A Statistical Framework for the Onondaga Lake Ambient Monitoring Program - Phase II

prepared for

Department of Drainage & Sanitation
Onondaga County, New York
by

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Introduction

The primary purpose of the Onondaga Lake Ambient Monitoring Program (AMP) is to provide information supporting future decisions on wastewater and watershed management (Onondaga County, 1998). These decisions may be based in part upon changes detected in Onondaga Lake, its tributaries, and the Seneca River over the next several years. Decisions may also rely upon comparisons of monitored conditions with water quality standards or management goals. The ability to detect such changes and the reliability of such comparisons depend in part upon the design of the monitoring program. Decisions should not be made based upon the monitoring results without an adequate understanding of the sources and magnitudes of variability in the data.

A previous report (Walker, 1998) describes a statistical framework with the following functions under the AMP:

- Identifying and quantifying sources of variability in the data;
- Evaluating uncertainty associated with summary statistics;
- Formulating and testing specific hypotheses; and
- Refining monitoring program designs;

The framework is being implemented in two phases. Sampling program designs for water quality components (phosphorus, nitrogen, Kjeldahl nitrogen, ammonia, chlorophyll-a, transparency, & bacteria) were evaluated in Phase I (Walker, 1999). Under Phase II, this report evaluates sampling program designs for the following biological measurements:

- Plankton
- Macrophytes
- Macroinvertebrates
- Fish

The County has provided designs for biological surveys to be conducted in 2000, as summarized in Table 1. Sampling designs are evaluated using variance component models calibrated to historical data from Onondaga Lake and other regional lakes. Data collected under the AMP in 1999 are used as a basis for evaluating stream and lake benthic macroinvertebrate sampling designs. The evaluations are preceded by a summary of general concepts and methodologies used in the AMP statistical framework.

General Concepts

AMP data will be used to test hypotheses regarding changes in lake water quality and biota following implementation of control measures. In designing a monitoring program, the general objective is to minimize the risk of reaching a false conclusion based upon the data. The outcome of a hypothesis test is subject to Type I and Type II errors. Both types of error are of potential concern when management decisions are to be made based upon the test result (USEPA, 1998; Walker, 1998). Peterman (1990) and Forney et al. (1994) discuss these concepts in the context of designing monitoring programs to support fisheries management.

When a Type I error, is committed, random variations in the data are mistakenly interpreted as a real change in the long-term mean; i.e., the null hypothesis of no trend is mistakenly rejected. The maximum probability of a Type I error (α) is specified in setting up the hypothesis test and is commonly referred to as the "significance level". Because α is specified, the risk of a Type I error is theoretically independent of monitoring program design. Type I error can be inflated when inappropriate statistical methods are used to test the hypothesis; e.g., when a method that assumes independent and normally distributed data is applied to data which are serially dependent and/or have heavily skewed distributions. These problems can be minimized by transforming the data or using nonparametric statistical methods.

When a Type II error is committed, the test fails to detect a real change; i.e., the null hypothesis of no trend is mistakenly accepted . To some degree, monitoring program design provides control over Type II error. The risk of Type II error (β) and the "power" ($1-\beta$) of the hypothesis test to detect real changes depend upon the following factors (Walker, 1998):

1) The choice of statistical method. This will depend upon the statistical properties of the variable being considered, design of the monitoring program, and expected time scale of the response to management measures. Depending upon dataset characteristics, some methods will be more powerful (have lower β) than others (Helsel & Hisrch, 1992).

2) The specified significance level of the hypothesis test (α) . This determines the maximum risk of a Type II error ($\beta_{max} = 1 - \alpha$), which occurs when the real change is infinitesimally small. For a small change and $\alpha = 0.05$, the risk of a type II error is 0.95 and the power (probability of detecting) the change would be only 0.05. Power increases with the magnitude of change.

3) The magnitude of the change to be detected. This would reflect a shift that is considered "significant" from a resource management perspective (e.g., change in classification). Power for detecting smaller changes would not be used as a basis for sampling design.

4) The number of years of monitoring. Power increases with the duration of the program. The total duration of the AMP is specified at 15 years and the frequency of biological measurements is, for the most part, biennial (every other year). With respect to program design, the only degree of freedom here would be to increase the sampling frequency, i.e., shift from biannual to annual sampling if more power is needed.

5) Random year-to-year variability ("noise") in the measured parameter. Year-to-year variations in the data reflect:

   a) True variations in biological populations. These may be driven by random variations in climate, hydrology, or biological processes. They are independent of the monitoring program design.

   b) Random errors in measuring the population mean within each year. These depend on within-year spatial & temporal variability, random sampling & analytical errors, and spatial & temporal sampling frequencies. This component is sensitive to monitoring program design.

Because of the last factor (5b), high precision (low measurement error) is a key objective in designing monitoring plans to detect changes over time. If measurement error is low relative to random year-to-year variations in the populations (5a), power for detecting trends will be relatively insensitive to further increases in sampling frequency. Precision is also important for characterizing current lake condition in relation to standards, criteria, or other reference lakes.

High accuracy (low bias) is another design objective. Accuracy may be influenced by spatial & temporal distribution of samples, sampling procedures, and analytical methods. It is assumed that accuracy will be controlled by locating stations in representative areas and by using state-of-the art-sampling and analytical procedures that meet or exceed NYSDEC guidance manuals (NYSDEC, 1989; Forney et al., 1994). Accuracy is more important for comparing lake conditions with standards, criteria, or reference lakes than for detecting relative changes over time. In measuring relative abundance (e.g., catch per unit effort) the concept of accuracy has no meaning, since the true number of organisms is not being counted. Precision and consistency of methods over time are the important factors in this case.

The AMP (Onondaga County, 1998, p. 39) discusses a target value of 20% for the relative standard error (RSE) of population means. The sampling designs are evaluated below by comparing the estimated precision of means computed on various spatial scales (station, region, lakewide) and temporal scales (sampling date, year) with the 20% RSE criterion. Yearly means are emphasized because they control power for detecting long-term trends. The "yearly mean" value reflects the relevant sampling season for each parameter (e.g., Fall, May-September), not necessarily the entire calendar year.

Depending upon inherent variability in the biological populations and practical constraints on the measurement process, it may not be feasible to attain the 20% RSE goal for each monitored parameter. The difficulty in attaining this level of precision for biological parameters is demonstrated by Phase I results (Walker, 1999). Even with the recommended increases in sampling frequency from biweekly to weekly, RSE values for chlorophyll-a (28%) and bacteria (31%) are still well above RSE for nutrients (5-9%), sampled at a biweekly frequency. An RSE of 20% may not be necessary to adequately classify the lake relative to other lakes or relative to independent ranking criteria or to detect a change with a magnitude that is considered significant from a resource perspective. For example, Canton & Chadwick (1988) evaluated sampling programs for stream benthic macroinvertebrates using a precision criterion of 40%. As a practical alternative to achieving an arbitrary level of precision, cost-effectiveness (increases in precision per unit per unit of additional sampling effort) can be as a basis for evaluating sampling program design.

Variance Component Models

Variance component models are useful in sampling program design because they explicitly represent the magnitudes and sources of measurement variations and their sensitivity to sampling intensity (Snedecor & Cochran, 1989; Walker, 1998). As discussed in the previous section, power for trend detection is strongly dependent on the total year-to-year variance in the measurement:

$$V_T = V_Y + E$$

V_T = total year-to-year variance in measurement (as CV^2)
V_Y = true year-to-year variance in measured population
E = random measurement error in yearly mean value = RSE^2

Although any consistent set of units can be used, variance components are expressed here as squared coefficients of variation (CV^2). The 20% RSE objective for the AMP corresponds to an E value of 0.2^2 or 0.04.

Depending upon the frequency distribution of the measurements, transformation of the original measurements (e.g., square roots or logarithms) may be appropriate to promote normality and satisfy assumptions of the statistical methods used in testing hypothesis. Variance components can be estimated on transformed data. CV^2 values are approximately equal to the variances of ln-transformed data (Snedocor & Cochran,1989). This is convenient because logarithmic transformations are frequently appropriate for water quality and biological data (Green,1979; Forney et al, 1994).

The V_Y term is an inherent system characteristic that is independent of the sampling program design. In practice, the V_Y term cannot be measured directly, but can be estimated from the observed total variance (V_T) and independent estimates of the measurement error component (E). Equations relating measurement error on various spatial scales (sample, depth, station, lake-wide) to sampling intensity are described below. The model formulations described below provide an initial framework for evaluating AMP designs. It is likely that both model structures and parameter estimates will evolve as data are collected and analyzed over the course of the AMP.

The following equation can be used to estimate measurement error for a monitoring program tracking the average yearly value at a given station or stratum, sampled at different depths with replication:

$$E_S = V_D / N_D + V_Z / N_D N_Z + V_R / N_D N_Z N_R$$

where,

E_S = measurement error (RSE^2) in yearly station or stratum mean
V_D = random, within-year temporal variance
V_Z = random variance with depth at a given station on a given date
V_R = variance among replicates
N_D = number of sampling dates per year
N_Z = number of sampled depths
N_R = number of replicates per sampling date

This equation represents a three-stage sampling design based upon a three-factor nested random analysis of variance model (Snedecor & Cochran, 1989). Depending on the magnitude of the individual terms, measurement error can be reduced by increasing the numbers of sampling dates, depths, and/or replicates. The dimensions of the equations (date, depth, replicates) are modified, as appropriate, to reflect the dimensions of the sampling design for each biological parameter. Because replicate variance term is divided by a relatively large number (N_D N_Z N_R = total number of samples collected at the station over the year), total measurement error is often insensitive to the number of replicates.

The date term reflects random temporal variations within each year. Fixed seasonal variations (regular seasonal patterns) would not be included because it is assumed that such variations would be factored out of trend tests (conducted using the seasonal Kendall test, for example). Provided that the sampling program is consistent from year to year, fixed seasonal variations would not influence the time series of annual means tested for trends or step changes. Within-year temporal variations in general would not be a factor in biological measurements which are conducted regularly in a specific season (for example, macroinvertebrates). In these cases, it would not be possible to repeat the measurements more than once in each year ($N_D = 1$), but it may be possible to improve precision by increasing the number of replicates (N_R).

The depth term reflects random variance within the sampled depth interval for each station and date. Under the current AMP design, only pelagic fish larvae and littoral macroinvertebrates will be sampled at multiple fixed depths. Assuming that the monitoring program design is consistent from year to year, fixed variations with depth (consistent from year to year) would not contribute to variability in the time series of annual means tested for trends and are not considered in estimating measurement error.

A two-stage model can be used for parameters that are not sampled with depth:

$$E_S = V_D / N_D + V_R / N_D N_R$$

A one-stage design is used for variables that are sampled only once per year at each station with replication:

$$E_S = V_R / N_R$$

If there is no replication, ($N_R = 0$), there is no basis for estimating measurement error.

For some parameters, a spatial component is added to estimate measurement error variance in the yearly lake-wide mean:

$$E_L = V_D / N_D + V_S / N_D N_S + V_Z / N_D N_S N_Z + V_R / N_D N_S N_Z N_R$$

where,

E_L = measurement error (RSE^2) in yearly lake mean
V_S = random spatial variance on each sampling date
N_S = number of stations

This equation represents a four-stage sampling design based upon a four-factor nested analysis of variance (Snedocor & Cochran, 1989). The equation assumes that the lake-wide mean is computed as the linear average of the station means on each date. If the mean is computed using weighted average across stations (stratified design based upon relative surface areas or shoreline length, for example), the last three variance terms would be weighted accordingly. This might apply, for example, to the stratified design used measure macrophyte biomass.

The random date variance terms (V_D) for the station and lake-wide means are assumed to be equal. This is equivalent to assuming that random temporal variations are correlated across stations. To the extent that this is not the case, the above equation would over-estimate E_L, since the uncorrelated portion of V_D would be divided by N_D and N_S (vs. N_D alone). This assumption leads to a conservative assessment of precision.

The spatial variance component (V_S) term reflects random spatial variance on a given sampling date. Fixed spatial variations (consistent from year to year) would not contribute to variability in the time series of annual means tested for trends. Fixed spatial variations would also be factored out if tests for trends are based upon a two-way analysis of variance (stations x time period).

Power Estimation

Power estimates are developed for one-tailed hypotheses tested with a t-test (step change in a direction that would reflect an improvement) or regression (linear trend). In practice, non-parametric methods (e.g., Seasonal Kendall, Mann-Whitney, Kruskal-Wallis) may be used to test for trends or step changes because they are more robust and powerful than parametric methods (linear regression, t-test) in the presence of outliers or departures from normality (Helsel & Hirsch, 1992; Gilbert, 1987). Simple equations for estimating the power of non-parametric procedures have not been developed, however. Using simulation techniques, Lettenmaier (1975) demonstrated that, as compared to parametric methods, nonparametric methods have slightly less power but similar response to sampling frequency when applied to normally distributed data. Nonparametric methods typically have higher power when applied to data that are not normally distributed or contain outliers (Helsel & Hirsch, 1992).

Future management measures will be implemented over a period of years. Chemical and biological responses to these measures may occur over a range of time scales. It is unlikely that either a step increase or linear trend will be the ideal model for observed lake responses. The choice of model will be determined by the sequence of management actions and observed patterns in the data. For these reasons, power estimates developed below for the t-test and linear regression provide approximate estimates of the power of hypotheses tested under the AMP.

If a one-tailed test is used to test for a hypothetical step increase in a given parameter, based upon n years of data before & after a hypothetical change, the following equations describe the hypothesis test and power estimation (Lettenmaier, 1975; Walker, 1998):

$$H_O: \quad D <= 0$$

$$t = D_M \; (n / 2)^{1/2} / CV_T$$

$$\text{Reject } H_O \text{ if: } \quad t > t_{\alpha,dof}$$

$$dof = 2n - 2$$

$$N_T = D \; (n / 2)^{1/2} / CV_T$$

$$\text{Power} = 1 - \beta = F(N_T - t_{\alpha,dof}, dof)$$

Where,

H_O = null hypothesis
D = actual step increase in long-term mean
D_M = measured step increase in long-term mean, as a fraction (0.5 = 50% increase)
N_T = dimensionless trend number
CV_T = random year-to-year coefficient of variation, $CV_T = V_T^{1/2}$
$t_{\alpha,dof}$ = one-tailed t-statistic with significance level α and dof degrees of freedom
F = cumulative distribution of Student’s t with dof degrees of freedom
Power = probability of detecting change (rejecting null hypothesis)
α = assumed significance level for test = maximum risk of Type I error
β = risk of Type II error for a change of magnitude D

These equations assume that CV_T is estimated from the data. The corresponding equations for a linear trend tested by linear regression with m years of data are:

$$H_o : \quad B <= 0$$

$$N_t \quad = \quad B \quad [\, m\,(m-1)\,(m+1)\,]^{1/2} \;/\; [\, 12^{1/2}\, CV_T \,]$$

$$B_A \;=\; B / k$$

$$dof \;=\; m - 2$$

$$\text{Power} \;=\; 1 - \beta \;=\; F\,(\, N_t - t_{\alpha,dof}\,,\, dof\,)$$

where,

N_t	=	dimensionless trend number
m	=	number of sampled years
B	=	trend, fraction per sampled interval (e.g. 0.1 = 10% increase per interval)
B_A	=	trend magnitude, fraction per year (e.g. 0.1 = 10% increase per year)
k	=	sampling interval (1=every year, 2 = every other year, etc.)

Under the AMP, most biological parameters will be sampled every 2 years for a period of 12 years. This provides approximately 3 years of baseline and 3 years of post-implementation data (n=3, m=6).

Figure 1 shows the dependence of power on the change magnitude (D = 0 to 2) and year-to-year variability (CV_T = .1 to .7) for α = 0.05. The CV_T range roughly corresponds to values estimated for various chemical and biological parameters based upon historical data from Onondaga & other regional lakes (see below). The bottom of Figure 1 shows "S80" values (defined as the step increase detectable with 80% confidence or β = 0.2) for significance levels ranging from 0.01 to 0.2. These values are derived by specifying β and back-solving the above equations for D. Corresponding results for a linear trend test are shown in Figure 2. The 80% power level is used as a sampling design criterion in the NYDEC Percid Sampling Manual (Forney et al., 1994)

The CV_T values in Figures 1 and 2 reflect the combined influences of random year-to-year variations in the biota and measurement error. The latter is reflected by the AMP precision target (RSE <= 0.2). In the absence of inherent year-to-year variations, a program designed with this level of precision would be able to detect step increases >=50% or linear trends >=7% per year with 80% confidence. With less precision (RSE = 0.3), corresponding values would be 75% and 10% per year, respectively. These values are read from the bottom panels of Figures 1 & 2 with α = 0.05. They represent optimistic estimates of power, since random year-to-year variations would be expected in all biological populations.

Evaluation Criteria

Using methods described above, the following statistics are computed for each parameter and used as a basis for evaluating the AMP design:

- Precision (RSE) of the Yearly Mean vs. 20% Target (Primary Criterion)
- CV of the Yearly Mean
- Precision (RSE) of the 3-year Mean (~Baseline)
- Power for Detecting Step Increases of 25, 50, & 100%
- S80 = Step Increase Detectable with 80% Confidence (%)
- Power for Detecting Linear Trends of 3 , 5, and 10 %/yr.
- T80 = Linear Trend Detectable with 80% Confidence (%/yr)

The above criteria are computed for station and/or lake-wide yearly means, as appropriate for each parameter.

Primary emphasis is placed on precision (RSE) of the yearly mean because (1) it is directly related to the design of the sampling program and (2) a target (RSE<=20%) has been specified for the AMP. The remaining criteria depend on the RSE and on random year-to-year variance. The latter is both beyond the control of the monitoring program and impossible to determine without a multi-year data sets collected with consistent protocols. Since such data sets do not exist for the biological parameters considered in this report, random year-to-year CV's in the range of 0.1 to 0.3 are assumed. This is based upon the estimate for chlorophyll (0.19) derived in Phase I (Walker, 1999). The 3-year mean is relevant for establishing average baseline (1999-2004) conditions and for classifying the lake relative to other reference lakes or independent criteria (e.g., trophic state).

To reflect uncertainty in variance component estimates, Monte-Carlo simulation techniques (Reckhow & Chapra, 1983) are used to predict the expected ranges of these criteria for assumed ranges of variance components. Variance component estimates are drawn from uniform distributions with ranges derived from literature references or historical Onondaga Lake data. The frequency distribution of each predicted performance measure is expressed in terms of the 80% confidence interval (10^{th}, 50^{th}, and 90^{th} percentile).

The following values are computed for each parameter, spatial scale, and performance measure:

- Median Estimate for AMP Design
- 10^{th} Percentile for AMP Design
- 90^{th} Percentile for AMP Design
- Median Estimate, Doubling the Number of Replicates
- Median Estimate, Doubling the Number of Sites (or Transects)

- Median Estimate, Doubling the Number of Years (Yearly vs. Biennial Sampling)

Results illustrate both the uncertainty in the estimates and the sensitivity to monitoring frequencies.

The analysis focuses on measures of abundance or relative abundance. Monitoring plans for the biological parameters list a wide range of indices (species richness, diversity, length distributions, growth rates, etc.) that will be computed from the data and are of interest from a management perspective. Because of the patchiness and temporal variability of biological populations, measurements of abundance are likely to be less precise than measurements of species composition or size distribution. Thus, if the RSE criterion is met for abundance, it is likely that it will also be met for the other indices. This is demonstrated below based upon 1999 macroinvertebrate and historical fish data from Onondaga Lake.

