Update of Statistical Framework for the Onondaga Lake Ambient Monitoring Program

Phase II–Biological Monitoring

prepared for

Department of Water Environment Protection

Onondaga County, New York

by

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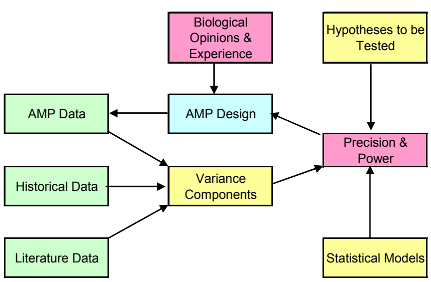
AMP Statistical Framework



Monitoring Program Design for Trend Detection

Null Hypothesis (H_o): No Trend

Outcome of Hypothesis Test:

	Reality	
Test Outcome	**No Trend**	**Trend**
H_o Accepted	Correct	Type II Error max prob. = β
H_o Rejected	Type I Error max prob. = α	Correct

"Significance Level" = α, Pre-Selected

Maximum (β) = 1 - α

Power = Probability of Detecting Trend = 1 - β

= Function ("Trend Number" , α)

$$\text{Trend Number} \sim \frac{\text{Magnitude of Trend} \times (\text{Years of Monitoring})^{1.5}}{\text{Standard Deviation of Yearly Means}}$$

THE VALUE OF CONSISTENT METHODOLOGY IN LONG-TERM ENVIRONMENTAL MONITORING

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Abstract. Long-term monitoring has a substantial history in both the biological and physical sciences. Over time the procedures and analytical methods involved in long-term monitoring have changed to improve the quality of data, but even over short time spans, differences occur that can make direct comparison of measurements either difficult or impossible. In many instances the lack of strictly defined methods or practices means that data from one project cannot be used to enhance other projects with any degree of statistical rigour. This is amply demonstrated in the field of soil classification where improvement in soil definitions, refinement of cut-off points and changes in descriptive techniques between soils is such that in many cases direct comparison of old with new data is impossible. The causes of, and safeguards against, such measurement inconsistency are examined here in the context of the United Kingdom Environmental Change Network (ECN) project. Examples of incompatible data arising from environmental studies are given and the efforts used to standardise methods and practices in the ECN programme are described in detail. The need for standard practices is demonstrated and considered in the light of the limitations of operating what are relatively rigid procedures.

Sources of Measurement Uncertainty
Beard et al., 1999

- Change In Technique
- Change in Personnel
- Change in External Environmental Factors
- Change in Measurement
- Change in Location
- Change in Spatial Coverage
- Change in Frequency or Timing of Measurement

Coping with Measurement Inconsistency
Beard et al., 1999

- Detailed Protocols
- Detailed Recording of Methodology
- Quality Control & Assurance
- Overlap Period for Changes in Methods
- Recording of ‘Meta Data’
- Measurement Synchronization

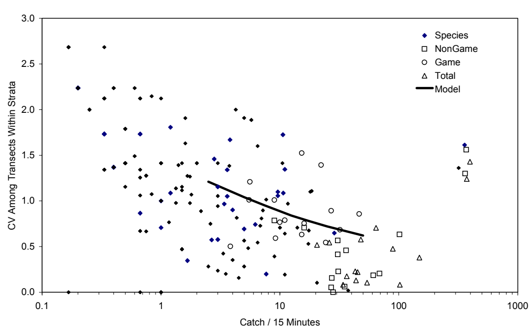
- *Otherwise ---Statistical “Adjustment”*

AMP Design for Biological Parameters - 2002 & Subsequent Years

Category	Years	Season	Frequency	Dates / Year	Method	Depths	Lake Strata	Sites/Stratum	Samples/Site
Pelagic Larvae	annual	April - MidAug	biweekly	7	miller trawl, double oblique tows, day	0-9 m integral	2 Basins (N/S)	4	1
Littoral Larvae	annual	April - MidAug	biweekly	7	seine	-	5	3	1
Juvenile Fish	annual	May-Oct	every 3 weeks	7	seine	-	5	3	3
Adult Total Fish, Littoral Zone	annual	Spring & Fall	twice	2	electrofishing	< 2 m	5	2.4	1
Adult Gamefish, Littoral Zone	annual	Spring & Fall	twice	2	elecrofishing	< 2 m	5	4.8	1
Adult Fish, Profundal Zone *	annual	Spring & Fall	twice	2	gill nets	4-5 m	5	1	1
Fish Nests *	annual	June	once	1	visual counts, by species	bottom	5	4.8	-
Photoplankton	annual	April-Oct	biweekly /monthly	~18 South, 3 North	tube	epil & photic zone compos.	2 (N/S)	1	1
Zooplankton	annual	April-Oct	biweekly	~18	net tow	epil & 15 m	2 (N/S)	Lake South + North (4 Dates)	1
Macrophyte Biomass	twice	august	twice	1	harvest	littoral zone	5	~ 4 transects	~6.4
Macrophyte Cover	twice	august	twice	1	observation	littoral zone	5	~ 4 transects	~95
Littoral Macroinvert.	biennial	July	once	1	dredge	3	5	-	36
Tributary Macroinvert	biennial	July	once	1	kick	1	n/a	10	4

