Update of AMP Statistical Framework

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OLTAC Meeting

March 20, 2007

Topics

- Structure & Role of AMPSF
- Analytical Approach
- Statistical Concepts
- Integration with AMP Yearly Reports
- Results* by Dataset
- Conclusions & Recommendations

* All Results Shown are DRAFT

AMP Design

Category	Years	Season	Freq	Dates / Year	Method	Depths	Lake Strata	Sites / Stratum	Samples/Site	Total Samp. /Yr	Metrics	Methodology	Historical Data
Pelagic Larvae	yearly	April - MidAug	biweekly	7	miller trawl, double oblique tows, day	0-9 m integral	2 Basins (N/S)	4	1	6 reps x 3 depths x 2 sites x 7 dates = 252	#/m^3	NYSDEC Percid Sampling Manual (1994)	No
Littoral Larvae	yearly	April - MidAug	biweekly	7	seine	-	5	3	1	3 reps x 12 sites x 7 dates = 252	#/m^3	NYSDEC Percid Sampling Manual	No
Pelagic Juvenile Fish	yearly	May-Oct	every 3 weeks	7	seine	-	5	3	3	3 reps x 12 sites x 5 dates = 180	c/e, l/w	NYSDEC Centrarchids	Yes, Early-Mid 1990's
Adult Total Fish, Littoral	yearly	Spring & Fall	twice	2	electrofishing	< 2 m	5	2.4	1	24 sections x 2 seasons = 48	c/e, l/w, PSD, RSD, etc	NYSDEC Percid Sampling Manual (1994)	No
Adult Gamefish, Littoral	yearly	Spring & Fall	twice	2	elecrofishing	< 2 m	5	4.8	1	24 sections x 2 seasons = 48	c/e, l/w, PSD, RSD, etc	NYSDEC Centrarchids Sampling Manual	No
Adult Fish, Profundal	yearly	Spring & Fall	twice	2	gill nets	4-5 m	5	1	1	2 sites x 4 reps x 2 seas = 16	c/e, l/w	NYSDEC Percid Sampling Manual	Some
Fish Nests	yearly	June	once	1	visual counts, by species	bottom	5	4.8	-	Count 50 Sections Once	count	Ringler et al. (1995)	Yes, 1991, 1993, 1994
Photoplankton	yearly	April-Oct	biweekly /monthly	~18 South, 3 North	tube	epil & photic zone compos.	2 (N/S)	1	1	18 South	count, biovolume	Ed Mills	Yes
Zooplankton	yearly	April-Oct	biweekly	~18	net tow	epil & 15 m	2 (N/S)	Lake S + N (4X)	1	2 depths x 18 dates = 72 (South)	count, biovolume	Ed Mills	Yes
Macrophyte Biomass	every 5 years	August	twice	1	harvest	littoral zone	5	~ 4 Trans	~6.4	125 / Lake	g/m2, % cover, spec ies richness	Ecologic	Some
Macrophyte Cover	every 5 years	August	twice	1	observation	littoral zone	5	~ 4 Trans	~95	125 / Lake	g/m2, % cover, spec ies richness	Ecologic	Some
Littoral Macroinvert.	every 5 years	July	once	1	dredge	3	5	-	36	5 sites x 2 trans x 3 depths x 6 reps = 180	counts, indices	NYSDEC/ Ecologic	Wagner
Tributary Macroinvert	every 2 years	July	once	1	kick	1	n/a	10	4	14 sites x 3 reps = 52	counts, indices	NYSDEC / Ecologic	No