It will be feasible to evaluate precision and power for all relevant indices using data from the first full year of AMP biomonitoring (2000). The full range of indices is evaluated below for lake and tributary benthic macroinvertebrates, which were sampled in 1999.

Calibration

Introduction

Variance components for most parameters are estimated from literature references and/or historical data from Onondaga Lake. Variance components for macro-invertebrates are estimated from 1999 AMP data. In other cases, there is no direct basis for initial calibration and "reasonable assumptions" are made. These assumptions will be refined as AMP data become available in the future.

Generally, historical data provide estimates of total year variance (V_t), but do not allow partitioning into the real (V_y) and measurement error (E) components. These initial values probably over-estimate actual AMP values because (a) they are extrapolated from other programs with various degrees of intensity and consistency; and (b) historical data may not have been collected with the state-of-the-art methods that will be used under the AMP.

Estimates of variance components derived from real data are themselves highly variable. For example, assume that total year-to-year variance for a given parameter is estimated at $V_T = 0.04$ ($CV_T = 0.2$) based upon 5 years of monthly data. The 90% confidence interval for CV_T would be 0.03 to 0.65 (Snedecor & Cochran, 1989). For this reason, it may be unwise to make radical changes in the AMP design based upon historical variance component estimates.
Multi-year data sets collected with a consistent protocol would be required to estimate random year-to-year variance (V_Y). Such data sets do not exist for the biological

parameters considered in this report. Year-to-year CV's for water quality parameters measured in the epilimnion at the Lake South station range from $CV_Y = 0.06$ to 0.3 (Walker, 1999). A range of 0.1 to 0.3 is assumed for biological parameters. This assumption influences the power estimates (S80, T80), but not the annual precision estimates (RSE).

Replicate Variability vs. Abundance

Published relationships between replicate variance and abundance for various biological measurements (Table 2) provide one basis for calibration. In general, the relative precision of organism counts tend to improve as the total count increases; i.e., abundant organisms can be counted more precisely than scarce ones (Green, 1979). Relationships have been published for macrophyte biomass (Downing & Anderson, 1985), electro-fishing (Miranda et al., 1996), fish larvae (Cyr et al., 1992), zooplankton (Downing et al., 1987), and stream benthic macroinvertebrates (Canton & Chadwick, 1988). The models predict replicate variance (S^2) as a function of abundance (X) and other independent variables, (e.g., sampler area for macrophytes, run duration for electrofishing, and sample volume for fish larvae).

Table 3 shows replicate CV's (= S / X) against abundance for each model over the abundance range represented in its calibration data set . CV's are highest for fish. The estimated CV range for electro-fishing derived for largemouth bass sampling in Mississippi reservoirs (0.6 to 1.2) is similar to the reported CV range for yellow perch and walleye sampling in New York lakes (0.64 - 0.93, Forney et al., 1994).

Historical Fish Data

Table 4 and Figure 3 describe typical year-to-year variability in fish (yellow perch & walleye) population measurements for New York lakes, as derived from the NYSDEC Percid Sampling Manual (Forney et al., 1994). Year-to-year CV's have been estimated from the means and ranges listed in the manual using method described by Snedocor & Cochran (1989). The summary includes measures of relative abundance based upon nets, electro-fishing, and angler catch rate. Variability appears to be similar for these three measures. For yellow perch, the median year-to-year CV is 0.39 and 80% of the values range from 0.18 to 0.88. For walleye, the median year-to-year CV is 0.47 and 80% of the values range from 0.18 to 1.80. Other historical fish data from Onondaga Lake (Ringler et al., 1995; Effler, 1995; Arrigo, 1998; Gandino, 1996; Tango, 1999) are used to estimate spatial and temporal variance components, as indicated in footnotes to the worksheets in Appendix A.

The year-to-year CV's reflect the combined effects of true year-to-year variability, seasonal variability (to the extent that lakes were not sampled precisely in the same season of each year), method variability (to the extent that methods and/or sampling designs were not consistent from year to year). It is likely that year-to-year CV's will be lower for AMP data,, given that it will be collected consistently from year to year using state-of-art procedures and with sampling intensity that meets or exceeds NYSDEC guidance manuals.

Fish populations are generally characterized by species in terms of relative abundance (catch per unit effort), size distribution, growth rates, stock density, etc. (Forney et al, 1994; NYSDEC,1989). Because of high temporal and spatial variance (patchiness), measurements of relative abundance (catch per unit effort) are generally more variable than the other measurements of size and species composition (Forney et al., 1994). Table 5 summarizes year-to-year variability in various fish population measurements from Onondaga Lake and other regional lakes. Median year-to-year CV's are 0.71 for catch per unit effort, as compared with 0.13 for whole lake fish nest count, 0.07 for survival rate, 0.08 for growth rate (length at age), 0.09 for proportional stock density, and 0.31 for relative stock density. Corresponding power estimates are shown in Figure 4.

Although the CV estimates cannot be applied directly to the AMP designs, the historical data suggest that changes in relative abundance will be more difficult to detect than changes in these other fish population parameters. This is important because the latter may be more important as measures of ecosystem health. A consensus should be reached on the most important indicator variables for measuring ecosystem health and their relevant scales. This will provide a better basis for evaluating the adequacy of the sampling program design.

Results for Abundance Measurements

Appendix A contains worksheets with assumptions and results for each of the following biological measurements:

- Phytoplankton
- Zooplankton
- Macrophyte Biomass
- Stream Macroinvertebrates
- Lake Littoral Macroinvertebrates
- Fish Nests
- Littoral Larvae
- Pelagic Larvae
- Pelagic Gill Nets
- Littoral Trap Nets
- Juvenile Fish (Seines)
- Adult Fish (Electrofishing)

Each worksheet contains a summary of the AMP design, variance component estimates, and evaluation criteria for each spatial scale. Results are summarized over all parameters in Table 6. For comparison purposes, Table 7 lists the same criteria for water quality variables evaluated in Phase I (Walker, 1999). Results for displayed in the following figures:

Figure 5 Precision of Yearly Means
Figure 6 Increases Detectable with 80% Confidence
Figure 7 Trends Detectable with 80% Confidence
Figure 8 Sensitivity of Precision to Increases in Sampling Frequency
Figure 9 Sensitivity of Detectable Change to Increases in Sampling Frequency

Results in the above figures refer to the largest relevant spatial scale for each parameter (station for tributary and littoral macroinvertebrates, phytoplankton, & zooplankton and lake for the remaining parameters). Results for other scales are listed on the worksheets in Appendix A. Except were noted, the RSE values discussed below refer to 50th percentile estimates.

Median RSE estimates are summarized as follows:

RSE	**Parameter**
0 - 20 %	Fish Nests, Macrophytes, Nutrient Concentrations, Transparency, Littoral Macroinvertebrates, Adult Fish
21 – 25%	Littoral Larvae, Pelagic Larvae, Juvenile Fish, Trap Nets
26 – 30%	Tributary Macroinvertebrates, Zooplankton, Chlorophyll-a
31 – 35%	Phytoplankton, Fecal Coliforms, Gill Nets

Confidence intervals (10th to 90th percentiles) for the RSE estimates range from ±2 to ±12% (Figure 5). These intervals are wide, considering that one objective is to compare the predicted values with the 20% criterion.

With the exception of gill nets, the RSE estimates are less than those derived and deemed acceptable for chlorophyll-a and fecal coliforms under Phase I. The 20% criterion may be unrealistic for most of these abundance measurements, considering that inherent variability and sampling difficulties for organisms in upper trophic levels are probably greater, as compared with lower levels (especially in the case of fish populations).

The overall range of RSE values for Phase II biological variables is 6% (fish nests) to 33% (gill nets). Increases detectable with 80% confidence range from 41 to 97%. Trends detectable with 80% confidence range from 5 to 13 % per year.

Without gill nets, the RSE range is 6% to 23%. The gill net value is for estimating the lake mean. This reflects that fact that only two sites (one in each basin) are sampled under the monitoring plan. If the number of replicates were doubled (from 4 to 8), the RSE would be 31%. If the number of sites were doubled (from 2 to 4), the RSE of the lake mean would be 24%. This is within the range of the results for the other biological variables. These results indicate that doubling the number of sites would be appropriate, if abundance measurements are important for gill nets.

As recommended by NYSDEC (Forney et al., 1994), electrofishing is the primary method for sampling fish populations in the Lake. The primary function of the trap net and gill surveys is to determine whether electrofishing is capturing a representative sample of the fish community (Ecologic, 1999). The relatively high RSE values for trap nets, gill nets, and seines (juveniles) may be of little significance, especially if other indices (stock density, growth rate, etc.) are more important than abundance to measure the health of fish populations. As demonstrated above (Table 5, Figure 4), precision is likely to be much higher for these other indices.

Results for Macroinvertebrate Indices

This section evaluates the AMP design for lake & tributary macroinvertebrates using data collected under the AMP in 1999. The evaluation is based upon indices and summary statistics provided by Ecologic. Results for lake littoral samples are listed in Table 8. Results for tributary samples are listed in Table 9 (Multi-Plate samples) and Table 10 (Kick Samples). The tables list the mean, relative standard error, and CV among replicates for each site. Corresponding power estimates for each program are summarized in Table 11.

For the tributary data, RSE values are computed directly from the CV's among replicates and the number of replicates at each site. The lake sampling design is more complex (2 transects, 3 depths per transect, 6 replicates). A total of 6 locations are sampled at each site. RSE values are computed from the CV's across locations and the number of locations. This accounts for random spatial (transect or depth) effects that may be present at a given site.

Figure 11 plots relative standard errors for each sampling program and index. RSE values are consistently below 20%, except for total abundance based upon tributary multi-plate samples (RSE = 0.28). RSE values for diversity and richness indices are consistently lower than RSE values for abundance or density. The importance of total abundance relative to the other indices would determine whether an increase in the number of replicates is appropriate.

Aside from detecting trends, detecting spatial variations is another objective of the program. These include upstream/downstream variations in each tributary and regional variations in the lake. Spatial variations in the indices (means ± 1 standard error) are plotted in Figure 12 (lake) and Figure 13 (tributary multiplate). For the abundance and density measures, standard errors are positively correlated with the site mean values. This indicates that a log transformation would be appropriate for statistical analyses. While interpretation of the index values and spatial patterns is beyond the scope of this report, significant differences across sites are indicated for each index (confirmed by analysis of variance). Upstream/downstream trends in some of the tributary indices (abundance, EPT richness, Hilsenhoff Biotic index) are evident. The sampling design appears adequate to resolve spatial variations.

Conclusions

1. In the absence of inherent year-to-year variations, a program designed with the AMP precision criterion (RSE <= 20%), would be expected to detect step increases >=50% or linear trends >=7% per year with 80% confidence. With an RSE of 30%, corresponding values would be 75% and 10% per year, respectively. These represent optimistic estimates of power, since random year-to-year variations would be expected in all biological populations. The magnitude of such variations is unknown for all of the biological measurements.

2. Median precision estimates for water quality and bioabundance measurements conducted under the AMP are summarized in the following RSE (relative standard errors of annual means) categories:

RSE	**Parameter**
0 - 20 %	Fish Nests, Macrophytes, Nutrient Concentrations, Transparency, Littoral Macroinvertebrates, Adult Fish
21 – 25%	Littoral Larvae, Pelagic Larvae, Juvenile Fish, Trap Nets
26 – 30%	Tributary Macroinvertebrates, Zooplankton, Chlorophyll-a
31 – 35%	Phytoplankton, Fecal Coliforms, Gill Nets

3. Among the Phase II biological variables, the AMP precision criterion (RSE < 20%) is met for fish nests, macrophytes, littoral macroinvertebrates, and adult fish.

4. Confidence intervals (10^{th} to 90^{th} percentiles) for the RSE estimates range from ±2 to ±12%. These intervals are wide, considering that one objective is to compare the predicted values with the 20% criterion. The wide intervals reflect uncertainty in the variance component estimates. Re-calibration of the models to actual AMP data would improve the estimates and provide a better basis for refining the sampling plans.

5. The overall range of RSE values is 6% to 33%. Increases detectable with 80% confidence range from 41 to 97%. Trends detectable with 80% confidence

range from 5 to 13 % per year. The power estimates assume that that random year-to-year variability in each population is characterized by CV = 10 to 30%, as estimated for chlorophyll-a under Phase I.

6. With the exception of gill nets, the RSE estimates are less than those derived and deemed acceptable for chlorophyll-a and fecal coliforms under Phase I. The 20% criterion may be unrealistic for some of the bioabundance measurements, considering that inherent variability and sampling difficulties for organisms in upper trophic levels are probably greater, as compared with lower levels (especially in the case of fish populations).

7. Without gill nets, the RSE range is 6% to 32%. Doubling the number of gill net sites (from 2 to 4) would reduce the RSE value from 33% to 24%. This is within the range of values for the other biological variables. This modification is recommended if relative abundance measurements are important for gill nets.

8. Historical data on fish populations in Onondaga Lake indicate that measurements of abundance (catch per unit effort) generally have lower precision than other fish population indices (growth rates, size distributions, stock density, etc.). It is likely that the RSE's for these other indices will be below 20%. This aspect can be evaluated based upon future AMP data.

9. Based upon the 1999 AMP data, the sampling program design for lake and tributary benthic invertebrates is adequate to resolve spatial variations and provide a level of precision that that achieves the AMP objective (RSE < 20%), except for abundance measurements using tributary multi-plate samplers (RSE = 29%). The later within the range of that achieved for the other biological parameters. Qualitative indices generally have better precision than abundance measurements.

10. Although this evaluation focuses on precision, the accuracy of the measurements is important for comparing results with independent standards or criteria. Consistent sampling procedures and analytical methods should be maintained over the duration of the AMP to ensure that any apparent trends in the data reflect actual changes in the biological populations, as opposed to changes in procedures or methods.

11. To provide a better basis for evaluating the adequacy of sampling plan, it is recommended that a consensus be reached on the following aspects:

    a. Specification of the important spatial scale for each parameter (i.e., station, lake region, or lake-wide mean)

    b. Ranking of the various indices for each parameter with respect to overall significance in tracking the population, especially the relative important of abundance measurements vs. other indices (diversity, growth rate, species richness, etc.)

c. Specification of a meaningful scale for each biological measurement and (e.g., classification system)

d. Increases or changes that would be considered significant from a management perspective, including any numerical criteria or target values that would reflect management objectives.

12. It is recommended that precision be re-evaluated using the first year of AMP data for each parameter before making additional changes to the sampling plan.

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Table 1

AMP Design for Biological Parameters

Category	Years	Season	Frequency	Dates / Year	Method	Sites	Depths	Replic.	Total Samp. /Yr	Metrics	Methodology	Historical Data
Pelagic Larvae	biennial*	April-July	biweekly	7	Miller High Spd Trawl @ 2.3 mph for 5 minutes	2 (1 North,1 South), Fixed	3 (1,3,5 m)	6	6 reps x 3 depths x 2 sites x 7 dates = 252	$\#/m^3$	NYSDEC Percid Sampling Manual (1994)	No
Littoral Larvae	biennial*	April-July	biweekly	7	10 m sweeps of a 300 um larval fish seine	15 (5 Strata, 3 Sites Each)	1 (1m)	3	3 reps x 15 sites x 7 dates = 315	$\#/m^3$	NYSDEC Percid Sampling Manual (1994)	No
Juvenile Fish	biennial*	May-Sept	Every 3 weeks	7	50' x 4' x 1/4" seine	15 (5 Strata, 3 Sites Each)	< 1 m	3	3 reps x 15 sites x 7 dates = 315	c/e, l/w	NYSDEC Centrarchids Sampling Manual (1989)	Yes
Nesting Survey	biennial*	June	once	1	Visual Counts	50 Sections, Fixed	Littoral, Bottom	1	Count 50 Sections Once	count	Ringler et al. (1995)	Yes
Adult Fish Community Structure	biennial*	May-June, Sept-Oct	monthly	4	Electrofishing	24 sections, eq shoreline, 15-min incr.	< 2 m	1	24 sections x 2 seas x 2 events = 96	c/e, l/w, PSD, RSD, etc	NYSDEC Centrarchids Sampling Manual (1989)	No
Adult Fish Community Structure	biennial*	May-June, Sept-Oct	monthly	4	Gill Nets	2 Sites	Epilimnion	4 consec nights	2 sites x 4 reps x 4 months = 32	c/e, l/w	NYSDEC Percid Sampling Manual (1994)	Yes
Adult Fish Community Structure	biennial*	May-June, Sept-Oct	monthly	4	Trap Nets	5 Sites	Littoral	3 consec nights	5 sites x 3 reps x 4 mos = 60	c/e, l/w	NYSDEC Percid Sampling Manual (1994)	Yes
Angler Census **	annual											No
Photoplankton	annual	Yearly	biweekly+ monthly winter /	~ 18	2 cm tygon tube	Lake South +Lake North (3 Dates)	Epil Comp (+ Surface, 3 m)	1	18 South	count, biovolume	Ed Mills	Yes
Zooplankton	annual	Yearly	biweekly / monthly winter	~18	vertical haul, 0.2 m diameter net, 80 micron mesh	Lake South (+ 3 at quarterly North)	Epil + 12m tow ???	1	2 depths x 18 dates = 72 (South)	count, biovolume	Ed Mills	Yes
Macrophytes	twice	???	once	1	Harvest	5 Strata, based on substrate	Littoral Zone	12 (4 transescts x 3 subplots)	60 / Lake	g/m2, % cover, spec ies richness	Ecologic	Some
Macrophytes **	annual	May-June	once	1	aerial photo	Whole Lake	Whole Lake	na	na	% Cover	Ecologic	Some
Littoral Macroinvert.	biennial	fall	once	1	Dredge	5 sites x 2 transects	3	6	5 sites x 2 trans x 3 depths x 6 reps = 180	counts, indices	NYSDEC/ Ecologic	Yes
Tributary Macroinvert	biennial	fall	once	integral	Plates	14	1	3 sampled + 2 reserve	14 sites x 3 reps = 52	counts, indices	NYSDEC / Ecologic	No

* annual for first 3 years

** Statistical evaluation not performed for angler census or for macrophyte surveys via aerial photos

Published Relationships Between Replicate Variance & Abundance

S =	Standard Deviation among replicates
X =	Abundance Measure
CV =	CV among replicates = S / X

Equation	Description		
1	Downing & Anderson. 1985	Macrophyte Biomass Density	
		$\log S^2 = 0.759 + 1.567 \log X - 0.157 \log A$	
		A = Sampler Area (cm^2)	100 to 10000
		X = Density (g/m^2)	0.0001 to 1,000,000
2	Miranda et al, 1996	Largemouth bass in Mississippi Res. (Electrofished)	
		$\log S^2 = 0.375 - 0.401 D + 1.55 \log X$	
		D = Duration of Sample (hours)	.08 to 1
		X = Catch per hour	16 to 98
3	Cyr et al., 1992	Larval Fish + Young-of-Year	
		$\log S^2 = 0.19 + 1.74 \log (X)$	
		X = Organism Count = V C	1 to 10,000
		V = Sample Volume	3 to 10,000 m3
		C = Organism Conc (no./m^3)	
4	Downing et al., 1987	Zooplankton	
		$S^2 = 0.296 X^{1.849}$	
		X = Organism Count (#/Liter)	10^{-6} to 10^3
5	Canton & Chadwick, 1988	Stream Benthic Macroinvertebrates Data from 16 River Systems	
		Regression of Data Tabulated in Article:	
		$\log S^2 = -0.746 + 1.91 \log (X)$	
		X = Count Per Sample	17 to 1891