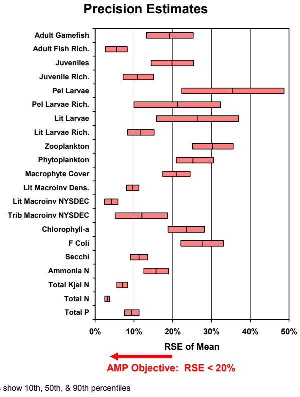
* Statistical evaluation not performed for angler census, adult fish in profundal zone (limited 2000 data, experimental sampling methods), fish nests, & aerial macrophyte surveys.

Replicate CV's vs. Abundance for Electrofishing



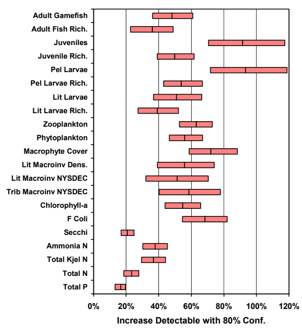
Model: Regression equation for largemouth bass (Miranda et al, 1996) used to estimate CV's in previous report (Walker, 2000)
Species: CV among transects for individual species
Total Counts: CV among transects for total fish count (gamefish, nongamefish, total fish pooled separately)

Precision Estimates



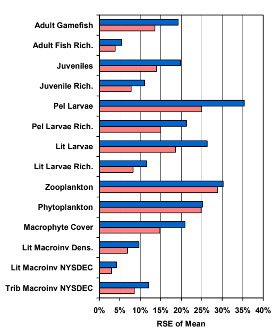
Bars show 10th, 50th, & 90th percentiles

Increases Detectable with 80% Confidence



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

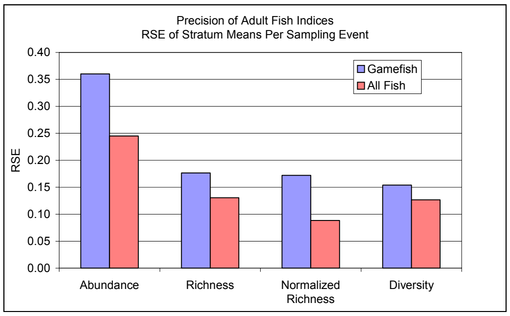
Sensitivity of Precision to Increases in Sample Replicates

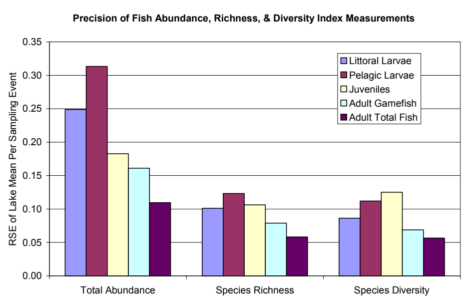


2X Reps = Double number of sites or replicates per stratum or station

Potential Metrics for Fish Population Data

Symbol	Description	Feature
N	Number of Organisms	Low Precision
Log (N+1)	Log Abundance ~ Geometric Mean	Stabilize Variance
$N^{.5}$	Square Root - Poisson Distribution	Stabilize Variance
S	Number of Species	Richness
(S - 1) / Log N	Normalized Richness	Reduce S/N Dependence
$\Sigma\ P_J \log P_J$	Shannon Weaver	Diversity





Some Unkind Words about Diversity Indices*

…connection between high diversity & high environmental quality does not appear to be valid generally..

…the belief that more diverse communities are more stable is without support..

…answers to which questions have not yet been found…

…at best ecologists may have lost a fair amount of time calculating relatively meaningless numbers…

…whatever the (Shannon-Weaver) index does measure seems to have no direct biological interpretation

… produced no noticeable increase in ecological understanding…

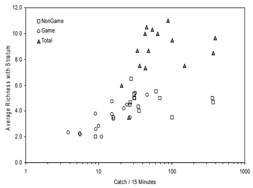
…contrary to …, diversity indices are not independent of sample size

…other statistical methods retain more of the information in the biological data while reducing them to a more useful & ecologically meaningful form.

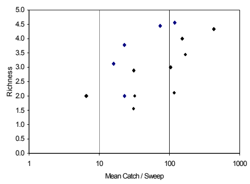
..when used for comparative purposes, simple indices such as S & d are biologically meaningful measures which are less ambigous than .. H..