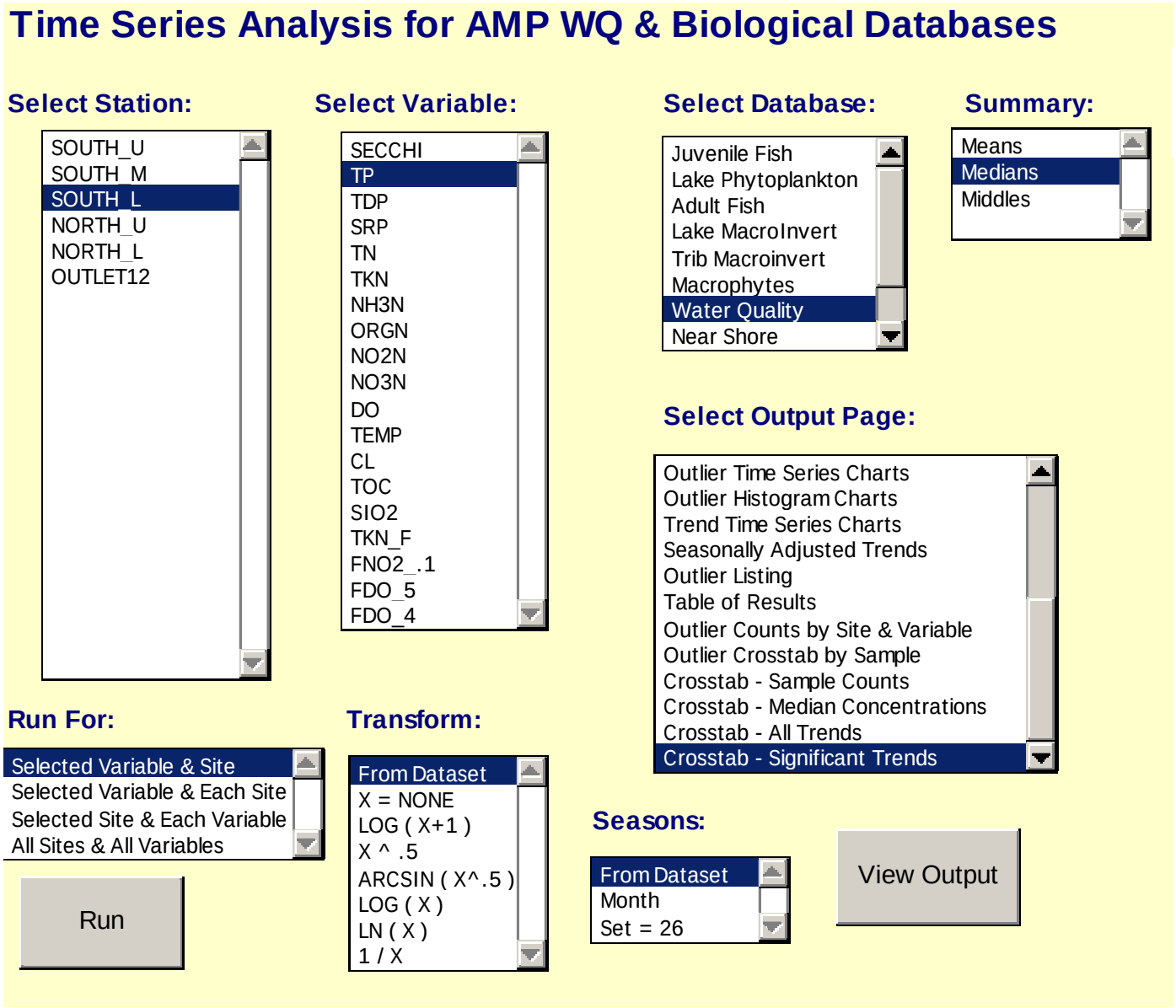
AMPSF Roles

- Evaluate AMP Design
  - Variability (Yearly, Seasonal, Spatial)
  - Precision of Yearly Means vs. RSE < 20%
  - Power for Detecting Trends
  - Sensitivity to Sampling Frequency
- Make Recommendations
  - Monitoring Plan
  - Database Structure & Content
  - Data Analysis & Reporting
  - Formulation & Testing of Hypotheses

AMPSF Reports

- Overall Scope & Concept (1998)
- Water Quality “Phase I” (1999, 2002)
- Biology “Phase II” (2000, 2002)
- WQ & Biology (2007)
  - Analyze 1999 - 2005 Data
  - Update Precision & Power
  - Focus on AMP Hypotheses

Analytical Software Adapted from AMP WQ Database



Tabular Output

Water Quality Site: SOUTH_L SOUTH 12-18 M Group by: Season
Variable: TP ppm Transf: LOG10(X)

Samples	97
Season	6
Years	7
Missing%	0%
N / Cell	2.3
N / Seas	16.2
N / Yr	13.9
Regress R2	0.50
Step R2	0.22