Replicate CV's vs. Abundance

Variable	Macrophytes	Electrofished Bass	Fish Larvae	Zooplankton	Stream Benthos
	A = 2500cm^2	D = 15 min	V = 300 m^3		
Metric	g/m^2	catch/hr	# / m^3	#/Liter	Count
Equation	1	2	3	4	5
Abundance					
1	1.30		0.59	0.54	
2	1.12		0.54	0.52	
3	1.02		0.51	0.50	
5	0.92		0.48	0.48	
7	0.85		0.46	0.47	
10	0.79	1.21	0.44	0.46	0.38
20	0.68	1.04	0.40	0.43	0.37
30	0.62	0.95	0.38	0.42	0.36
50	0.56	0.84	0.36	0.40	0.36
70	0.52	0.78	0.34	0.39	0.35
100	0.48	0.72	0.33	0.38	0.34
200	0.41	0.62	0.30	0.36	0.33
300	0.38			0.35	0.33
500	0.34			0.34	0.32
700	0.31			0.33	0.32
1000	0.29			0.32	0.31

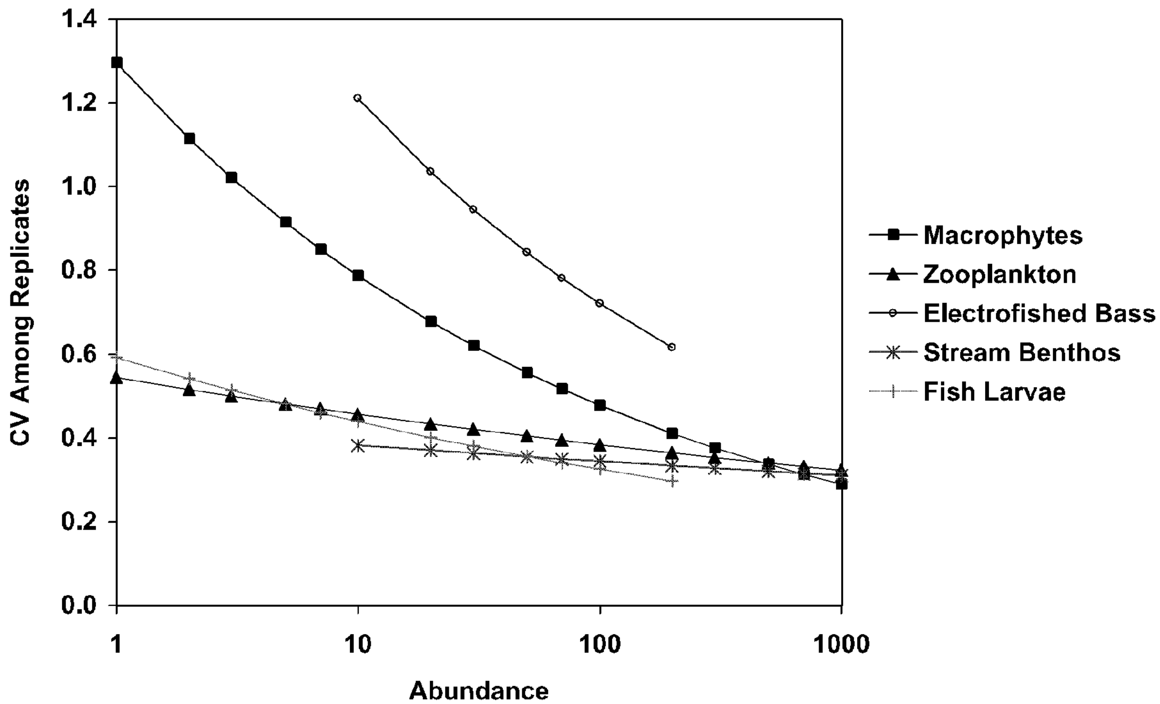


Table 4

Year-to-Year Variability in Fish Populations of New York Lakes

Forney et al (1994), Percid Sampling Manual, Tables II-2, II-3, III-4

			Yellow Perch--->				Walleye--->				
Years	**Lake**	**Period**	**Mean**	**Min**	**Max**	**CV**	**Mean**	**Min**	**Max**	**Std D**	**CV**
Standard Nets (Number)											
4	Canadarago	73-76	35.0	15.0	46.0	0.43	0.01	0.00	0.04	0.02	1.90
5	Canadarago	83-93	75.0	55.0	102.0	0.27	13.00	8.00	21.00	5.59	0.43
2	Chautauqa	78-80	1.2	1.1	1.3	0.15	7.80	4.80	10.80	5.32	0.68
2	Chautauqua	89-91	16.0	7.4	24.0	0.92	6.60	4.80	8.30	3.10	0.47
3	Whitney Point	78-91	3.8	1.7	6.8	0.79	4.40	3.70	5.00	0.77	0.17
NonStandard Nets (Number)											
12	Oneida	58-59	24.5	12.0	32.0	0.25	9.30	6.80	14.20	2.27	0.24
10	Oneida	70-79	22.7	14.0	31.0	0.24	5.10	1.90	8.60	2.18	0.43
10	Oneida	80-89	25.4	13.0	47.0	0.44	8.00	4.90	12.60	2.50	0.31
4	Oneida	90-93	14.1	10.0	17.0	0.24	3.70	2.80	5.00	1.07	0.29
Electrofishing (number/hour)											
4	Canadarago	S/O 73-6	161.0	60.0	287.0	0.69					
5	Canadarago	May 81-85	200.0	107.0	266.0	0.34	19.40	8.30	43.50	15.14	0.78
2	Canadarago	Oct 81-82	184.0	169.0	199.0	0.14	1.50	0.00	3.00	2.66	1.77
2	Canadarago	Oct 84-85					26.65	24.60	28.70	3.63	0.14
3	Eaton Brook Res.	Oct 91-93	37.0	25.0	44.0	0.30	3.60	2.30	6.30	2.36	0.66
2	Findley		120.9	79.2	162.5	0.61					
6	Friends	May 85-90	41.0	9.3	121.0	1.08	0.02	0.00	0.10	0.04	1.96
12	Ronkonkoma	May 79-90	40.0	9.0	83.0	0.57					
6	Loon Lake	May 85-90	92.0	21.0	132.0	0.48	0.08	0.00	0.20	0.08	0.98
5	Port Bay, Lake Ont	Oct 89-93	4.3	0.0	11.0	1.10	23.80	15.00	25.00	4.30	0.18
Angler Catch Rates (Creel Surveys) (number/hour)											
3	Oneida	57-59	0.20	0.13	0.31	0.53	0.15	0.04	0.34	0.18	1.18
3	Oneida (Ice)	57-59	0.30	0.25	0.38	0.26	0.39	0.11	0.53	0.25	0.64
3	Erie	88-90	1.48	0.49	2.24	0.70	0.20	0.15	0.24	0.05	0.27
4	Canadarago	73-76	0.35	0.24	0.48	0.33					
3	Dryden	65-67	0.19	0.18	0.22	0.12					
4	Dryden (Ice)	65-68	1.72	1.20	2.30	0.31					
Percentiles											
	10%		0.32			0.18	0.07			0.05	0.18
	25%		1.66			0.25	0.30			0.21	0.28
	50%		23.60			0.39	4.40			2.27	0.47
	75%		49.50			0.63	8.65			3.37	0.88
	90%		148.96			0.88	20.28			5.37	1.80

Table 5

Typical Year-to-Year CV's in Fish Population Measurements

Reference/Variable		No. of Years	Year-to-Year CV 25%	50%	75%	3-Year RSE	Step S80	Trend T80
Forney et al.(1994), Relative Abundance Measures in New York Lakes								
Yellow Perch - All Methods		2-12	0.25	0.39	0.63	0.22	97%	12%
Yellow Perch - Nets		2-10	0.27	0.43	0.79	0.25	108%	14%
Yellow Perch - Electrofishing		2-12	0.34	0.57	0.69	0.33	142%	18%
Yellow Perch - Angler Surveys		3-4	0.27	0.32	0.48	0.19	81%	10%
Walleye - All Methods		2-12	0.28	0.47	0.88	0.27	118%	15%
Walleye - Nets		2-10	0.43	0.47	0.68	0.27	118%	15%
Walleye - Electrofishing		2-12	0.42	0.78	1.38	0.45	196%	25%
Walleye - Angler Surveys		3-4	0.45	0.64	0.91	0.37	160%	20%
Tango(1999), Table 3.2 Catch Per Unit Effort, Trapnets, 1989-1994								
Bowfin		5		0.69		0.40	173%	22%
Gizzard Shad		5		0.89		0.51	222%	29%
Brown Bullhead		5		0.59		0.34	149%	19%
Channel Catfish		5		0.38		0.22	94%	12%
White Sucker		5		0.52		0.30	130%	17%
Shorthead Redhorse		5		0.76		0.44	192%	25%
Carp		5		0.39		0.23	99%	13%
Golden Shiner		5		1.53		0.88	384%	49%
Northern Pike		5		0.48		0.27	119%	15%
White Perch		5		1.22		0.71	307%	39%
Pumpkinseed		5		0.88		0.51	221%	28%
Bluegill		5		0.72		0.42	181%	23%
Smallmouth Bass		5		0.70		0.40	175%	22%
Yellow Perch		5		0.81		0.47	203%	26%
Walleye		5		0.73		0.42	183%	23%
Freshwater Drum		5		0.87		0.50	218%	28%
LargeMouth Bass		5		0.43		0.25	108%	14%
Black Crappie		5		0.33		0.19	84%	11%
Combined		5	0.49	0.71	0.85	0.41	178%	23%
Ringler et al. (1996), Fish Nests, 1991,1993-1994								
Lakewide Fish Nest Count		3		0.13		0.08	34%	4%
Gandino (1996), Table 14, Length At Age, Years 1979-1980, 1991-1994								
Smallmouth Bass	Age 0 Years	2		0.11		0.06	28%	4%
Smallmouth Bass	Age 1 Years	3		0.07		0.04	18%	2%
Smallmouth Bass	Age 2 Years	4		0.09		0.05	22%	3%
Smallmouth Bass	Age 3 Years	6		0.05		0.03	14%	2%
Smallmouth Bass	Age 4 Years	6		0.04		0.02	10%	1%
Smallmouth Bass	Age 5 Years	6		0.08		0.05	20%	3%
Smallmouth Bass	Age 6 Years	6		0.08		0.05	20%	3%
Smallmouth Bass	Age 7 Years	5		0.08		0.05	21%	3%
Smallmouth Bass	Age 8 Years	5		0.05		0.03	13%	2%
	All		0.05	0.08	0.08		20%	3%
Gandino (1996), Table 18, Survival Rates								
Smallmouth Bass		4		0.07		0.04	18%	2%
Gandino (1996), Table 29, Proportional Stock Density (PSD)								
Smallmouth Bass		4		0.08		0.05	21%	3%
LargeMouth Bass		3		0.15		0.09	39%	5%
Bluegill		3		0.01		0.01	3%	0%
Pumpkinseed		3		0.10		0.06	26%	3%
Median			0.06	0.09	0.12		23%	3%
Gandino (1996), Table 29, Relative Stock Density (RSD)								
Smallmouth Bass	RSD305	4		0.21		0.12	53%	7%
Smallmouth Bass	RSD292	3		0.22		0.12	54%	7%
Smallmouth Bass	RSD356	3		0.63		0.36	158%	20%
Smallmouth Bass	RSD430	3		0.58		0.33	145%	19%
LargeMouth Bass	RSD305	3		0.13		0.07	32%	4%
LargeMouth Bass	RSD330	3		0.31		0.18	77%	10%
LargeMouth Bass	RSD402	3		0.55		0.32	139%	18%
LargeMouth Bass	All		0.21	0.31	0.57		77%	10%

No. of Years — Number of Years Used to Calculate CV's
3-Year RSE — Relative Standard Error of 3-Year (Baseline) Mean = Standard Error / Mean, for Median CV

Power Evaluated for AMP Design (3 years per period, biennial frequency, 1-tailed test, $\alpha = 0.05$, Median CV's)
S80 — Step Increase (%) Detectable with 80% Confidence
T80 — Trend (%/yr) Detectable with 80% Confidence

Summary of Results for Phase II Biological Parameters

Variable	Scale(a)	AMP 10%	AMP 50%	AMP 90%	2X Reps 50%	2X Sites[c] 50%	2X Years 50%
Relative Standard Error of Yearly Mean							
Trib Macroinv	S	17%	29%	42%	21%		29%
Lit Macroinv	S	13%	19%	28%	18%	14%	19%
Macrophytes	L	8%	9%	11%	7%	7%	9%
Phytoplankton	S	27%	32%	37%	32%		
Zooplankton	S	21%	27%	33%	25%		
Fish Nests	L	4%	6%	9%			6%
Lit Larvae	L	18%	21%	24%	20%	15%	21%
Pel Larvae	L	18%	24%	31%	24%	22%	24%
Juveniles	L	16%	22%	29%	22%	22%	22%
Trap Nets	L	19%	22%	25%	20%	16%	22%
Gill Nets	L	29%	33%	39%	31%	24%	33%
Adult Fish	L	17%	19%	22%	18%	14%	19%
Increase Detectable with 80% Confidence (%)							
Trib Macroinv	S	63%	88%	118%	72%		61%
Lit Macroinv	S	55%	70%	91%	68%	61%	48%
Macrophytes	L	39%	55%	73%	53%	53%	39%
Phytoplankton	S	56%	66%	77%	66%		
Zooplankton	S	49%	58%	71%	56%		
Fish Nests	L	32%	41%	50%			28%
Lit Larvae	L	58%	75%	93%	75%	74%	52%
Pel Larvae	L	62%	78%	96%	78%	75%	54%
Juveniles	L	58%	75%	92%	75%	74%	52%
Trap Nets	L	61%	75%	90%	71%	64%	52%
Gill Nets	L	84%	97%	113%	92%	77%	67%
Adult Fish	L	58%	70%	85%	67%	61%	48%
Linear Trend Detectable with 80% Confidence (% / yr)							
Trib Macroinv	S	8.1%	11.4%	15.1%	9.2%		10.1%
Lit Macroinv	S	7.0%	9.0%	11.6%	8.7%	7.8%	8.0%
Macrophytes (b)	L						
Phytoplankton	S	9.1%	10.8%	12.7%	10.8%	8.7%	
Zooplankton	S	8.0%	9.6%	11.6%	9.2%	7.9%	
Fish Nests	L	4.1%	5.2%	6.4%			4.7%
Lit Larvae	L	7.4%	9.6%	11.9%	9.6%	9.5%	8.6%
Pel Larvae	L	8.0%	10.0%	12.3%	10.0%	9.7%	8.9%
Juveniles	L	7.5%	9.6%	11.9%	9.6%	9.4%	4.3%
Trap Nets	L	7.9%	9.6%	11.6%	9.1%	8.1%	8.5%
Gill Nets	L	10.8%	12.5%	14.5%	11.8%	9.9%	11.1%
Adult Fish	L	7.4%	8.9%	10.9%	8.6%	7.8%	7.9%

a Spatial Scales, S = Site, Stratum, or Region, L = Lake

b Linear trend not measureable for macrophytes (total of 2 sampling years)

c 2X Transects for Littoral Macroinvertebrates

Summary of Results for Phase I Water Quality Parameters

Lake South Epilimnion, May-September Averages

Variable	CHL-A	F-COLI	SECCHI	NH3N	TKN	TN	TP
Frequency (a)	Weekly	Weekly	Weekly	Biweekly	Biweekly	Biweekly	Biweekly
Samples/Year	18	18	18	11	11	11	11
Sampled Depths	1	1	1	3	3	1	3
Replicates	1	1	1	1	1	1	1
Years in Baseline	5	5	5	5	5	5	5
Original Variance Component Estimates (b)							
Year	0.19	0.30	0.16	0.21	0.15	0.12	0.06
Date	1.23	1.34	0.47	0.28	0.17	0.12	0.27
Depth				0.19	0.07		0.22
Replicate	0.00	0.00	0.00	0.10	0.08	0.09	0.15
Considering Replicate CV's Derived from 1999 Data (c)							
Year	0.19	0.30	0.16	0.21	0.15	0.12	0.06
Date	1.23	1.32	0.46	0.28	0.17	0.12	0.27
Depth				0.19	0.07	0.00	0.22
Replicate	0.10	0.20	0.05	0.10	0.08	0.09	0.15
RSE of Date Mean	0.10	0.20	0.05	0.12	0.06	0.09	0.15
RSE of Yearly Mean	0.29	0.32	0.11	0.09	0.05	0.05	0.09
CV of Yearly Mean	0.35	0.44	0.19	0.23	0.16	0.13	0.11
RSE of Baseline Mean	0.16	0.20	0.09	0.10	0.07	0.06	0.05
Power for Det. 25% Increase	0.25	0.18	0.58	0.45	0.73	0.87	0.94
Power for Det. 50% Increase	0.66	0.48	0.97	0.92	0.99	1.00	1.00
Power for Det. 100% Increase	0.99	0.94	1.00	1.00	1.00	1.00	1.00
Incr. Detect. with 80% Conf.	0.60	0.76	0.34	0.40	0.27	0.22	0.19
Power for Det. 3%/Yr Trend	0.18	0.14	0.38	0.29	0.49	0.65	0.77
Power for Det. 5%/Yr Trend	0.34	0.25	0.73	0.59	0.86	0.96	0.99
Power for Det. 10%/Yr Trend	0.81	0.63	1.00	0.98	1.00	1.00	1.00
Trend Detect. with 80% Conf.	0.10	0.12	0.05	0.07	0.05	0.04	0.03

Notes:

a CHL-A, F-COLI, SECCHI sampled weekly June-Aug, biweekly May & Sept

b Variance Components from Phase I Report, 1993-1997 Data, (Walker, 1999)

c Replicate CV's

	Assumed	Calculated From 1999 Lake Data - South Station	
CHL-A	0.10	0.10	6 samples
SECCHI	0.05	0.00	4 dates
F-COLI	0.20	not calculated: most replicates < detection	

Lake Littoral Macroinvertebrate Indices

	Density			Diversity			NCO Richness			Species Richness			Dominance - 3		
Site	**Mean**	**RSE**	**RepCV**	**Mean**	**RSE**	**RepCV**	**Mean**	**RSE**	**RepCV**	**Mean**	**RSE**	**RepCV**	**Mean**	**RSE**	**RepCV**
1	4719	0.21	0.68	1.55	0.09	0.14	0.86	0.60	0.46	5.08	0.17	0.26	0.95	0.03	0.05
2	16546	0.21	0.58	2.59	0.09	0.16	3.58	0.15	0.45	15.44	0.07	0.18	0.71	0.06	0.12
3	4799	0.15	0.53	2.65	0.02	0.11	2.11	0.11	0.49	11.78	0.07	0.29	0.72	0.02	0.10
4	6197	0.19	0.60	3.23	0.05	0.12	2.08	0.18	0.72	16.57	0.11	0.26	0.57	0.06	0.18
5	4547	0.13	0.57	2.56	0.04	0.11	2.22	0.08	0.33	10.67	0.03	0.26	0.72	0.03	0.09
Mean	7362	0.18	0.59	2.52	0.06	0.13	2.17	0.22	0.49	11.91	0.09	0.00	0.73	0.04	0.00
Median	4799	0.19	0.58	2.59	0.05	0.12	2.11	0.15	0.46	11.78	0.07	0.26	0.72	0.03	0.10

RSE = Relative Standard Error

Rep CV = CV among Replicates

Sampling Design: 2 Transects, 3 Depths per Transect, 6 Replicates

RSE computed from variance across means for each transect & depth (effective sample size = 6).