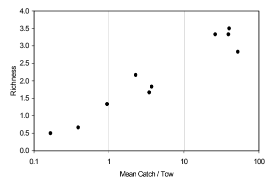
S = Number of Species
d = Normalized Richness (S-1) / Log N
H = Shannon Weaver = Sum [Pj log Pj]

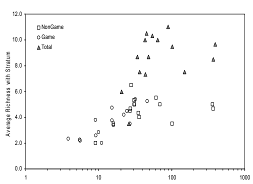
*Green, R., "Sampling Design & Statistical Methods for Environmental Biologists", Wiley & Sons, pp 96-102, 1979

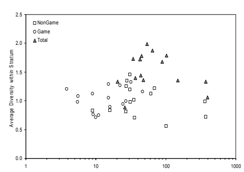


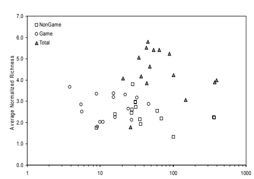
Species Richness vs. Abundance
Adult Gamefish
Littoral Larvae
Pelagic Larvae





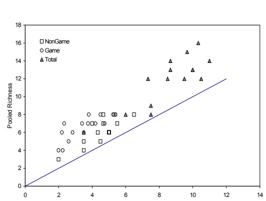


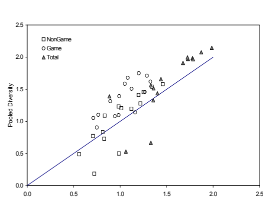


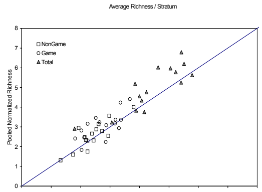


Species Richness & Diversity vs.
Relative Abundance
Adult Fish

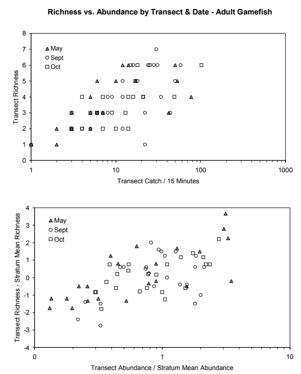
Richness – Number of Species
Diversity – Shannon-Weaver Index
Normalized Richness =
(Richness – 1) / Log (Count)



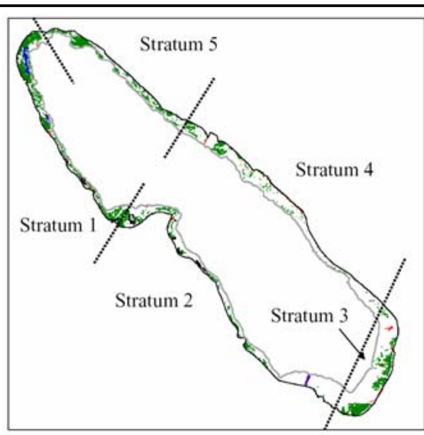


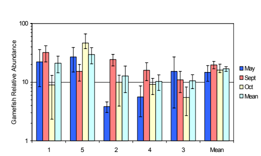


Effect of Pooling Samples Within Strata
on Species Richness & Diversity
Adult Fish Data



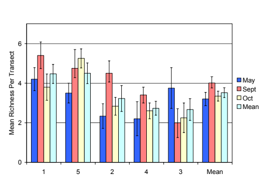
Top Panel: Raw Data, r = 0.72
Bottom Panel: Monthly Stratum Means (~Spatial Variations) Removed, r = 0.59

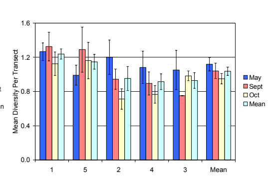


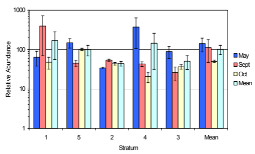


Spatial & Temporal Distribution of
Adult Gamefish
Year 2000 Survey

Strata Sorted North-> South

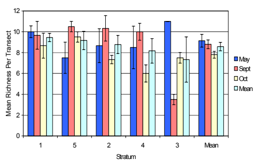


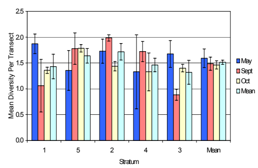




Spatial & Temporal Distribution of
All Adult Fish
Year 2000 Survey

Strata Sorted North-> South





Refinement of AMP
Concepts for Discussion

- Appropriate Metrics
  - Indices (Abundance, Richness, Diversity, etc.)
  - Stratum vs. Lake Mean
  - Seasonal vs. Yearly Mean
- Precision vs. Relevant Scale for Each Metric
- Specific Hypotheses
  - Spatial Variation
  - Change or Trend
  - Comparison with Criteria/Standards
  - Comparison with Other Lakes/Streams
- Tradeoff – Consistent vs. “Improved” Designs