Variance Components

Source	CV	p 2T	Signif
Total	0.915		
Cells	0.926		
Season	0.753	**0.00**	**
Yr_Total	0.406	**0.00**	**
Yr_Trend	0.250	0.08	**
Yr_Rand	0.310	0.00	**
Error	0.327		

Statistics	Data	Transf	Filtered	Anova
Count	97	97	97	42
Median	0.28	-0.55	-0.57	-0.56
Mean	0.29	-0.63	-0.55	-0.65
Std Dev	0.16	0.34	0.17	0.34
Skewness	0.14	-1.12	0.28	-1.14

Null Hypothesis Tails = 1 , Alpha = 0.1

Method	p 1 T	Slope	SE	Signif
1- SK 1	**0.00**	**-7.2%**	**2.4%**	**
1- SK 2	**0.05**	**-7.2%**	**2.4%**	**
2- Lin Reg	**0.04**	**-12.6%**	**5.6%**	**
3- Step Reg	0.14	-30.5%	25.4%	
4- Difference	**0.00**	**-29.4%**	**8.4%**	**

1 - Monotonic Trend (Seasonal Kendall, Versions 1 & 2)
2 - Linear Trend (Regres 3 Step Change after 2002
4 - Difference (Period 1 Mean vs Period 2 Mean)

Precision & Power - vs. Samples / Yr

Design	N	N / 2	N x 2
Sampl/Yr	13.9	6.9	27.7
CV_W	0.44	0.44	0.44
CV_Y	0.31	0.31	0.31
CV_YT	0.33	0.35	0.32

Precision - Relative Std Error of Mean %

Yearly Mn	0.11	0.16	0.08
Long-Term	0.12	0.13	0.12
Period Mn	0.04	0.06	0.03

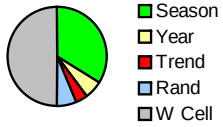
Prob. of Detecting Trends with 10 yrs of data

Change %	N	N / 2	N x 2
10%	0.26	0.25	0.27
20%	0.51	0.47	0.52
30%	0.75	0.71	0.77
50%	0.97	0.96	0.98
100%	1.00	1.00	1.00