Tributary Macroinvertebrate Indices - Multiplate Samples

	Species Richness			Diversity			EPT Richness			Hilsenhoff Biotic Index			Total Abundance		
Site	**Mean**	**RSE**	**RepCV**	**Mean**	**RSE**	**RepCV**	**Mean**	**RSE**	**RepCV**	**Mean**	**RSE**	**RepCV**	**Mean**	**RSE**	**RepCV**
HB 1	21.2	0.06	0.13	2.31	0.17	0.38	1.20	0.31	0.70	7.19	0.04	0.08	1128.0	0.25	0.57
HB 2	28.4	0.09	0.20	4.23	0.02	0.05	1.00	0.32	0.71	6.11	0.01	0.02	227.2	0.37	0.83
HB 3	15.2	0.07	0.16	1.74	0.08	0.18	0.20	1.00	2.24	8.17	0.01	0.03	340.4	0.34	0.75
HB 4	19.2	0.08	0.18	3.41	0.02	0.05	0.40	0.61	1.37	8.25	0.02	0.06	90.2	0.30	0.66
LC 1	19.2	0.11	0.24	3.21	0.06	0.15	0.00	0.00	0.00	6.77	0.02	0.04	383.0	0.46	1.03
LC 2	19.2	0.16	0.36	3.21	0.08	0.17	0.00	0.00	0.00	7.27	0.03	0.07	143.8	0.25	0.57
LC 3	20.4	0.07	0.15	2.97	0.04	0.09	0.00	0.00	0.00	8.26	0.02	0.03	555.0	0.36	0.79
LC 4	21.0	0.13	0.28	2.80	0.08	0.17	0.20	1.00	2.24	8.75	0.01	0.02	877.6	0.21	0.47
OC 1	32.4	0.03	0.06	4.14	0.01	0.02	2.60	0.09	0.21	5.89	0.01	0.02	278.8	0.11	0.24
OC 2	17.6	0.07	0.15	2.45	0.04	0.09	3.00	0.11	0.24	7.09	0.01	0.03	139.0	0.15	0.33
OC 3	20.8	0.10	0.21	3.30	0.02	0.05	1.80	0.41	0.91	6.64	0.01	0.01	252.9	0.24	0.54
OC 4	29.6	0.03	0.06	3.58	0.04	0.09	6.40	0.06	0.14	6.10	0.01	0.02	582.8	0.14	0.32
OC 5	38.0	0.06	0.14	4.36	0.02	0.05	4.80	0.24	0.54	7.00	0.02	0.05	431.9	0.35	0.78
OC 6	19.4	0.11	0.24	2.73	0.06	0.14	0.00	0.00	0.00	8.73	0.01	0.03	509.2	0.57	1.27
Mean	23.0	0.08	0.18	3.17	0.05	0.12	1.54	0.30	0.66	7.30	0.02	0.04	424.3	0.29	0.65
10%	18.1	0.04	0.08	2.35	0.02	0.05	0.00	0.00	0.00	6.10	0.01	0.02	140.4	0.15	0.33
50%	20.6	0.07	0.17	3.21	0.04	0.09	0.70	0.17	0.39	7.14	0.01	0.03	361.7	0.28	0.62
90%	31.6	0.12	0.27	4.20	0.08	0.18	4.26	0.88	1.98	8.59	0.03	0.06	789.2	0.43	0.97

Sampling Design: 5 Replicates Per Site
RSE = Relative Standard Error = Standard Error / Mean = RepCV / $5^{1/2}$
RepCV = CV among Replicates

Transfer to Plot

Index	RSEL	Median	RSEH
Species	0.04	0.07	0.12

Table 10

Tributary Macroinvertebrate Indices - Kick Samples

		Species Richness			EPT Richness			Hilsenorf Biotic Index			Percent Model Affinity		
Site	Reps	Mean	RSE	RepCV	Mean	RSE	RepCV	Mean	RSE	RepCV	Mean	RSE	RepCV
HB 1	3	18.33	0.24	0.41	3.00	0.38	0.67	4.80	0.04	0.07	33.67	0.27	0.47
OC 1	2	22.00	0.32	0.45	5.00	0.20	0.28	4.40	0.05	0.06	47.50	0.31	0.43
OC 3	3	18.33	0.07	0.11	7.00	0.08	0.14	5.43	0.02	0.03	53.00	0.16	0.27
OC 4	2	15.00	0.07	0.09	5.00	0.00	0.00	5.34	0.01	0.01	63.00	0.06	0.09
Mean		18.42	0.17	0.27	5.00	0.17	0.27	4.99	0.03	0.05	49.29	0.20	0.32
Median		18.33	0.15	0.26	5.00	0.14	0.21	5.07	0.03	0.05	50.25	0.21	0.35

RSE = Relative Standard Error = Standard Error / Mean
RepCV = CV among Replicate Samples
Reps = Number of Replicate Samples

Power of AMP Macroinvertebrate Sampling Designs

			Power for Detecting Step Change Hypothetical Increase (%)				Power for Detecting Linear Trend Hypothetical Trend (%/yr)			
Program	Index	RSE	25%	50%	100%	S 80	3%	5%	10%	P 80
Lake	Density	0.195	0.30	0.82	0.99	0.49	0.31	0.63	0.98	0.06
	Diversity	0.045	1.00	1.00	1.00	0.11	1.00	1.00	1.00	0.01
	NCO Richness	0.151	0.46	0.94	1.00	0.38	0.44	0.82	1.00	0.05
	Species Richness	0.074	0.94	1.00	1.00	0.19	0.93	1.00	1.00	0.02
	Dominance - 3	0.031	1.00	1.00	1.00	0.08	1.00	1.00	1.00	0.01
Trib Multi	Species Richness	0.075	0.94	1.00	1.00	0.19	0.92	1.00	1.00	0.02
	Diversity	0.041	1.00	1.00	1.00	0.11	1.00	1.00	1.00	0.01
	EPT Richness	0.173	0.37	0.88	1.00	0.43	0.36	0.72	0.99	0.06
	Hilsenhoff Biotic Index	0.014	1.00	1.00	1.00	0.04	1.00	1.00	1.00	0.00
	Total Abundance	0.275	0.18	0.53	0.96	0.69	0.19	0.39	0.88	0.09
Trib Kick	Species Richness	0.066	0.97	1.00	1.00	0.16	0.96	1.00	1.00	0.02
	EPT Richness	0.082	0.91	1.00	1.00	0.21	0.88	1.00	1.00	0.03
	Hilsenorf Biotic Index	0.017	1.00	1.00	1.00	0.04	1.00	1.00	1.00	0.01
	Percent Model Affinity	0.157	0.43	0.92	1.00	0.39	0.42	0.79	1.00	0.05

RSE & Power Calculated for Median Replicate CV's & 6 sampling events (every other year for 12 years)
S80 = Step Increase Detectable with 80% Confidence (%)
T80 = Linear Trend Detectable with 80% Confidence (%/year)

List of Figures

1 Power for Detecting Step Changes vs. Yearly CV & Significance Level

2 Power for Detecting Linear Trends vs. Yearly CV & Significance Level

3 Year-to-Year CV's of Fish Abundance Measurements in New York Lakes

4 Power of Historical Monitoring Programs for Detecting Changes in Fish Pop.

5 Precision of Yearly Means

6 Increases Detectable with 80% Confidence

7 Trends Detectable with 80% Confidence

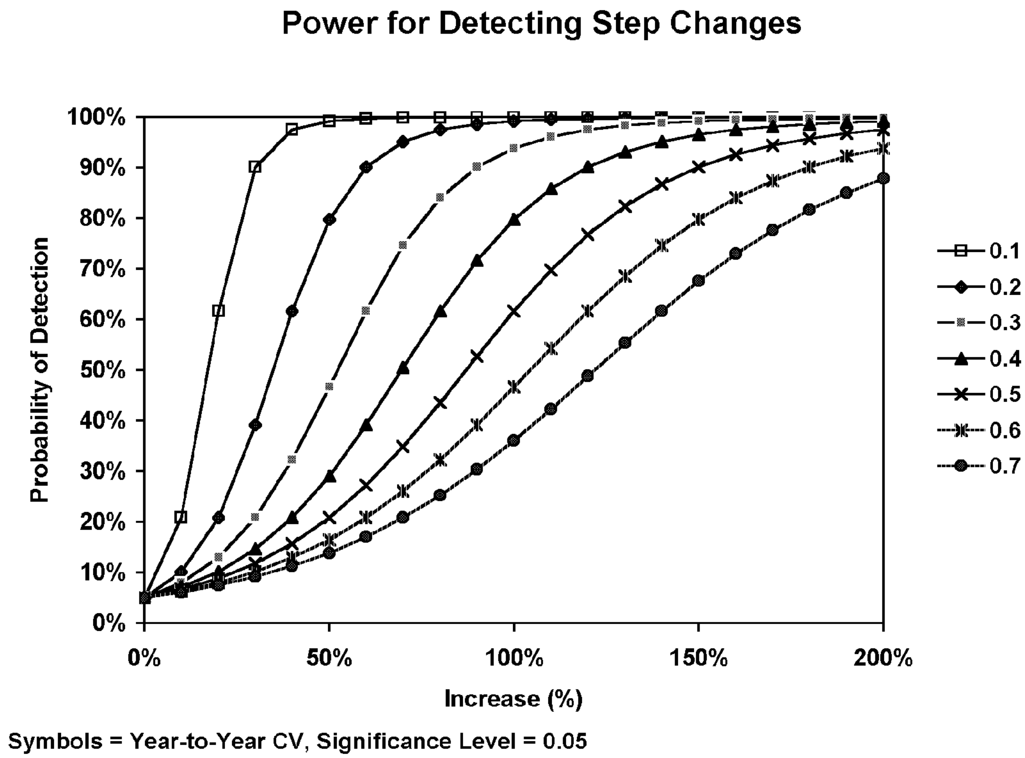
8 Sensitivity of Precision to Increases in Sampling Frequency

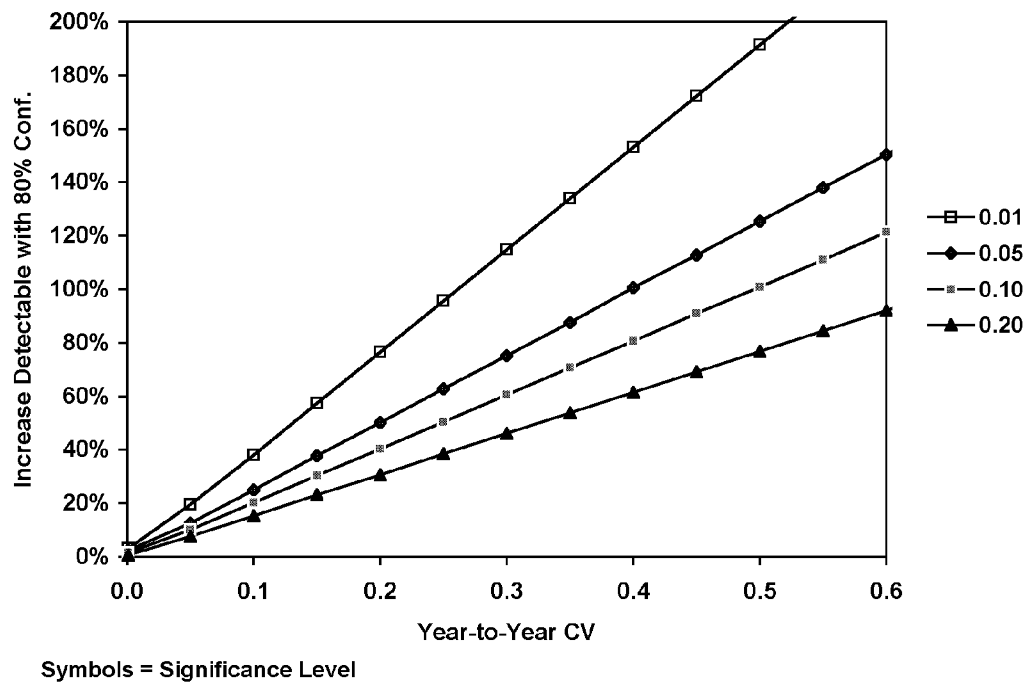
9 Sensitivity of Detectable Change to Increases in Sampling Frequency

10 RSE Values for Macroinvertebrate Sampling Program

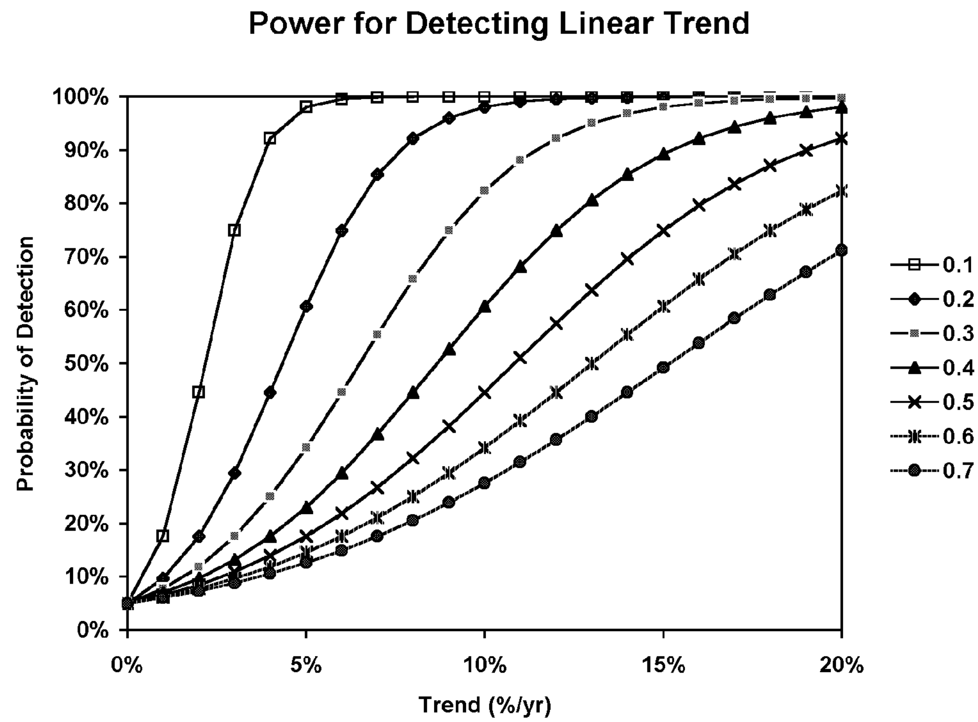
11 Spatial Variations in Lake Macroinvertebrate Indices

12 Spatial Variations in Tributary Multiplate Indices

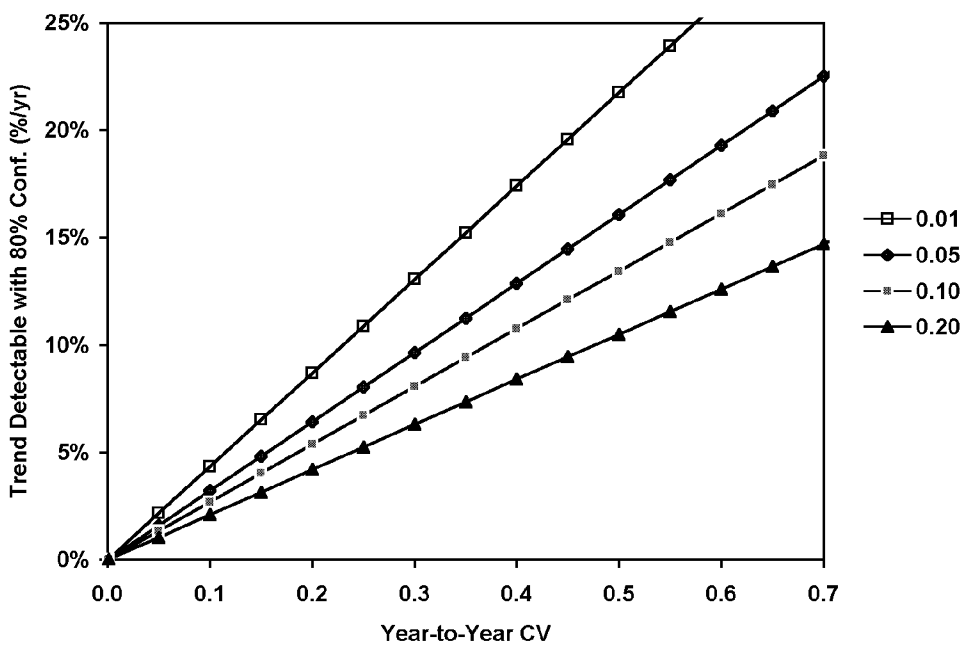




One-tailed t-test with 3 Years of baseline & 3 years of post-implementation data.



