-weighting of data must be modified to apportion the estuarine area among the multiple stations. Area-weighted mean values of any metric are calculated use the following equation (U.S. EPA 2002 and Diaz-Ramos et al. 1996).

$$\bar{y} = \frac{1}{A} \sum_{i=1}^n \frac{y_i}{\Pi_i} \quad \text{Equation 1}$$

where:

$\bar{y}$ = the area-weighted mean

Π_i = the inclusion probability for a station (1/ estuarine area within hexagon i)

A = the total area of sampled estuarine water in the stratum

y_i = the variable of interest measured in hexagon i

n = the number of hexagons sampled in the stratum

For most of the NER coastal parks, all estuarine resources fall within a single park stratum. For ACAD, CACO and COLO, however, the mean condition from multiple strata must be combined to generate a value for the whole park. This will be the area-weighted average from the individual strata.

$$Y = \sum_{i=1}^m w_i \bar{y}$$

Equation 2

where:

Y = the estimated mean condition for the combined strata,

w_i = relative area of stratum i to the total park area.

m = the number of strata

The Horvitz-Thompson estimator is commonly used to calculate sample variance for this type of design (Cochran 1977); however, Stevens and Olsen (2003) have developed a local neighborhood variance estimator specifically targeted toward accommodating the nature of this design. Either may be applied here, but the latter yields notably smaller variance, particularly when there are strong spatial patterns associated with the data.

Average park-wide condition shall be reported for each of the variables listed in Table 21. These data are to be included in the annual data report in tabular and graphical format. For parks with multiple strata, the values are reported for each stratum, and also combined into a park-wide estimate using Equation 2.

Table 21. Average condition of the estuary for selected area-weighted variables. These data are to be included in the annual data report in tabular and graphical format. Station values are weighted by the area of estuarine resource within the respective hexagons. For parks with multiple strata, these values are reported for each stratum, and then also combined into a park-wide estimate.

	surface	mid-depth	bottom	single value for station
Dissolved oxygen (mg l ⁻¹)	X	X	X	
Dissolved oxygen (% saturation)	X	X	X	
Chlorophyll <i>a</i> (µg l ⁻¹)	X	X	X	
Turbidity (NTU)	X	X	X	
Temperature (°C)	X	X	X	
Salinity (psu)	X	X	X	
PAR Attenuation (K _d m ⁻¹)				X
Sediment Organic Carbon (%)				X

The second approach to reporting of spatial data is to use rating criteria. For this, NCBN and NETN have adopted critical threshold values (Table 22) that have been accepted by the U.S. EPA for national coastal condition reporting (U.S. EPA 2001, 2004). These are also largely consistent with the thresholds used for the NOAA National Estuarine Eutrophication Assessment (Bricker et al. 1999). The only change to these thresholds is that water clarity is expressed as K_d (m^{-1}) rather than as an index. Cutoff values of K_d have been calculated from the EPA criteria for turbidity using the thresholds for areas with significant SAV resources. For NPS reporting on these indicators, the proportion of the resource area that falls into each of four quality categories (good, fair, poor, or missing) shall be calculated for each park (and where applicable, stratum). The fourth (“missing”) category is used when there are missing data for any of the spatial elements within a park. Equations for making these calculations are given below; however, Microsoft Excel worksheet macros have been developed for this purpose at the U.S. EPA, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division (Current contacts are John Kiddon kiddon.john@epamail.epa.gov and Hal Walker walker.henry@epamail.epa.gov). Example charts for reporting of proportion data are shown in Figure 26. Cumulative frequency distribution plots are useful for interpreting data grouped by park or stratum.

The proportion of the area of a resource meeting a prescribed threshold is:

$$\hat{P}_z = \frac{1}{A} \sum_{i=1}^n \frac{y_i}{\Pi_i} \quad \text{Equation 3}$$

where

$\hat{P}_z$ = the estimated proportion of the area at or below a response value of z
 $y_i = 1$ if the response value is less than or equal to z , and otherwise is 0
 Π_i = the inclusion probability for a station ($1/\text{estuarine area within hexagon } i$)
 A = the total area of sampled estuarine water in the stratum
 n = the number of hexagons sampled in the stratum