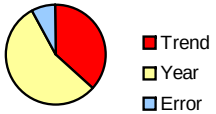
Change Detectable with 90% Confidence

Incre %	32.6%	34.8%	31.5%

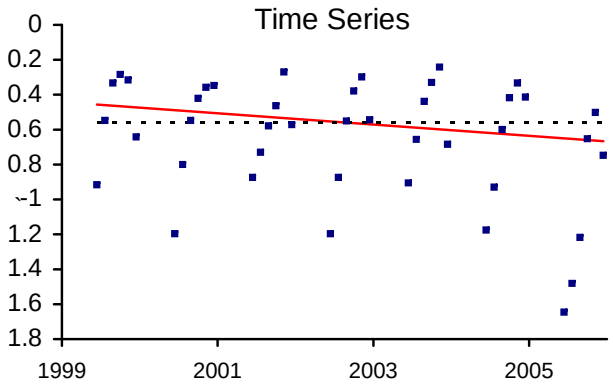
Variance Comp

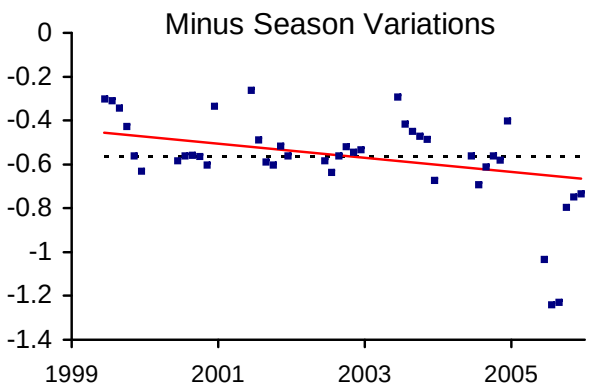


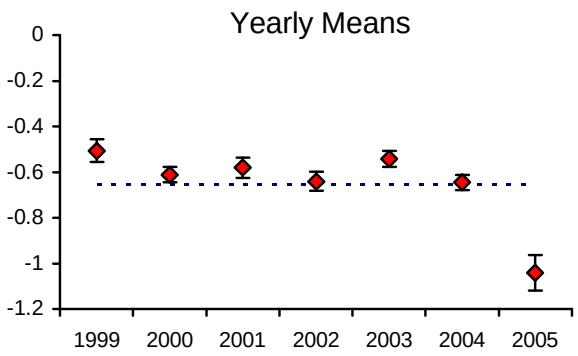
Yearly Time Series

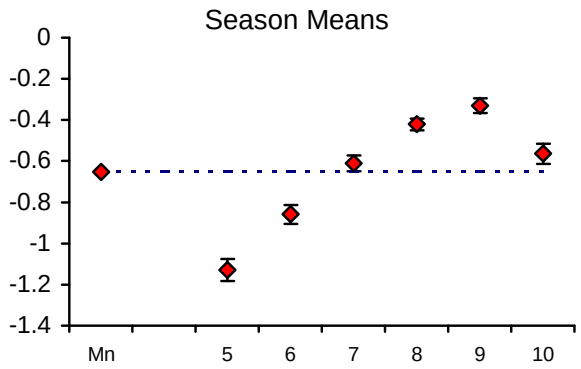


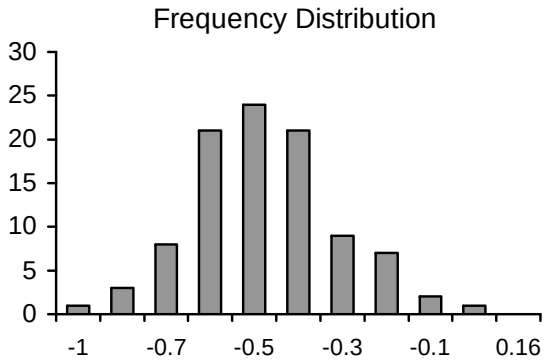
Diagnostic Output

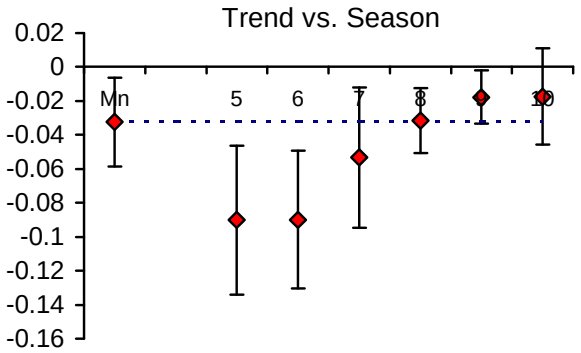






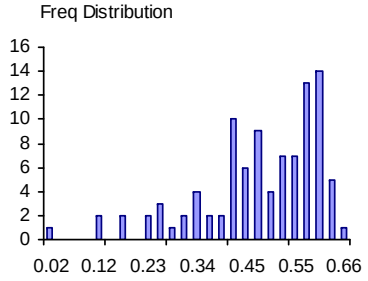


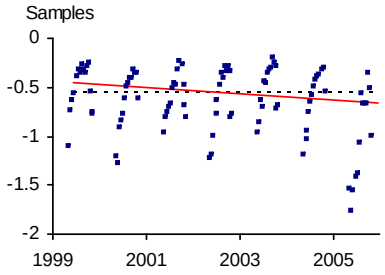


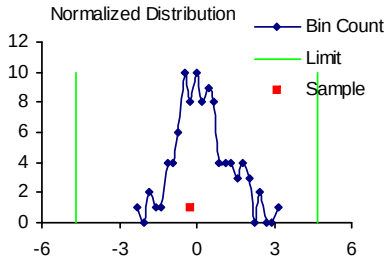


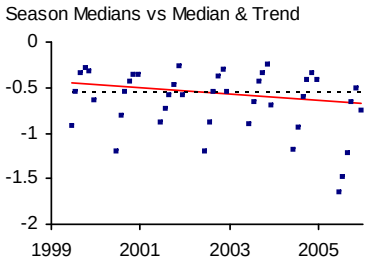
Diagnostic Output

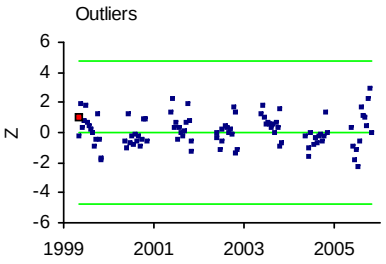
Database:	Water Quality		
Site	SOUTH_L	SOUTH 12-18 M	
Variable	TP	LOG10(X)	
Samples	97	Outliers	0
Date Range	5/4/1999	10/27/2005	
Median	0.28033	ppm	
Trend / Year	-7.2%	p = 0.00	