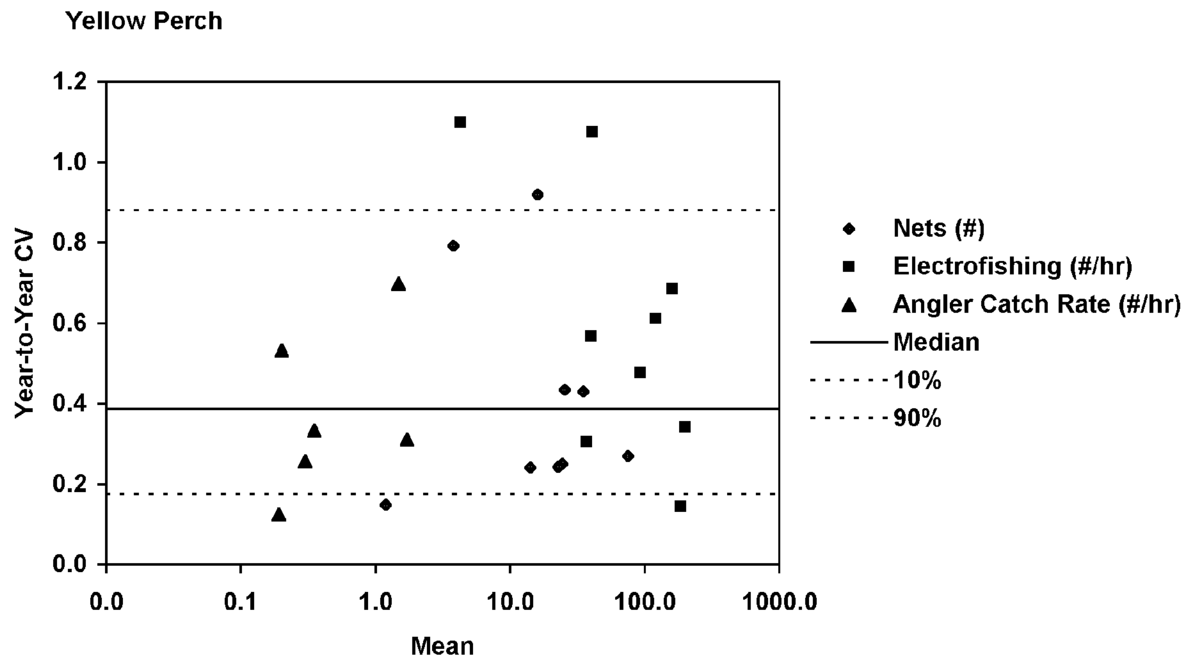
Symbols = Year-to-Year CV, Significance Level = 0.05



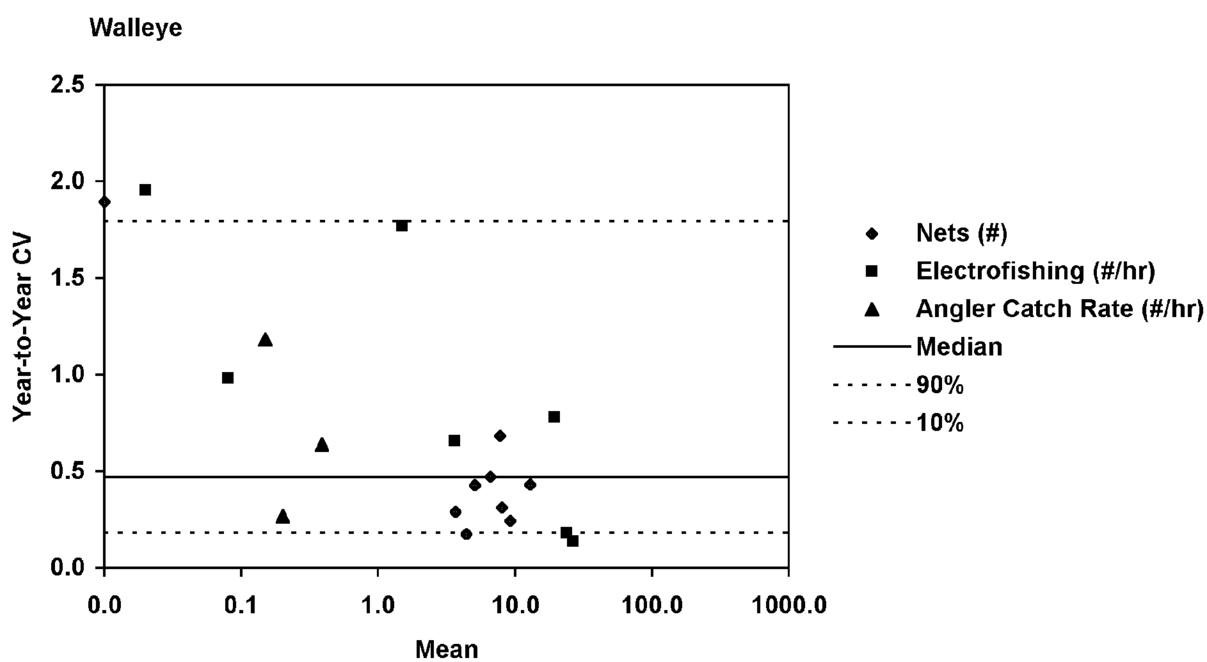
Symbols = Significance Level

Linear regression analysis based upon 6 years of data, collected every other year.

Year-to-Year CV's of Fish Abundance Measurements in New York Lakes

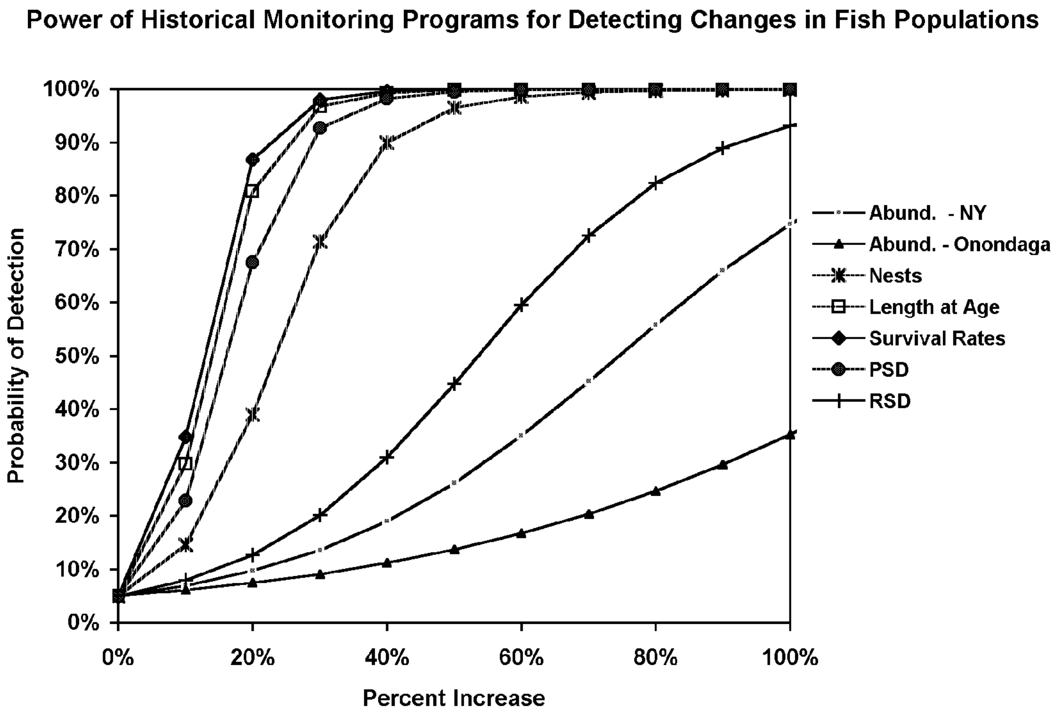


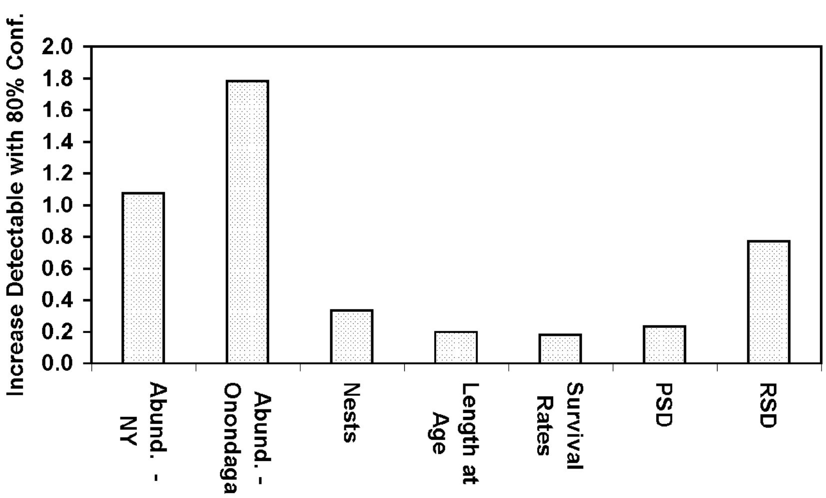
Median CV = 0.39 10% = 0.18 90% = 0.88



Median CV = 0.47 10% = 0.18 90% = 1.80

Computed from Data Tablulated in Forney et. al (1994)





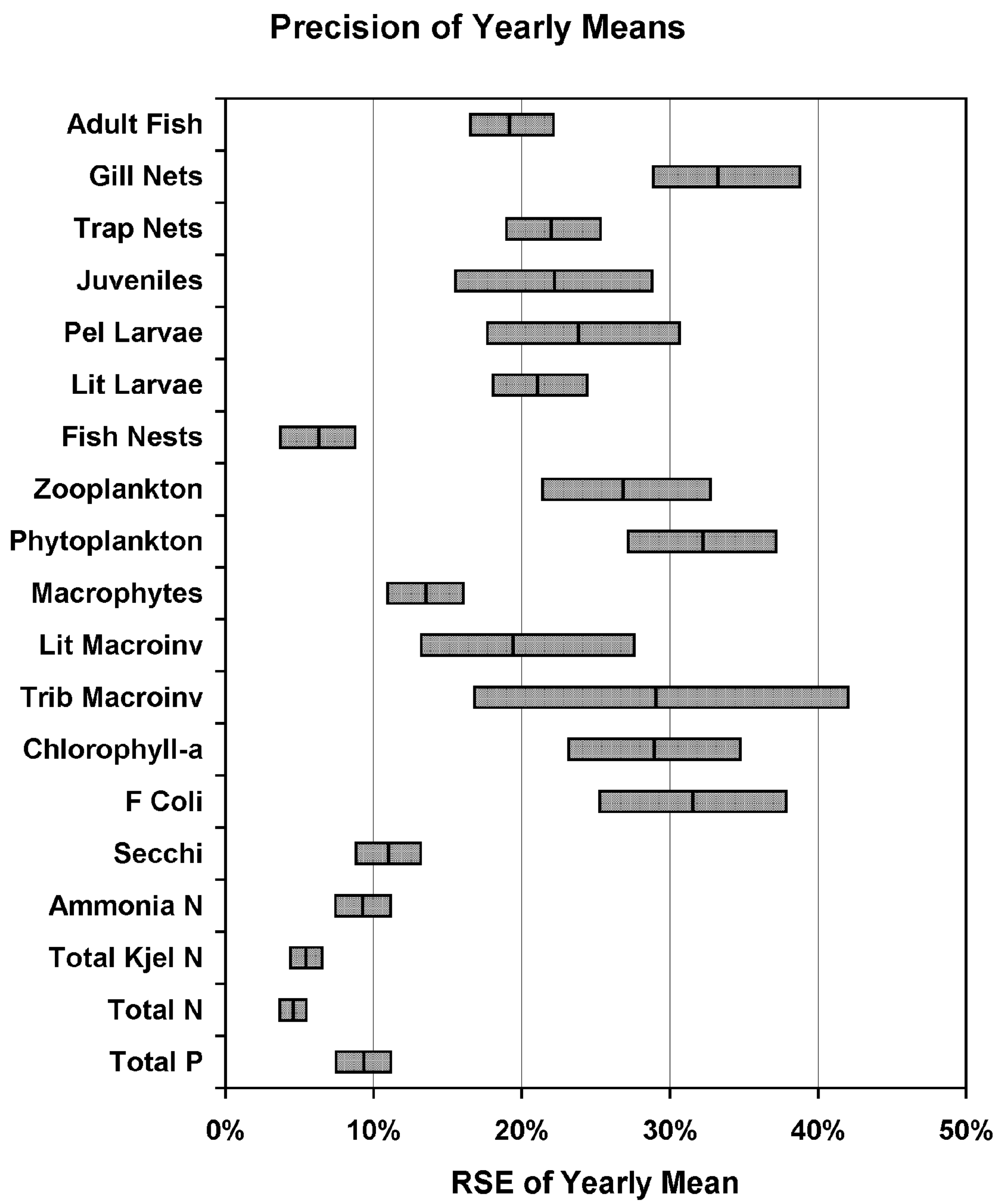
Parameter	Yearly CV
Abund. - NY	0.43
Abund. - Onondaga	0.71
Nests	0.13
Length at Age	0.08
Survival Rates	0.07
PSD	0.09
RSD	0.31

Median yearly CV's estimated from historical data from & Onondaga & other New York lakes.

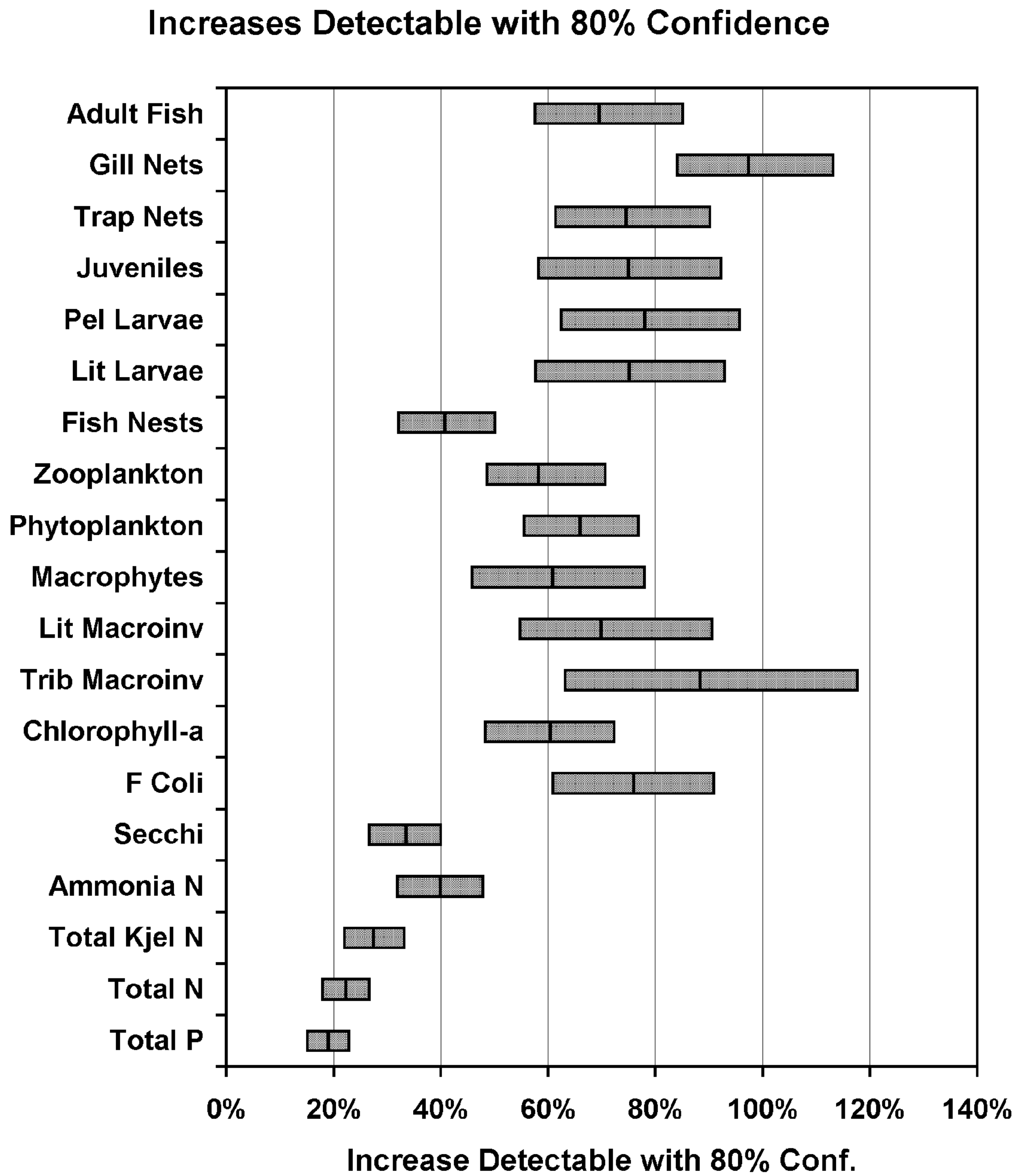
Power evaluated for 1-tailed t-test with 3 years of data for each time period
Significance level = 0.05.