When combining strata for ACAD, CACO and COLO, the park-wide proportions are calculated as:

$$\hat{U} = \sum_{i=1}^m w_i \hat{P}_i \quad \text{Equation 4}$$

where

$\hat{U}$ = the estimated proportion area for the combined strata
 $\hat{P}_i$ = the estimated proportion area for the stratum i
 w_i = relative area of stratum i to the total
 m = the number of strata

The Microsoft Excel macros developed and provided by EPA currently use the binomial approximation for calculating variance on proportion data. Jackknife methods may provide more

Table 22. Critical values used in establishing the portion of the estuary (or stratum) that falls within a given quality category. These are based upon the threshold values that are in use by both the U.S. EPA National Coastal Assessment and the NOAA National Eutrophication Assessment (U.S. EPA 2001, 2002, 2004, and Bricker et al. 1999).

	Good	Fair	Poor
Chlorophyll <i>a</i> (near surface)	< 5 µg /l	5-20 µg /l	> 20 µg /l
Dissolved Oxygen (near bottom)	> 5 ppm	2-5 ppm	< 2 ppm
Water Clarity K_d (SAV standard)	< 0.92 m ⁻¹	0.92-1.61 m ⁻¹	> 1.61 m ⁻¹
Sediment Total Organic Carbon (TOC)	< 2%	2-5 %	> 5%

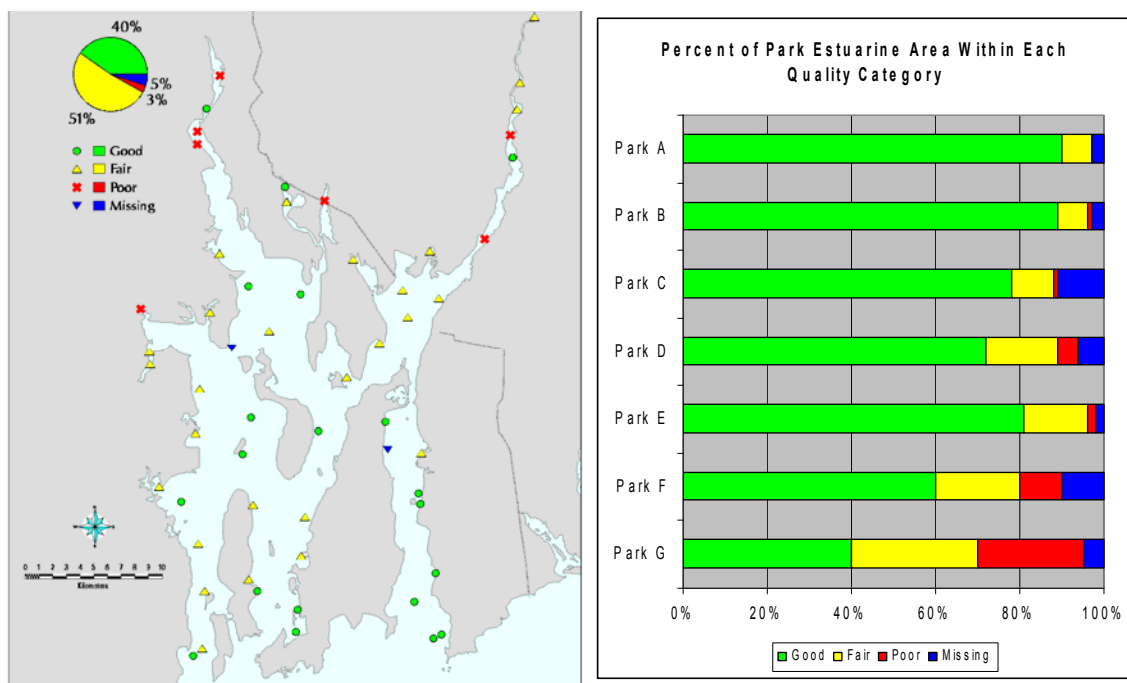


Figure 26. Example graphics for reporting of area-weighted proportion data (figure A courtesy John Kiddon, U.S. EPA).

realistic estimates, but have not as yet been coded into the programming (John Kiddon personal communication).

The Estuarine Monitoring Database includes automated routines to export these data in Excel format to be analyzed with the EPA macros. Select *Analysis and Export* from the *Main Menu*, and then select *Export Data to Excel*. From the list of available reports, highlight *Spatial Survey WQ Data – threshold export*. Click *Preview* to view the table or *Export* to save it to an Excel formatted file.