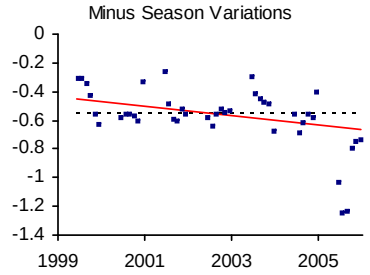


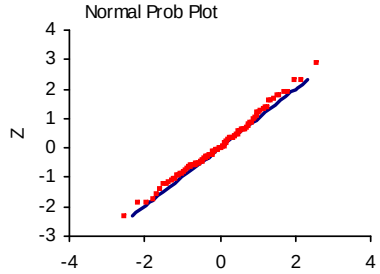












Data Analysis

Testing Hypotheses

Null Hypothesis (H_o): No Improvement (1-Tailed)

Outcome of Hypothesis Test:

	Reality	
Test Outcome	No Trend	Trend
H_o Accepted	Correct	Type II Error 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)

$$\text{Trend Number} \sim \frac{\text{Size of Trend} \times (\text{Years of Monitoring})^{1.5}}{\text{Std Dev of Yearly Means}}$$

Increasing Power for Detection

- Given Factors:
  - Choice of Tails & Significance Level (α)
  - Duration of Monitoring
  - Size of Hypothetical Trend

- Power Controlled by Year-to-Year Variance:
  - Uncertainty in Yearly Mean Measurements ~ Vs / Ns
  - Actual Year-to-Year Variance
    - Random (Natural, Background, Unexplained, etc)
    - Covariance with External Factors
      (Loads, Hydrology, Climate, Biology, etc.)

- Increase Power by:
  - Monitoring Every Year
  - Increasing Precision of Yearly Means
    - Analytical, Sampling Methods (decrease Vs)
    - Spatial & Temporal Frequency (increase Ns)
  - Using Best Statistical Method
  - Adjusting Data for Covariance with External Factors

Methods for Testing Trend Hypotheses

- Regression of Annual (or Seasonal) Means
  - Linear Trend
  - Step Trend e.g. Year 1-3 vs. Year 4-6
  - OK with Consistent Sampling vs. Season
- Seasonal Kendall Test
  - Version 1 (Used Here for Screening, 1-Tail, $p<.1$)
  - Version 2 (Conservative, AMP Reports, 2-Tails, $p<.1$)
  - Accounts for Seasonal Variations in Mean
  - Does not Account for Seasonal Variations in Trends

Structure of AMP Annual Report (Ecologic, 2006)

- Architecture
  - Table 1-1: Objectives & Structure
  - Table 1-2: Elements vs. ACJ Objectives
  - Table 1-3: Management Questions
  - Table 1-4: Hypotheses to be Tested
  - Table 1-5: Metrics
- Data Analysis & Interpretation
- Regulatory Compliance
  - Table 3-1: Compliance - Tributaries
  - Table 3-2: Compliance - METRO Discharge
  - Table 3-3: Lake (South Deep) (? Shoreline ?)
  - Table 3-4: Seneca River
- Ten-Year Trends
  - Table 3-5: Tributary Loads
  - Table 3-6: Lake & Tributary Concentrations
- Report Card (Tables 3-9 thru 3-22)

AMP Report Card
Hypothesis, Metrics, & Status

- 3-9: Metrics vs. Uses
- 3-10: Lake WQ & Habitat
- 3-11: Ammonia N
- 3-12: Nitrite-Nitrogen
- 3-13: Total Phosphorus
- 3-14: Dissolved Oxygen
- 3-15: Bacteria
- 3-16: Chlorophyll-a
- 3-17: Transparency
- 3-18: Phytoplankton
- 3-19: Zooplankton
- 3-20: Macrophytes
- 3-21: Macroinvertebrates
- 3-22: Fish

Dimensions of AMP Hypotheses

- Goal Attainment
  - Regulatory Limits (NH3, NO2, DO, Bacteria)
  - Guidance Values (TP, Chl-a, Secchi)
  - Biological Indices (%BGA, %PTolerant, %Cover)
- Correlation with Loads (TP, NH3)
- Trend / Improvement