Results for Onondaga Lake unless otherwise noted

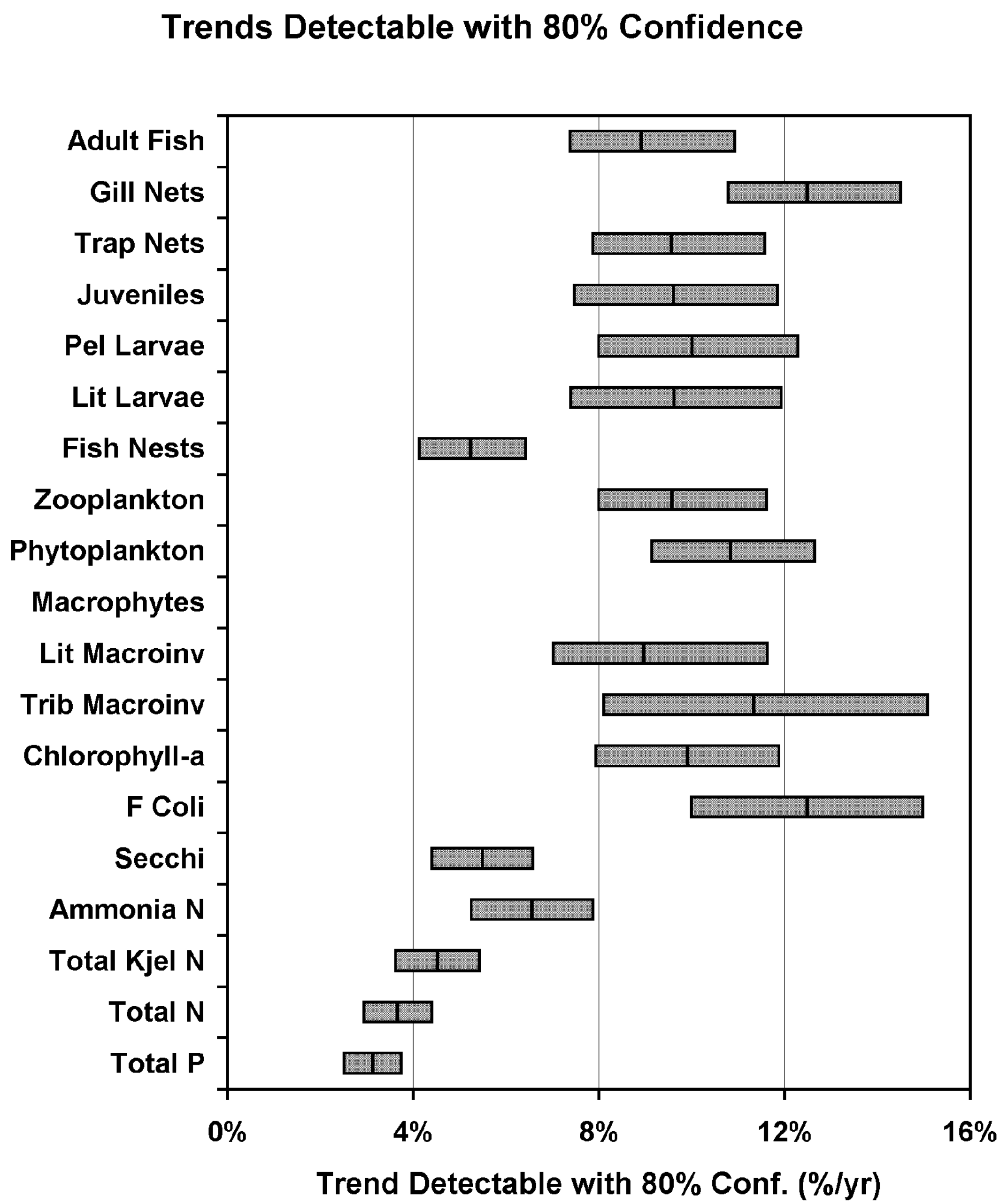
Figure 5



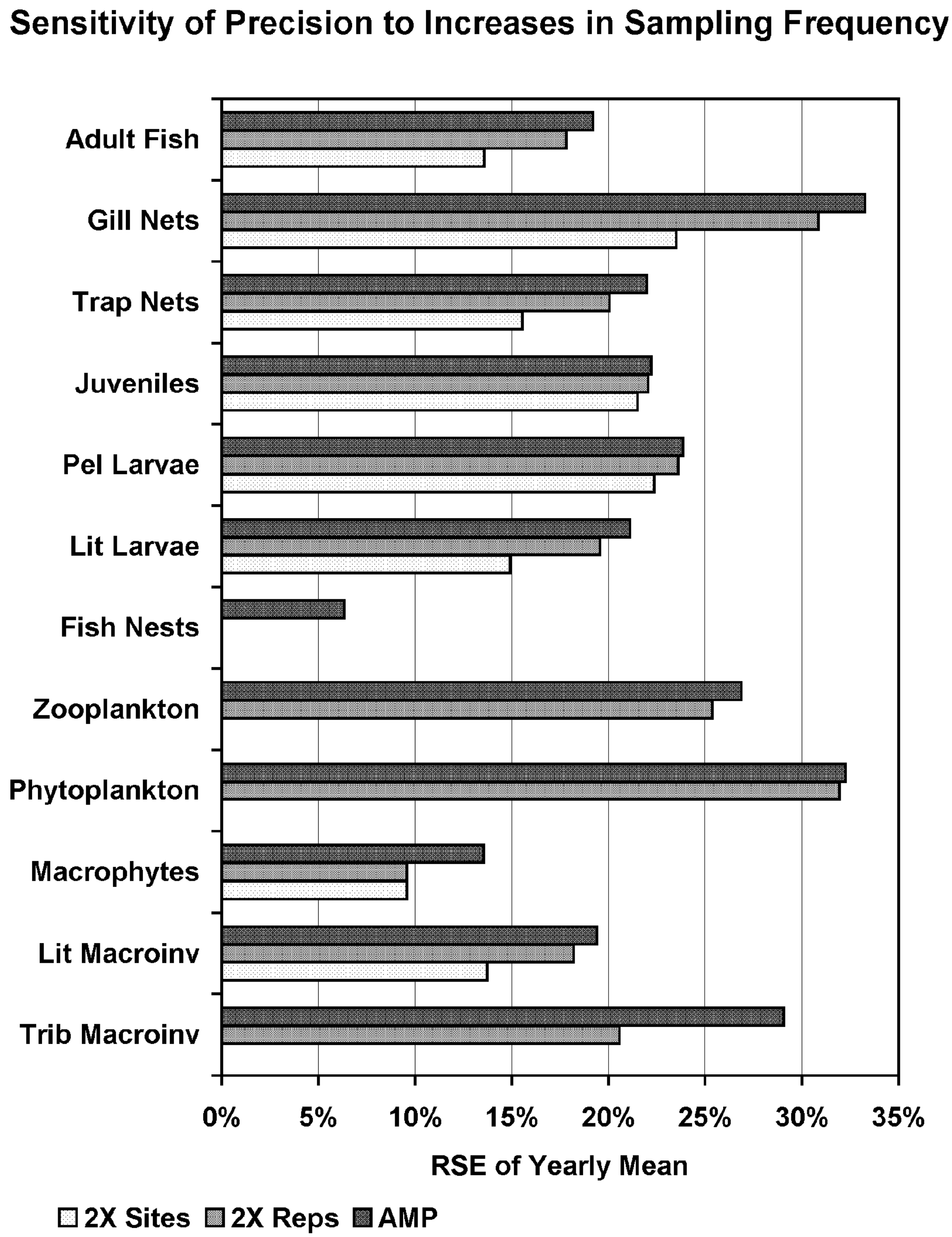
Bars show 10th, 50th, & 90th percentile estimates.



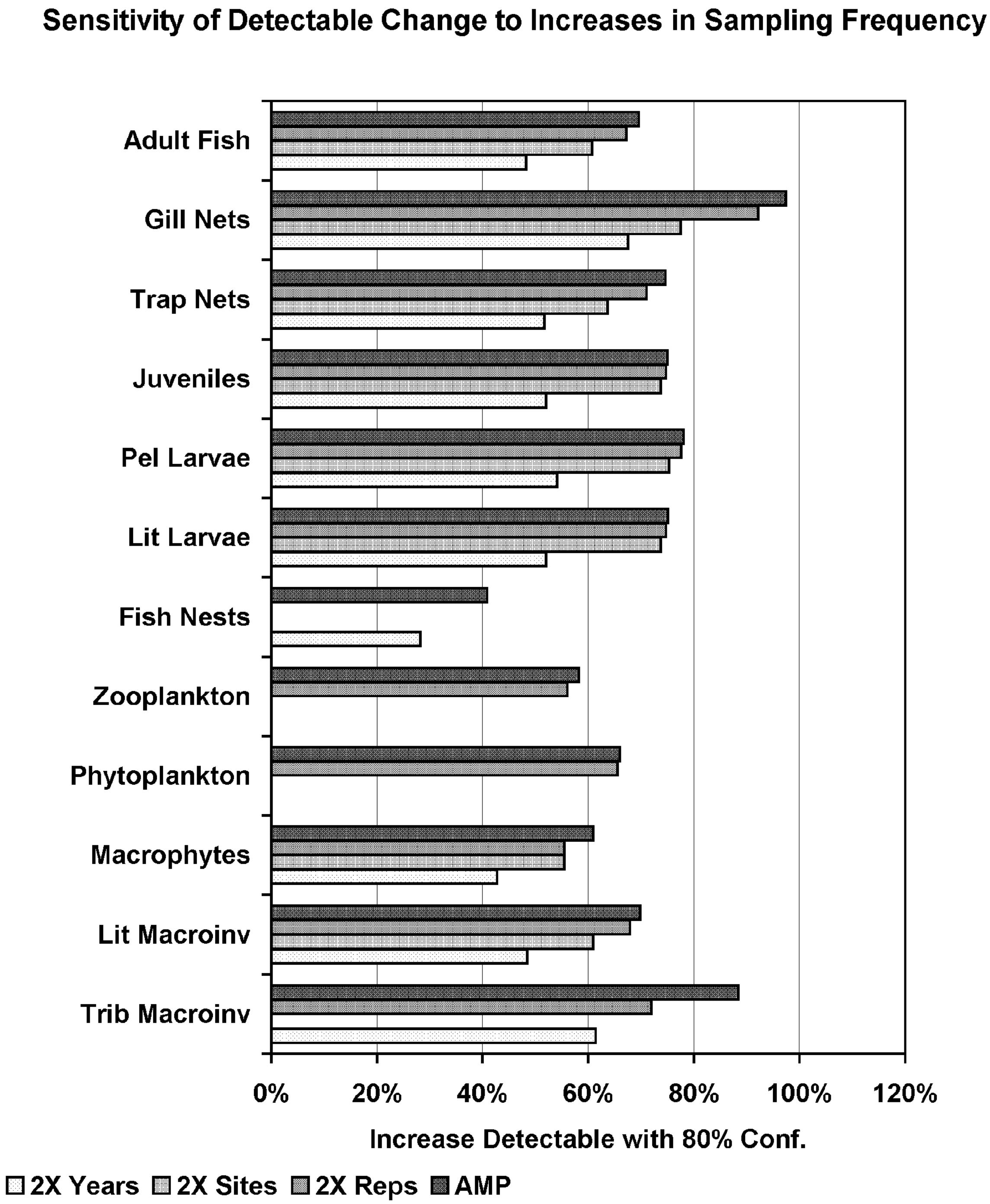
An increase of 100% means a doubling.
Bars show 10th, 50th, & 90th percentile estimates.



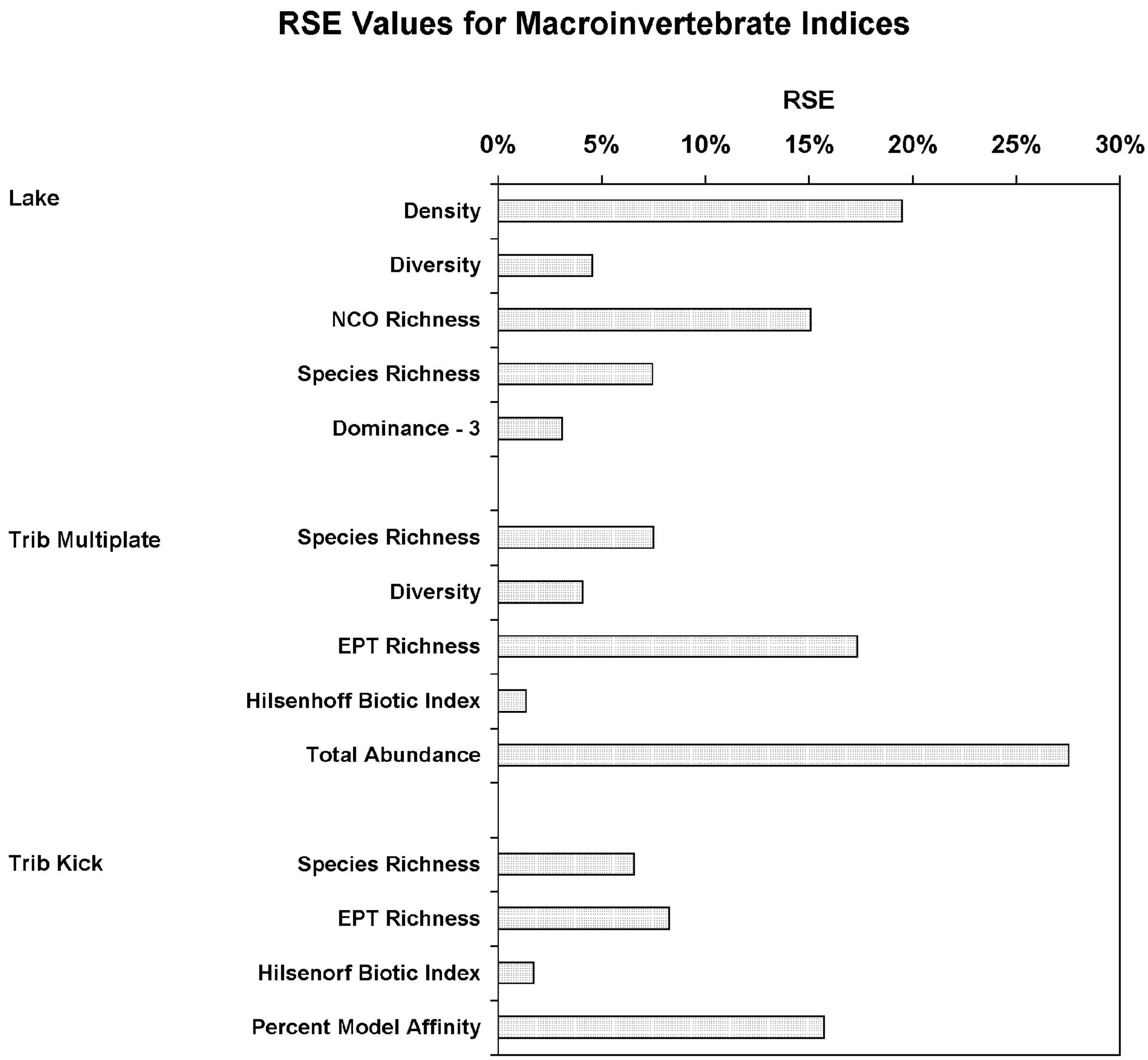
Trends Detectable with 80% Confidence
Adult Fish
Gill Nets
Trap Nets
Juveniles
Pel Larvae
Lit Larvae
Fish Nests
Zooplankton
Phytoplankton
Macrophytes
Lit Macroinv
Trib Macroinv
Chlorophyll-a
F Coli
Secchi
Ammonia N
Total Kjel N
Total N
Total P
0%
4%
8%
12%
16%
Trend Detectable with 80% Conf. (%/yr)



2X Reps = Double Replicates
2X Sites = Double Sampling Sites or Transects



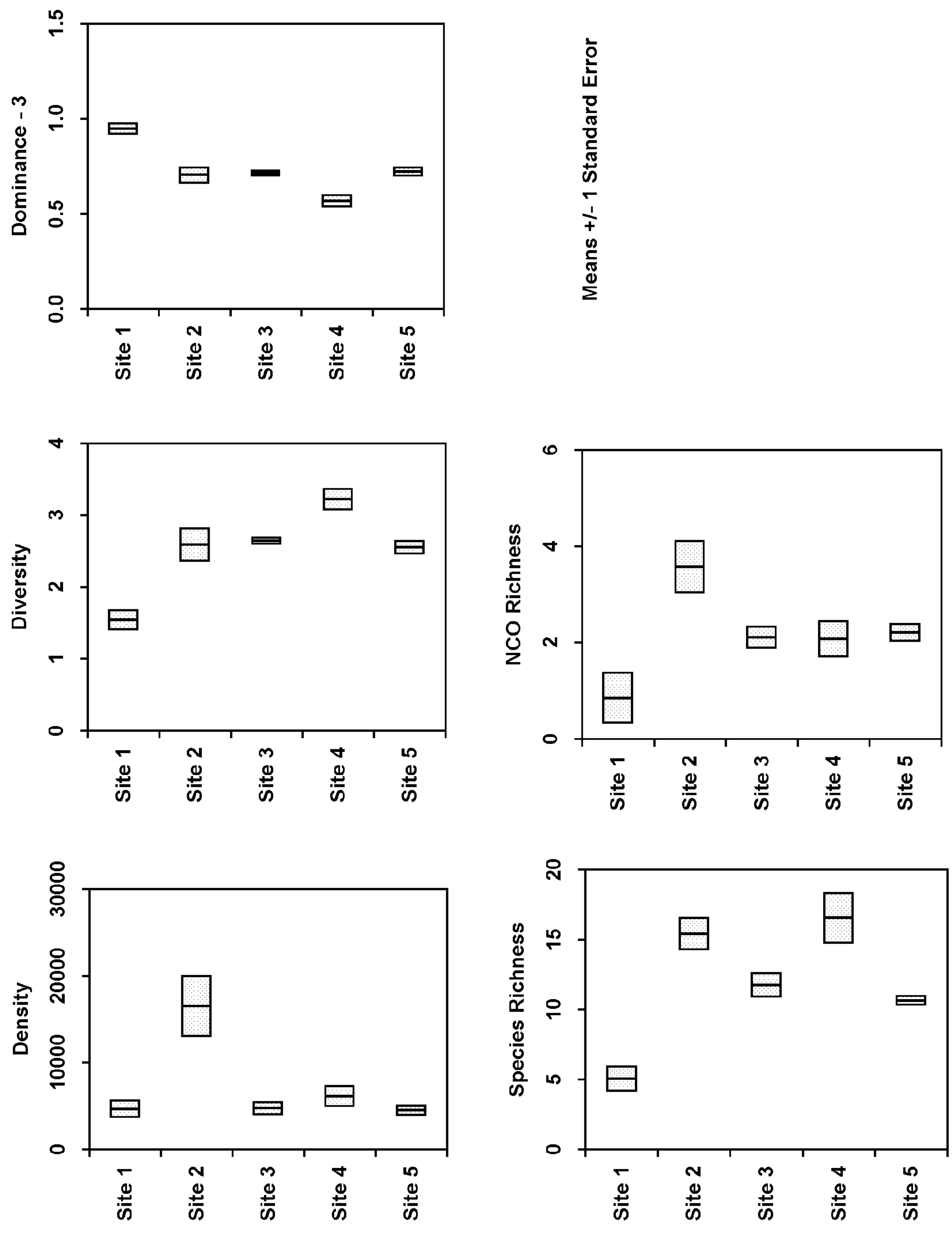
2X Reps = Double Replicates
2X Sites = Double Sampling Sites or Transects
2X Years = Sample Every Year vs. Every Other Year



Computed from median replicate cv's , 1999 data.
Replicate Sampless = 6 for Lake, 5 for Trib Multiplate, 3 for Trib Kick

Figure 11

Spatial Variations in Lake Littoral Macroinvertebrate Indices



Spatial Variations in Tributary Multiplate Indices

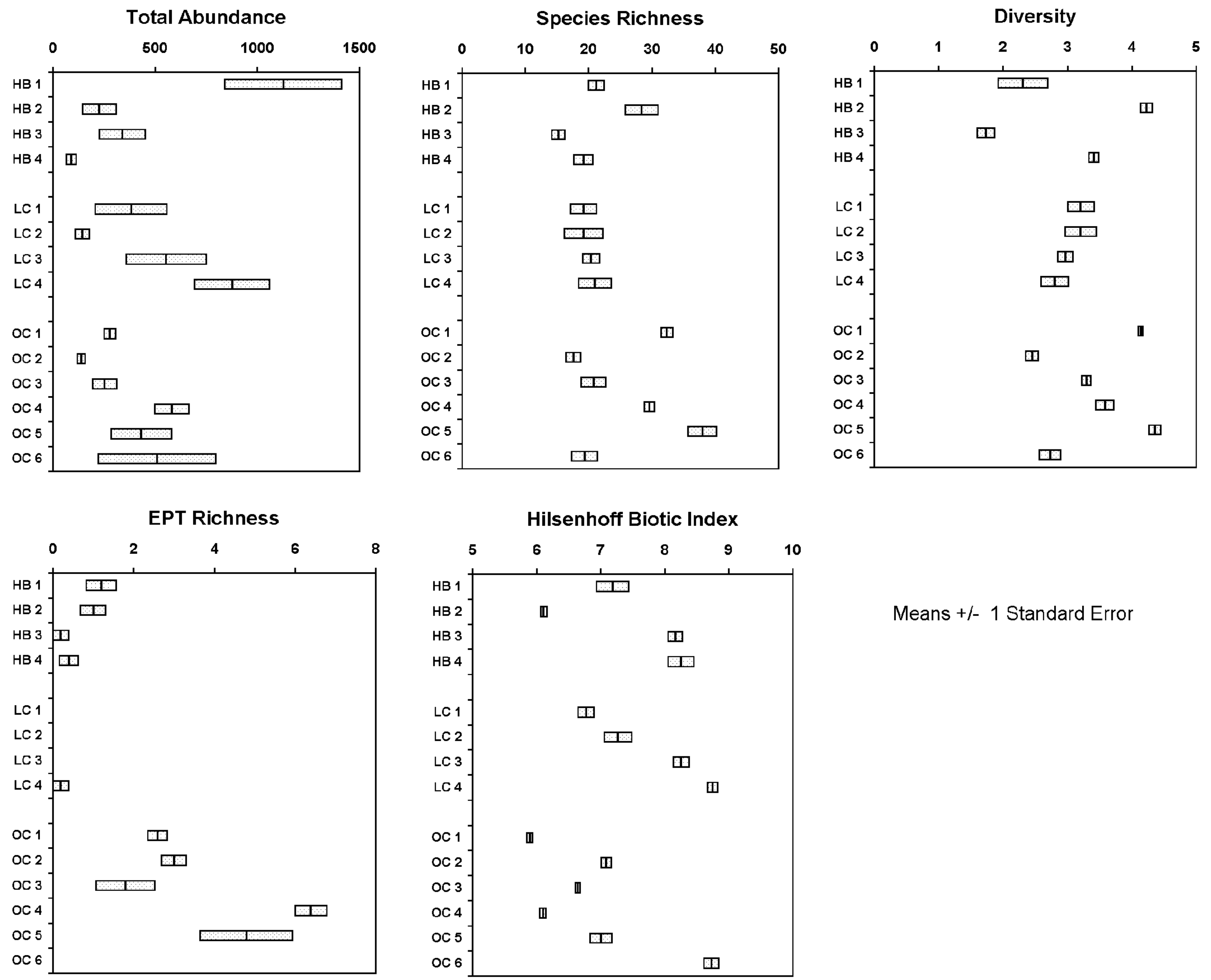


Figure 12

Appendix A

Worksheets for Abundance Measurements

A-2 Phytoplankton

A-3 Zooplankton

A-4 Macrophyte Biomass

A-5 Stream Macroinvertebrates

A-6 Lake Littoral Macroinvertebrates

A-7 Fish Nests

A-8 Littoral Larvae

A-9 Pelagic Larvae

A-10 Pelagic Gill Nets

A-11 Littoral Trap Nets

A-12 Juvenile Fish

A-13 Adult Fish

Worksheet for Phytoplankton

Method	Tygon Tube	
Frequency	Biweekly	
Dates Per year	10	May-Sept
Sites	1	Lake South, Quarterly at North
Depths	1	Epilimnetic Composite
Replicates	1	
Sampling Interval	1	Years
Baseline Years	5	
Metric	Organism Counts, Biomass, May-Sept, Lake South	
Methodology	OCDSS / Dr. Ed Mills	