Trend Station Data

Data from the trend stations serve two purposes: 1) detecting interannual change (trend analysis) and 2) evaluating variability of the indicator metrics in time (through the index period) and through space (throughout the estuary). Because their positions are not re-randomized each year, spatial variability is reduced. This makes them useful for detecting interannual change and long-term trends. By keeping the number of trend stations low (20%) they are able to serve double duty for estimating area-weighted average condition (Area-Weighted Spatial Data) without adding unnecessary bias to those estimates. And because trend stations are measured four times during each index period, we are able to interpret results of the weekly spatial survey within the context of temporal variability within the index period as well as spatial variability throughout the estuary.

For analysis and reporting purposes, data should be evaluated by individual station. Means and standard errors for the index period should be calculated for each of the trend stations; and these data should be examined for patterns associated with location in the estuary, as well as for trends with past year data. While averaging through time is appropriate, averaging across stations is to be avoided because equal weighting is not a reasonable assumption. That is the role of the probability survey and the area-weighted data analysis (Area-Weighted Spatial Data).

Continuous (Index Period) Water-Quality Data

The role of the continuous monitoring data is similar to that of the trend data except that temporal resolution is further emphasized, displacing any ability to resolve spatial patterns. Estuaries are highly pulsed systems, and even the weekly sampling at trend stations may reasonably be expected to miss ecologically important events such as phytoplankton blooms, or episodes of low dissolved oxygen and high turbidity. All spatial data from the weekly survey cruises should be evaluated within the context of the continuous record for that period. This will improve interpretation and also allow for ongoing evaluation of the timing and duration of the index period used for all estuarine monitoring.

Although not spatially representative, data from the logging station can also be used to track inter-annual changes. Because there is no spatial replication, we can only interpret results within the context of that one station. Temporal replication, on the other hand, is very good. Each logging station is sampled 96 times per day (as many as 3000 times during the index period), so slight changes are more likely to be captured by statistical tests.

External Data Sources

Numerous programs conduct monitoring activities within and adjacent to NER coastal parks that may be helpful for tracking the condition of NPS estuarine resources (Kopp and Neckles 2002). The use of these data presents a particular challenge however. On the one hand, NPS should leverage its financial resources by making the greatest possible use of existing data and information resources. On the other hand, NPS has no control over data quality for external programs, and in many cases no meaningful way to evaluate it. Quality assurance, quality control and precisely defined data quality objectives are all fundamental components of water-quality monitoring within the NPS Vital Signs program. Other programs have their own (or sometimes undefined) data quality objectives. This makes it inadvisable to integrate NPS data with data from external sources to generate common summary statistics. Externally-generated data should certainly not be ignored where they are relevant to NPS estuarine resources, but those data (or data products) must be interpreted with careful attention to differences or uncertainties in data quality. The following precautionary guidance is provided for use of externally-generated data within Vital Signs reports to interpret the condition of NPS resources.

- a) Do not pool data from external sources with those from this protocol in such a way that they contribute a single summary statistic, data table, or graph without first evaluating compatibility of sampling design, and comparability of methods and data quality.
- b) Avoid working with raw data from external sources to generate new summary statistics or graphics. To the extent that it is feasible, present instead finished data products (graphs and tables) as prepared by the originating data owner. If new summary statistics or graphics are prepared, they should be discussed with the manager of the originating monitoring program to avoid making invalid comparisons or interpretations.
- c) In the absence of documentation to the contrary, it should not be assumed that sampling design, methods, or data quality are the same between monitoring years or condition assessments for external monitoring programs.

Submerged Aquatic Vegetation Reporting

Seagrass Mapping

Producing maps that are thematically and geographically precise and accurate is very expensive, so measures are rarely replicated. All data have inherent errors, however, and this includes seagrass mapping data. Nevertheless, seagrass area is generally reported as a single value, and rarely are error terms included despite the fact that $n=1$ (Kurz 2000). Change analysis is complicated by the lack of a thorough understanding of the accuracy and error associated with individual maps. This can make it difficult to interpret with rigor the small change between sequential maps. C-CAP mapping protocols instead rely on carefully constraining the errors, and evaluating them with quality assurance measures. Caution is advised when analyzing change to incorporate the best available estimates of these error terms.