Long-Term Trends in P Load & Lake P Concentration

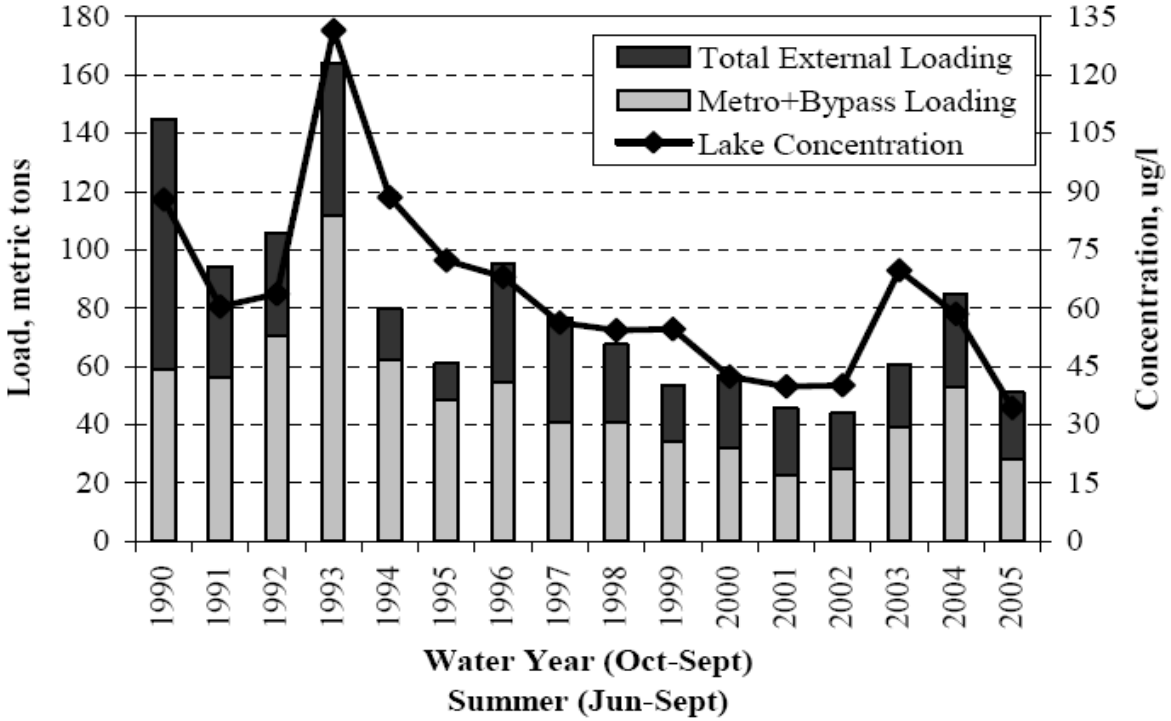


Figure 2-14. Total Phosphorus: Water Year (October to September) external loading and Metro (Outfalls 001 and 002) loading to the lake, compared with South Deep summer (June-September) daily average concentrations for depths 0 to 6 meters. Onondaga Lake, 1990-2005.