Design	Min	Mean	Max	2X Reps	2X Dates	Notes
Replicates	1	1	1	2	1	
Dates	10	10	10	10	20	
Interval	1	1	1	1	1	
Years in Baseline	5	5	5	5	5	
Variance Components						
Yearly	0.10	0.20	0.30	0.20	0.20	a
Dates	0.80	1.00	1.20	1.00	1.00	b
Replicates	0.10	0.20	0.30	0.20	0.20	c
Predicted Percentiles	10%	50%	90%	50%	50%	
Site Mean						
RSE of Daily Mean	0.12	0.20	0.28	0.14	0.20	
RSE of Yearly Mean	0.27	0.32	0.37	0.32	0.23	
Year-to-Year CV	0.33	0.38	0.44	0.38	0.30	
RSE of Baseline Mean	0.15	0.17	0.20	0.17	0.14	
Power for Det. 25% Increase	0.18	0.22	0.27	0.22	0.30	
Power for Det. 50% Increase	0.48	0.59	0.71	0.59	0.76	
Power for Det. 100% Increase	0.94	0.98	0.99	0.98	0.99	
Incr. Detect. with 80% Conf.	0.57	0.66	0.76	0.66	0.53	
Power for Det. 3%/Yr Trend	0.14	0.16	0.19	0.16	0.21	
Power for Det. 5%/Yr Trend	0.25	0.30	0.37	0.30	0.41	
Power for Det. 10%/Yr Trend	0.63	0.74	0.85	0.75	0.89	
Trend Detect. with 80% Conf.	0.09	0.11	0.12	0.11	0.09	

References:

a assumed for all bio variables

b 1998 Lake Data, May-Sept, Lake South Epilimnetic Composites
CV across Dates (reflecs replicate + temporal variance):

	Counts	Biovolume	
Bluegreens	1.34	0.94	
Diatoms	1.44	1.06	
Total	0.55	1.18	
Nominal Range	0.80	to	1.30
Temporal Variance Only			
Adjusted	0.79	to	1.26
Assumed	0.8	to	1.2

c Assumed Range 0.1 to 0.3

Worksheet for Zooplankton

Method	Tygon Tube	
Frequency	Biweekly	
Dates per Years	10	For May-Sept; also sampled in other months
Sites	1	Lake South, Quarterly at Lake North
Depths	1	Epilimnetic Composite
Replicates	1	
Sampling Interval	1	Years
Baseline Years	5	
Metric	Organism Counts, May-Sept, Total Zooplankton, Lake South	
Methodology	OCDSS / Dr. Ed Mills	

Design	Min	Mean	Max	2X Reps	2X Dates	Notes
Replicates	1	1	1	2	1	
Dates	10	10	10	10	20	
Interval	1	1	1	1	1	
Years in Baseline	5	5	5	5	5	
Variance Components						
Yearly	0.10	0.20	0.30	0.20	0.20	a
Dates	0.50	0.75	1.00	0.75	0.75	b
Replicates	0.30	0.40	0.50	0.40	0.40	c
Predicted Percentiles	10%	50%	90%	50%	50%	
Site Mean						
RSE of Daily Mean	0.32	0.40	0.48	0.28	0.40	
RSE of Yearly Mean	0.21	0.27	0.30	0.25	0.19	
Year-to-Year CV	0.27	0.34	0.39	0.32	0.28	
RSE of Baseline Mean	0.12	0.15	0.17	0.14	0.12	
Power for Det. 25% Increase	0.21	0.26	0.35	0.27	0.34	
Power for Det. 50% Increase	0.57	0.68	0.84	0.71	0.83	
Power for Det. 100% Increase	0.97	0.99	1.00	0.99	1.00	
Incr. Detect. with 80% Conf.	0.47	0.58	0.67	0.56	0.48	
Power for Det. 3%/Yr Trend	0.16	0.18	0.24	0.19	0.23	
Power for Det. 5%/Yr Trend	0.29	0.35	0.48	0.37	0.47	
Power for Det. 10%/Yr Trend	0.72	0.83	0.94	0.85	0.93	
Trend Detect. with 80% Conf.	0.08	0.10	0.11	0.09	0.08	

References:

a assumed for all bio variables

b 1998 Lake Data, April-July, Lake South Epilimnetic Composites
Interquartile Ranges of CV's Across Dates - Zooplankton Species

Replicate + Temporal Variance				
Biomass	0.60	to	0.98	
Counts	0.63	to	1.18	
Nominal Range	0.60	to	1.20	
Temporal Variance Only				
Adjusted	0.52	to	1.09	replicate variance removed
Assumed Range	0.50	to	1.00	

c Downing et al, 1987 Regression of Replicate Variance against zooplankton count
1,189 sets of replicate samples compiled from literater

Count (#/L)	CV			
Count	1	10	100	1000
CV	0.54	0.46	0.38	0.32
Assumed range:		0.3	to	0.5

Worksheet for Macrophyte Biomass

Method	Harvest	
Seasons	Summer	
Strata	5	defined based upon substrate
Transects	4	at random within each site
Subplots	3	randomly selected within 10 meter zones
Interval	5	measured in two years
Baseline Years	1	
Metric	g/m2	
Methodology	EcoLogic, Inc.	

Design	Min	Mean	Max	2X Reps	2X Sub	2X Yrs	Notes
Strata	5	5	5	5	5	5	
Subplots	3	3	3	6	3	3	
Transects	4	4	4	4	8	4	
Interval	5	5	5	5	5	3	
Years in Baseline	1	1	1	1	1	2	
Variance Components							
Yearly	0.10	0.20	0.30	0.20	0.20	0.20	a
Transects	0.00	0.00	0.00	0.00	0.00	0.00	b
Strata	0.00	0.00	0.00	0.00	0.00	0.00	c
Subplots	0.80	1.05	1.30	1.05	1.05	1.05	d
Predicted Percentiles	10%	50%	90%	50%	50%	50%	
Stratum Mean							
RSE of Subplot Mean	0.49	0.61	0.72	0.43	0.61	0.61	
RSE of Stratum Mean	0.24	0.30	0.36	0.21	0.21	0.30	
Year-to-Year CV	0.30	0.36	0.43	0.29	0.29	0.36	
RSE of Baseline Mean	0.30	0.36	0.43	0.29	0.29	0.26	
Power for Det. 25% Increase	0.12	0.14	0.17	0.20	0.20	0.23	
Power for Det. 50% Increase	0.27	0.34	0.43	0.50	0.50	0.59	
Power for Det. 100% Increase	0.69	0.82	0.91	0.95	0.95	0.98	
Incr. Detect. with 80% Conf.	0.82	0.98	1.15	0.75	0.75	0.66	
Lake Mean							
RSE of Lake Mean	0.11	0.14	0.16	0.10	0.10	0.14	
Year-to-Year CV	0.18	0.24	0.31	0.22	0.22	0.24	
RSE of Baseline Mean	0.18	0.24	0.31	0.22	0.22	0.17	
Power for 25% Increase	0.19	0.26	0.38	0.30	0.30	0.42	
Power for 50% Increase	0.47	0.65	0.86	0.72	0.72	0.90	
Power for 100% Increase	0.94	0.99	1.00	1.00	1.00	1.00	
Incr. Detect. with 80% Conf.	0.46	0.61	0.78	0.55	0.55	0.43	

References:

a — assumed for all bio variables

b — Transects & subplots treated as replicates

c — assume spatial variance factored out by stratified sampling plan

d — Downing & Anderson (1985) formula relating replicate variance to density & sample area

Sample Size	2500	cm2	
Density (g/m2)	1	3	10
CV	1.30	1.02	0.79
Assumed Range	0.8	to	1.3

Linear trend analysis is not practical with total of 2 sampling years

Worksheet for Stream Macroinvertebrates

Method	Multiplate Samplers	
Seasons	Fall	
Sites	14	6 Onondaga, 4 Harbor, 4 Ley
Replicates	5	
Interval	2	years
Baseline Years	3	
Metric	Counts	
Methodology	Ecologic / NYSDEC Protocol	

Design	Min	Mean	Max	2X Reps	2X Yrs	Notes
Replicates	5	5	5	10	5	
Interval	2	2	2	2	1	
Years in Baseline	3	3	3	3	5	
Variance Components						
Yearly	0.10	0.20	0.30	0.20	0.20	a
Replicates	0.30	0.65	1.00	0.65	0.65	b
Predicted Percentiles	10%	50%	90%	50%	50%	
Site Mean						
RSE of Site Mean	0.17	0.29	0.41	0.21	0.29	
Year-to-Year CV	0.25	0.35	0.46	0.29	0.35	
RSE of Baseline Mean	0.15	0.20	0.27	0.17	0.16	
Power for Det. 25% Increase	0.11	0.14	0.20	0.17	0.24	
Power for Det. 50% Increase	0.23	0.36	0.60	0.50	0.64	
Power for Det. 100% Increase	0.68	0.87	0.97	0.95	0.98	
Incr. Detect. with 80% Conf.	0.64	0.88	1.16	0.72	0.61	
Power for Det. 3%/Yr Trend	0.12	0.15	0.21	0.19	0.17	
Power for Det. 5%/Yr Trend	0.19	0.27	0.43	0.37	0.33	
Power for Det. 10%/Yr Trend	0.50	0.71	0.91	0.85	0.79	
Trend Detect. with 80% Conf.	0.08	0.11	0.15	0.09	0.10	
Upstream / Downstream Contrasts - Yearly						
RSE of Yearly Site Difference	0.24	0.41	0.58	0.29	0.41	
Power for 25% Difference	0.10	0.12	0.22	0.20	0.12	
Power for 50% Difference	0.17	0.27	0.58	0.49	0.27	
Power for 100% Difference	0.44	0.71	0.97	0.95	0.71	
Difference Detect. with 80% Conf.	0.66	1.13	1.60	0.75	1.13	
Upstream / Downstream Contrasts - Baseline						
RSE of Baseline Difference	0.21	0.29	0.38	0.23	0.22	
Power for 25% Difference	0.15	0.21	0.31	0.27	0.29	
Power for 50% Difference	0.35	0.51	0.75	0.68	0.71	
Power for 100% Difference	0.82	0.96	1.00	0.99	1.00	
Difference Detect. with 80% Conf.	0.53	0.74	0.96	0.59	0.56	

References:

a assumed for all bio variables

b Replicate CV's Total Abundance - Trib Multiplate Samplers - 1999
10%-90% Range 0.33 to 0.97

Worksheet for Littoral Macroinvertebrates

Method	Dredge	
Seasons	Fall	
Sites	5	Littoral
Transects	2	at random within each site (stratum)
Depths	3	0.5, 1.0, 1.5 meters
Replicates	6	
Interval	2	
Baseline Years	3	
Metric	Count/m^2	Tracked Separately at Each Site
Methodology	Ecologic	

Design	Min	Mean	Max	2X Reps	2X Trans.	2X Yrs	Notes
Replicates	6	6	6	12	6	6	
Transects	2	2	2	2	4	2	
Depths	3	3	3	3	3	3	
Dates	1	1	1	1	1	1	
Interval	2	2	2	2	2	1	
Years in Baseline	3	3	3	3	3	5	
Variance Components							
Yearly	0.10	0.20	0.30	0.20	0.20	0.20	a
Transects	0.00	0.17	0.33	0.17	0.17	0.17	b
Depths	0.08	0.30	0.52	0.30	0.30	0.30	b
Replicates	0.38	0.57	0.76	0.57	0.57	0.57	b
Predicted Percentiles	10%	50%	90%	50%	50%	50%	
Site Mean							
RSE of Depth Mean	0.17	0.23	0.30	0.16	0.23	0.23	
RSE of Transect Mean	0.15	0.22	0.31	0.20	0.22	0.22	
RSE of Site Mean	0.14	0.19	0.27	0.18	0.14	0.19	
Year-to-Year CV	0.22	0.28	0.36	0.27	0.24	0.28	
RSE of Baseline Mean	0.13	0.16	0.21	0.16	0.14	0.12	
Power for Det. 25% Increase	0.13	0.18	0.24	0.19	0.22	0.34	
Power for Det. 50% Increase	0.34	0.52	0.71	0.55	0.64	0.82	
Power for Det. 100% Increase	0.86	0.96	0.99	0.96	0.98	1.00	
Incr. Detect. with 80% Conf.	0.56	0.70	0.90	0.68	0.61	0.48	
Power for Det. 3%/Yr Trend	0.15	0.19	0.25	0.20	0.23	0.23	
Power for Det. 5%/Yr Trend	0.26	0.38	0.52	0.40	0.47	0.46	
Power for Det. 10%/Yr Trend	0.69	0.87	0.96	0.89	0.93	0.93	
Trend Detect. with 80% Conf.	0.07	0.09	0.12	0.09	0.08	0.08	

References:

a assumed for all bio variables

b Variance Components of 1999 Lake Data
For Total Counts by Family & 5 Dominant Species at Each Site

Percentile	10%	90%
Transect	0.00	0.33
Depth	0.08	0.52
Replicate	0.38	0.76

Worksheet for Fish Nests

Method	Visual Counts	
Season	June	
Sites	50	segments of equal shoreline length assumed aggregated into 10 regions
Replicates	1	per site
Sampling Interval	2	Years
Baseline Years	3	
Metric	Count	
Methodology	Ringler et al, 1996 (Methods Used in 1993-1994)	

Design	Min	Mean	Max	2X Yrs	Notes
Regions	10	10	10	10	
Replicates	1	1	1	1	
Interval	2	2	2	1	
Years in Baseline	3	3	3	5	
Variance Components					
Yearly	0.10	0.15	0.20	0.15	a
Regions	0.00	0.00	0.00	0.00	b
Regional Std Error	0.10	0.20	0.30	0.20	c
Predicted Percentiles	10%	50%	90%	50%	
Region Total					
RSE of Region Total	0.12	0.20	0.28	0.20	
Year-to-Year CV	0.19	0.25	0.32	0.25	
RSE of Baseline Mean	0.11	0.14	0.19	0.11	
Power for Det. 25% Increase	0.15	0.21	0.32	0.39	
Power for Det. 50% Increase	0.41	0.62	0.84	0.89	
Power for Det. 100% Increase	0.91	0.97	0.99	1.00	
Incr. Detect. with 80% Conf.	0.47	0.63	0.81	0.44	
Power for Det. 3%/Yr Trend	0.07	0.07	0.08	0.09	
Power for Det. 5%/Yr Trend	0.30	0.45	0.65	0.53	
Power for Det. 10%/Yr Trend	0.77	0.92	0.99	0.96	
Trend Detect. with 80% Conf.	0.06	0.08	0.10	0.07	
Lake Total					
RSE of Yearly Total	0.04	0.06	0.09	0.06	
Year-to-Year CV	0.13	0.16	0.20	0.16	
RSE of Baseline Mean	0.07	0.09	0.12	0.07	
Power for 25% Increase	0.29	0.41	0.61	0.71	
Power for 50% Increase	0.79	0.91	0.97	0.99	
Power for 100% Increase	0.99	1.00	1.00	1.00	
Incr. Detect. with 80% Conf.	0.32	0.41	0.51	0.28	
Power for Det. 3%/Yr Trend	0.29	0.40	0.57	0.48	
Power for Det. 5%/Yr Trend	0.60	0.77	0.92	0.85	
Power for Det. 10%/Yr Trend	0.98	1.00	1.00	1.00	
Trend Detect. with 80% Conf.	0.04	0.05	0.06	0.05	

References:

a Ringler et al. (1996), Nest Counts , 3 Years

Mean	1506		
CV	0.13		
Assumed Range	0.1	to	0.2

b Total nest count would be independent of spatial variations, since entire littoral zone is surv

c Std Error in Regional Count Computed from Poisson Distribution

	Min	Max	
Counts / Region	10	300	Ringler et al (1996)
Poisson CV	0.32	0.06	
Assumed Range	0.1	to	0.3

Worksheet for Littoral Larvae

Method	Larval Fish Seine				
Seasons	Biweekly, April-July				
Dates Per year	7				
Sites	15	Assumed Aggregated into	5	regions	
Depths	1				
Replicates	3	per site or	9	per region	
Sampling Interval	2	years			
Baseline Years	3				
Metric	# / m^3 filtered				
Methodology	NYSDEC Percid Sampling Manual				

Design	Min	Mean	Max	2X Reps	2X Sites	2X Yrs	Notes
Regions	5	5	5	5	10	5	
Replicates	9	9	9	18	9	9	
Dates	7	7	7	7	7	7	
Interval	2	2	2	2	2	1	
Years in Baseline	3	3	3	3	3	5	
Variance Components							
Yearly	0.10	0.20	0.30	0.20	0.20	0.20	a
Dates	0.30	0.55	0.80	0.55	0.55	0.55	see juvenile wksht
Sites	0.30	0.40	0.50	0.40	0.40	0.40	see fish wksht
Replicates	0.50	0.75	1.00	0.75	0.75	0.75	see pel _larvae wksht
Predicted Percentiles	10%	50%	90%	50%	50%	50%	
Regional Mean							
RSE of Date Mean	0.18	0.25	0.32	0.18	0.25	0.25	
RSE of Yearly Mean	0.16	0.23	0.30	0.22	0.23	0.23	
Year-to-Year CV	0.24	0.30	0.38	0.30	0.30	0.30	
RSE of Baseline Mean	0.14	0.18	0.22	0.17	0.18	0.14	
Power for Det. 25% Increase	0.13	0.16	0.23	0.17	0.16	0.30	
Power for Det. 50% Increase	0.32	0.46	0.67	0.48	0.46	0.76	
Power for Det. 100% Increase	0.83	0.94	0.98	0.94	0.94	0.99	
Incr. Detect. with 80% Conf.	0.59	0.76	0.95	0.74	0.76	0.53	
Power for Det. 3%/Yr Trend	0.14	0.17	0.24	0.18	0.17	0.21	
Power for Det. 5%/Yr Trend	0.25	0.34	0.49	0.35	0.34	0.41	
Power for Det. 10%/Yr Trend	0.65	0.82	0.94	0.83	0.82	0.89	
Trend Detect. with 80% Conf.	0.08	0.10	0.12	0.10	0.10	0.09	
Lake Mean							
RSE of Date Mean	0.18	0.21	0.24	0.20	0.15	0.21	
RSE of Yearly Mean	0.15	0.22	0.30	0.22	0.22	0.22	
Year-to-Year CV	0.23	0.30	0.37	0.30	0.29	0.30	
RSE of Baseline Mean	0.13	0.17	0.21	0.17	0.17	0.13	
			0.00				
Power for 25% Increase	0.13	0.16	0.23	0.17	0.17	0.30	
Power for 50% Increase	0.32	0.47	0.69	0.47	0.48	0.77	
Power for 100% Increase	0.84	0.94	0.98	0.94	0.94	1.00	
Incr. Detect. with 80% Conf.	0.58	0.75	0.93	0.75	0.74	0.52	
Power for Det. 3%/Yr Trend	0.14	0.18	0.24	0.18	0.18	0.21	
Power for Det. 5%/Yr Trend	0.25	0.34	0.50	0.35	0.35	0.42	
Power for Det. 10%/Yr Trend	0.12	0.15	0.21	0.15	0.15	0.22	
Trend Detect. with 80% Conf.	0.07	0.10	0.12	0.10	0.09	0.09	