Remapping of seagrass habitat is prescribed for 5-year intervals. For each of these, the network should use detailed maps to report the geographic distribution of SAV, areas of habitat increase, and areas of loss. For some of the mapping programs it will also be feasible to report on

individual SAV cover classes. In addition to changes in areal extent, changes in frequency distribution among cover classes may illuminate interesting trends.

Seagrass Condition Measures

The objective of monitoring seagrass condition indicators is to compare trends in seagrass characteristics at different depths in existing seagrass habitat. The question of interest is whether changes in seagrass structural measures over time differ among the depth transects; we expect responses to nutrient enrichment to occur first in the deepest areas of seagrass beds, so significant differences in trends between deep and shallow transects may signify management problems associated with estuarine nutrient load.

The first step in analysis and reporting of seagrass condition measurements is to transform measured values (e.g. number of shoots counted in a 1/16 m² quadrat, biomass of vegetation collected within a 0.0035m² core) into standard, ecologically meaningful variables (e.g. density and biomass per m²). The continuous variables of interest and their derivation are listed in Table 23, and sample calculations are provided in an attached MS Excel worksheet (Appendix G).

Because data on seagrass condition indicators are collected from permanent sampling quadrats, consecutive samples are correlated. The advantage of using permanent sampling quadrats lies in the power of the statistical tests used to detect change over time. Effectively, we are analyzing the *change* from one time period to the next at given sample locations rather than comparing mean conditions at each time period. The error for this test is the variation in the *change* between two time periods rather than the variation among sampling units at either time period (Green 1993, Elzinga et al. 1998). By eliminating the contribution of spatial variation among sampling units to experimental error, this approach results in a powerful ability to detect changes over time and a reduction in the number of sampling units needed to detect a certain magnitude of change.

The appropriate statistical approach to determining whether temporal patterns in seagrass condition measures differ among depths is a repeated measures analysis, with quadrats as the subjects of repeated sampling (Winer 1971). The design incorporates the between-subjects effect of depth and within-subjects main effect of time. Univariate repeated measures ANOVA assumes that all between-times correlations are the same (i.e., correlation between measurements of Year 1 and Year 2 is the same as between Year 2 and Year 3, Year 1 and Year 3, etc.) This assumption can be tested (Mauchley's criterion; Potvin et al. 1990) and if warranted, significance levels of the univariate test can be adjusted or a multivariate ANOVA can be applied (Potvin et al. 1990, Green 1993). Additional assumptions of both univariate and multivariate approaches to repeated-measures ANOVA are common to any parametric technique, namely normality and homogeneity of error variances (Green 1993). Residual analysis should be used to diagnose departures from these assumptions (e.g. Neter et al. 1990); should the data deviate strongly from these basic assumptions, the data must be transformed appropriately.

Annual reports should include graphs of mean seagrass response vs. depth station, or mean seagrass response vs. time at each depth station. These figures should be accompanied by results

of the tests described above to determine whether annual changes in seagrass condition differs significantly among depths.

Temperature, salinity, and sediment data should be presented as ancillary information. These habitat characteristics provide a framework within which to interpret measures of seagrass condition. Continuous temperature data should be cropped to eliminate data outside the period of deployment from the stored record. Temperatures should be plotted as logged (i.e. there are no derived variables) over time for each depth station. Salinity should be reported as individual measurements at each depth station, and sediment characteristics reported as means for each depth station at each monitoring interval.

Table 23. Derivation of seagrass condition variables.

Variable	Derivation
Total Shoots / m ²	(Shoots/0.0625 m ²)*16
Reproductive Shoots / m ²	(Reproductive shoots/0.25 m ²)*4
Canopy height (cm)	Direct measurement
Percent cover	Direct measurement
Total biomass (g/m ²)	(Total shoots/m ²) * (Total g/shoot), where g/shoot = (total g/core) / (number of meristems/core)
Aboveground biomass (g/m ²)	(Total shoots/m ²) * (Aboveground g/shoot), where Aboveground g/shoot = (Leaf + Sheath g/core) / (number of meristems/core)
Leaf biomass (g/m ²)	(Total shoots/m ²) * (Leaf g/shoot), where Leaf g/shoot = (Leaf g/core) / (number of meristems/core)
Ratio leaf:root+rhizome biomass	(Leaf g/core) / (Root+Rhizome g/core)
Ratio shoot:root+rhizome biomass	(Leaf + Sheath g/core) / (Root+Rhizome g/core)

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