References:

a assumed for all bio variables

Worksheet for Pelagic Larvae

Method	Trawl			
Seasons	Biweekly, April-July			
Dates Per year	7			
Sites	2	Fixed, North & South		
Depths	3	1,3,5 meters, treated here as replicates		
Replicates	6	per depth	total reps/site =	18
Sampling Interval	2	Years		
Baseline Years	3			
Metric	# / m^3 filtered			
Methodology	NYSDEC Percid Sampling Manual			

Design	Min	Mean	Max	2X Reps	2X Sites	2X Yrs	Notes
Sites	2	2	2	2	4	2	
Replicates	18	18	18	36	18	18	
Dates	7	7	7	7	7	7	
Interval	2	2	2	2	2	1	
Years in Baseline	3	3	3	3	3	5	
Variance Components							
Yearly	0.10	0.20	0.30	0.20	0.20	0.20	a
Dates	0.30	0.55	0.80	0.55	0.55	0.55	see juvenile wksht
Basins	0.30	0.40	0.50	0.40	0.40	0.40	see fish wksht
Replicates	0.50	0.75	1.00	0.75	0.75	0.75	b
Predicted Percentiles	10%	50%	90%	50%	50%	50%	
Basin Mean							
RSE of Date Mean	0.13	0.18	0.22	0.13	0.18	0.18	
RSE of Yearly Mean	0.15	0.22	0.29	0.21	0.22	0.22	
Year-to-Year CV	0.23	0.30	0.37	0.29	0.30	0.30	
RSE of Baseline Mean	0.13	0.17	0.21	0.17	0.17	0.13	
Power for Det. 25% Increase	0.13	0.17	0.24	0.17	0.17	0.31	
Power for Det. 50% Increase	0.33	0.48	0.69	0.49	0.48	0.78	
Power for Det. 100% Increase	0.85	0.94	0.98	0.95	0.94	1.00	
Incr. Detect. with 80% Conf.	0.57	0.74	0.93	0.73	0.74	0.51	
Power for Det. 3%/Yr Trend	0.14	0.18	0.25	0.18	0.18	0.21	
Power for Det. 5%/Yr Trend	0.26	0.35	0.51	0.36	0.35	0.42	
Power for Det. 10%/Yr Trend	0.67	0.83	0.95	0.84	0.83	0.90	
Trend Detect. with 80% Conf.	0.07	0.10	0.12	0.09	0.10	0.08	
Lake Mean							
RSE of Date Mean	0.26	0.31	0.36	0.30	0.22	0.31	
RSE of Yearly Mean	0.18	0.24	0.31	0.24	0.22	0.24	
Year-to-Year CV	0.25	0.31	0.38	0.31	0.30	0.31	
RSE of Baseline Mean	0.14	0.18	0.22	0.18	0.17	0.14	
Power for 25% Increase	0.13	0.16	0.21	0.16	0.16	0.29	
Power for 50% Increase	0.31	0.44	0.62	0.44	0.47	0.74	
Power for 100% Increase	0.83	0.93	0.98	0.93	0.94	0.99	
Incr. Detect. with 80% Conf.	0.62	0.78	0.96	0.78	0.75	0.54	
Power for Det. 3%/Yr Trend	0.14	0.17	0.22	0.17	0.18	0.20	
Power for Det. 5%/Yr Trend	0.24	0.32	0.45	0.33	0.34	0.39	
Power for Det. 10%/Yr Trend	0.12	0.14	0.19	0.15	0.15	0.21	
Trend Detect. with 80% Conf.	0.08	0.10	0.12	0.10	0.10	0.09	

References:

a assumed for all bio variables

b Cyr et al, 1994 equation, Sample Variance vs. Abundance, Fish Larvae

Total in Sample	10	100	1000
Replicate CV	0.92	0.68	0.51
Assumed Range	0.5	to	1

Worksheet for Pelagic Gill Nets

Method	Gill Nets	
Seasons	Spring & Fall, Twice in Each Season	
Sites	2	selected randomly within each basin (north, south)
Depths	1	total water column depth > 10 m
Replicates	8	4 nites per event x 2 events per season
Sampling Interval	2	Years
Baseline Years	3	
Metric	catch per unit effort, seasons analyzed separately	
Methodology	NYSDEC Percid Sampling Manual (1994)	

Design	Min	Mean	Max	2X Reps	2X Sites	2X Yrs	Notes
Sites	2	2	2	2	4	2	
Replicates	8	8	8	16	8	8	
Interval	2	2	2	2	2	1	
Years in Baseline	3	3	3	3	3	5	
Variance Components							
Yearly	0.10	0.20	0.30	0.20	0.20	0.20	a
Sites	0.30	0.40	0.50	0.40	0.40	0.40	see fish wksht
Replicates	0.50	0.70	0.90	0.70	0.70	0.70	see fish wksht
Predicted Percentiles	10%	50%	90%	50%	50%	50%	
Site Mean							
RSE of Yearly Mean	0.19	0.25	0.31	0.18	0.25	0.25	
Year-to-Year CV	0.25	0.32	0.38	0.27	0.32	0.32	
RSE of Baseline Mean	0.15	0.18	0.22	0.15	0.18	0.14	
Power for Det. 25% Increase	0.13	0.15	0.20	0.19	0.15	0.28	
Power for Det. 50% Increase	0.31	0.42	0.60	0.56	0.42	0.73	
Power for Det. 100% Increase	0.83	0.92	0.97	0.97	0.92	0.99	
Incr. Detect. with 80% Conf.	0.64	0.80	0.96	0.67	0.80	0.55	
Power for Det. 3%/Yr Trend	0.14	0.17	0.21	0.20	0.17	0.20	
Power for Det. 5%/Yr Trend	0.24	0.31	0.43	0.41	0.31	0.38	
Power for Det. 10%/Yr Trend	0.64	0.78	0.91	0.89	0.78	0.86	
Trend Detect. with 80% Conf.	0.08	0.10	0.12	0.09	0.10	0.09	
Lake Mean							
RSE of Yearly Mean	0.29	0.33	0.39	0.31	0.24	0.33	
Year-to-Year CV	0.34	0.39	0.45	0.37	0.31	0.39	
RSE of Baseline Mean	0.19	0.22	0.26	0.21	0.18	0.17	
Power for 25% Increase	0.11	0.13	0.14	0.13	0.16	0.21	
Power for 50% Increase	0.24	0.30	0.39	0.33	0.44	0.57	
Power for 100% Increase	0.70	0.82	0.90	0.85	0.93	0.97	
Incr. Detect. with 80% Conf.	0.84	0.97	1.13	0.92	0.77	0.67	
Power for Det. 3%/Yr Trend	0.12	0.14	0.16	0.14	0.17	0.16	
Power for Det. 5%/Yr Trend	0.20	0.24	0.29	0.26	0.33	0.29	
Power for Det. 10%/Yr Trend	0.10	0.12	0.13	0.12	0.15	0.16	
Trend Detect. with 80% Conf.	0.11	0.12	0.15	0.12	0.10	0.11	

References:

a assumed for all bio variables

Worksheet for Littoral Trap Nets

Method	Trap Nets	
Seasons	Spring & Fall, Twice within Each Season	
Sites	5	
Depths	1	
Replicates	6	3 nites per event x 2 events per season
Sampling Interval	2	Years
Baseline Years	3	
Metric	catch per unit effort, seasons analyzed separately	
Methodology	NYSDEC Percid Sampling Manual (1994)	

Design	Min	Mean	Max	2X Reps	2X Sites	2X Yrs	Notes
Sites	5	5	5	5	10	5	
Replicates	6	6	6	12	6	6	
Interval	2	2	2	2	2	1	
Years in Baseline	3	3	3	3	3	5	
Variance Components							
Yearly	0.10	0.20	0.30	0.20	0.20	0.20	a
Sites	0.30	0.40	0.50	0.40	0.40	0.40	see fish wksht
Replicates	0.50	0.70	0.90	0.70	0.70	0.70	see fish wksht
Predicted Percentiles	10%	50%	90%	50%	50%	50%	
Site Mean							
RSE of Yearly Mean	0.22	0.29	0.35	0.20	0.29	0.29	
Year-to-Year CV	0.28	0.35	0.42	0.28	0.35	0.35	
RSE of Baseline Mean	0.16	0.20	0.24	0.16	0.20	0.16	
Power for Det. 25% Increase	0.12	0.14	0.18	0.18	0.14	0.24	
Power for Det. 50% Increase	0.27	0.36	0.51	0.51	0.36	0.65	
Power for Det. 100% Increase	0.76	0.88	0.95	0.95	0.88	0.99	
Incr. Detect. with 80% Conf.	0.71	0.87	1.05	0.71	0.87	0.61	
Power for Det. 3%/Yr Trend	0.13	0.15	0.19	0.19	0.15	0.18	
Power for Det. 5%/Yr Trend	0.22	0.28	0.37	0.37	0.28	0.34	
Power for Det. 10%/Yr Trend	0.57	0.71	0.86	0.86	0.71	0.80	
Trend Detect. with 80% Conf.	0.09	0.11	0.14	0.09	0.11	0.10	
Lake Mean							
RSE of Yearly Mean	0.19	0.22	0.25	0.20	0.16	0.22	
Year-to-Year CV	0.24	0.30	0.36	0.28	0.25	0.30	
RSE of Baseline Mean	0.14	0.17	0.21	0.16	0.15	0.13	
Power for 25% Increase	0.13	0.17	0.21	0.18	0.20	0.31	
Power for 50% Increase	0.34	0.47	0.64	0.51	0.61	0.78	
Power for 100% Increase	0.86	0.94	0.98	0.95	0.97	1.00	
Incr. Detect. with 80% Conf.	0.61	0.75	0.90	0.71	0.64	0.52	
Power for Det. 3%/Yr Trend	0.14	0.18	0.22	0.19	0.22	0.21	
Power for Det. 5%/Yr Trend	0.26	0.35	0.46	0.37	0.44	0.42	
Power for Det. 10%/Yr Trend	0.12	0.15	0.19	0.16	0.18	0.22	
Trend Detect. with 80% Conf.	0.08	0.10	0.12	0.09	0.08	0.08	

References:

a assumed for all bio variables

Worksheet for Juvenile Fish

Method	Seine				
Seasons	Every Three Weeks, May-September				
Dates Per year	7				
Sites	15	Assumed Aggregated into	5	regions	
Depths	1	1 meter			
Replicates	3	Per site	9	Per region	
Sampling Interval	2	Years			
Baseline Years	3				
Metric	catch per unit effort				
Methodology	NYSDEC Centrarchids Sampling Manual				

Regions	5	5	5	5	10	5	
Replicates	9	9	9	18	9	9	
Dates	7	7	7	7	7	7	
Interval	2	2	2	2	2	2	
Years in Baseline	3	3	3	3	3	5	
Variance Components	Min	Mean	Max	2X Reps	2X Sites	2X Yrs	Notes
Yearly	0.10	0.20	0.30	0.20	0.20	0.20	a
Dates	0.30	0.55	0.80	0.55	0.55	0.55	b
Regions	0.30	0.40	0.50	0.40	0.40	0.40	see Fish worksheet
Replicates	0.50	0.70	0.90	0.70	0.70	0.70	see Fish worksheet
Predicted Percentiles	10%	50%	90%	50%	50%	50%	
Regional Mean							
RSE of Date Mean	0.18	0.23	0.29	0.16	0.23	0.23	
RSE of Yearly Mean	0.16	0.23	0.29	0.22	0.23	0.23	
Year-to-Year CV	0.24	0.30	0.37	0.30	0.30	0.30	
RSE of Baseline Mean	0.14	0.17	0.21	0.17	0.17	0.13	
Power for Det. 25% Increase	0.13	0.16	0.22	0.17	0.16	0.30	
Power for Det. 50% Increase	0.33	0.46	0.66	0.48	0.46	0.77	
Power for Det. 100% Increase	0.85	0.94	0.98	0.94	0.94	1.00	
Incr. Detect. with 80% Conf.	0.60	0.76	0.93	0.74	0.76	0.52	
Power for Det. 3%/Yr Trend	0.14	0.18	0.23	0.18	0.18	0.53	
Power for Det. 5%/Yr Trend	0.25	0.34	0.48	0.35	0.34	0.89	
Power for Det. 10%/Yr Trend	0.67	0.82	0.94	0.83	0.82	1.00	
Trend Detect. with 80% Conf.	0.08	0.10	0.12	0.09	0.10	0.04	
Lake Mean							
RSE of Date Mean	0.18	0.21	0.24	0.19	0.15	0.21	
RSE of Yearly Mean	0.16	0.22	0.29	0.22	0.22	0.22	
Year-to-Year CV	0.23	0.30	0.37	0.30	0.29	0.30	
RSE of Baseline Mean	0.13	0.17	0.21	0.17	0.17	0.13	
Power for 25% Increase	0.13	0.17	0.23	0.17	0.17	0.30	
Power for 50% Increase	0.33	0.47	0.68	0.47	0.48	0.77	
Power for 100% Increase	0.85	0.94	0.98	0.94	0.94	1.00	
Incr. Detect. with 80% Conf.	0.58	0.75	0.92	0.75	0.74	0.52	
Power for Det. 3%/Yr Trend	0.14	0.18	0.24	0.18	0.18	0.54	
Power for Det. 5%/Yr Trend	0.26	0.34	0.49	0.35	0.35	0.90	
Power for Det. 10%/Yr Trend	0.12	0.15	0.21	0.15	0.15	0.60	
Trend Detect. with 80% Conf.	0.07	0.10	0.12	0.10	0.09	0.04	

References:

a	assumed for all bio variables				
b	Arrigo(1998) - CV across dates, littoral zone density, May-Sept Samples				
	9 Dates		0.80		
	7 Dates		0.32	excluding two dates with zero catch	
	Assumed Range	0.30	to	0.80	

Worksheet for Adult Fish

Method	Electrofishing				
Seasons	Mid-Spring & Early Fall , Twice in Each Season				
Sites	24	Assumed Aggregated into	6	Regions	
Depths	< 2 m	with	4	Reps/Region	
Replicates	8	4 samples per region x 2 events per season			
Sampling Interval	2	Years			
Years in Baseline	3				
Metric	Catch per hour, assumed to be tracked separately				
Methodology	NYSDEC Percid Sampling Manual				

Design	Low	Mean	High	2X Reps	2X Sites	2X Yrs	Notes
Regions	6	6	6	6	12	6	
Replicates	8	8	8	16	8	8	
Interval	2	2	2	2	2	1	
Years in Baseline	3	3	3	3	3	5	
Variance Components							
Yearly	0.10	0.20	0.30	0.20	0.20	0.20	a
Across Regions	0.30	0.40	0.50	0.40	0.40	0.40	b
Replicates	0.50	0.70	0.90	0.70	0.70	0.70	c
Predicted Percentiles	10%	50%	90%	50%	50%	50%	
Regional Mean Per Season							
RSE of Seasonal Mean	0.19	0.25	0.30	0.18	0.25	0.25	
Year-to-Year CV	0.26	0.32	0.38	0.27	0.32	0.32	
RSE of Baseline Mean	0.15	0.18	0.22	0.15	0.18	0.14	
Power for Det. 25% Increase	0.13	0.15	0.20	0.19	0.15	0.28	
Power for Det. 50% Increase	0.31	0.42	0.58	0.56	0.42	0.73	
Power for Det. 100% Increase	0.83	0.92	0.97	0.97	0.92	0.99	
Incr. Detect. with 80% Conf.	0.66	0.80	0.96	0.67	0.80	0.55	
Power for Det. 3%/Yr Trend	0.14	0.17	0.21	0.20	0.17	0.20	
Power for Det. 5%/Yr Trend	0.24	0.31	0.42	0.41	0.31	0.38	
Power for Det. 10%/Yr Trend	0.64	0.78	0.90	0.89	0.78	0.86	
Trend Detect. with 80% Conf.	0.08	0.10	0.12	0.09	0.10	0.09	
Lake Mean Per Season							
RSE of Seasonal Mean	0.17	0.19	0.22	0.18	0.14	0.19	
Year-to-Year CV	0.23	0.28	0.34	0.27	0.24	0.28	
RSE of Baseline Mean	0.13	0.16	0.20	0.15	0.14	0.12	
Power for 25% Increase	0.14	0.18	0.23	0.19	0.22	0.34	
Power for 50% Increase	0.38	0.53	0.69	0.56	0.65	0.82	
Power for 100% Increase	0.89	0.96	0.98	0.96	0.98	1.00	
Incr. Detect. with 80% Conf.	0.58	0.70	0.85	0.67	0.61	0.48	
Power for Det. 3%/Yr Trend	0.15	0.19	0.24	0.20	0.23	0.23	
Power for Det. 5%/Yr Trend	0.29	0.38	0.50	0.40	0.47	0.46	
Power for Det. 10%/Yr Trend	0.73	0.87	0.95	0.89	0.93	0.93	
Trend Detect. with 80% Conf.	0.07	0.09	0.11	0.09	0.08	0.08	

References:

a assumed for all bio variables

b Ringler (Effler, 1995, p 476), Spatial CV = 0.46 - 0.67
Juvenile Fish Populations, Onondaga Lake, 12 Lake Regions, May+Oct Averages

Assume	50%	of spatial variance is fixed & the remainder is random	
Observed Range	0.46	to	0.67
Random Component	0.33	to	0.47
Assumed Range	0.30	to	0.50

c Forney et al (1994), p III-10
Pooled Data from Canadarago, Chautauqua, Oneida, & Conesus Lakes
CVs among gamefish electrofishing runs = 0.64 for yellow perch, 0.85 for walleye

Miranda et al (331), regression relating replicate variance to duration & catch rate
Largemouth bass in Mississippi Reservoirs, duration = 15 minutes

Catch Rate (#/hr)		10	20	100
CV		0.72	0.59	0.38
Assumed Range:	0.5	to	0.9	