Long-Term Trends in Ammonia N

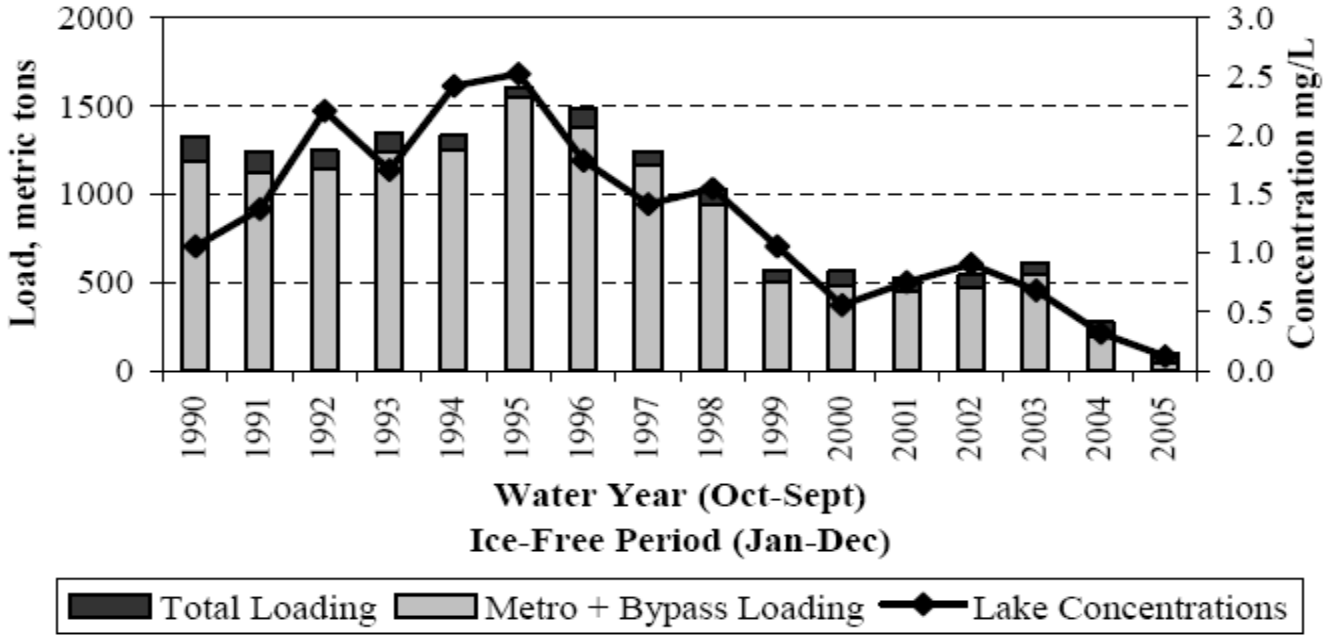
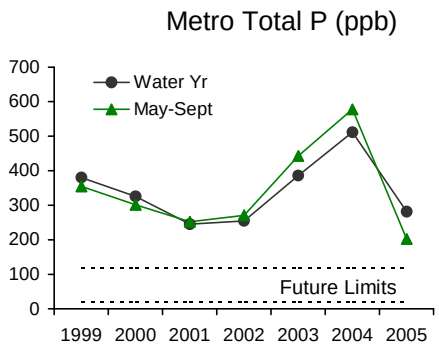
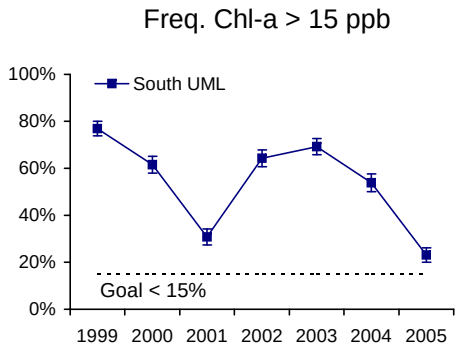
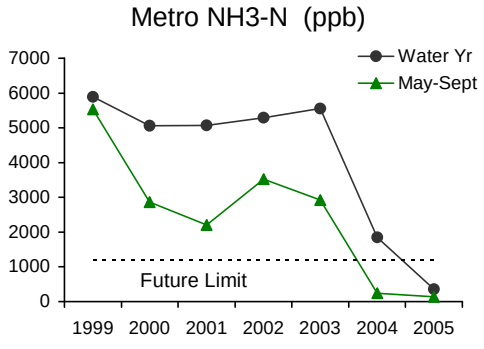


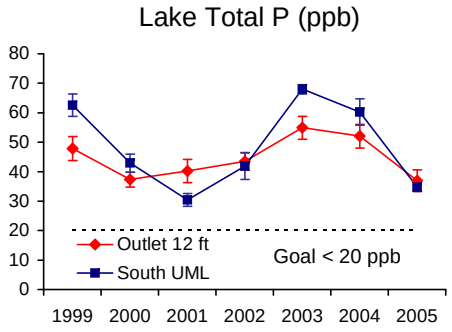
Figure 2-27. Water year (October to September) external ammonia load and average annual (January to December, ice-free period) concentrations of ammonia in Onondaga Lake. For example, loading for the period 10/2004 to 09/2005 is paired with concentration for 2005. Lake concentrations are the annual average of sample date averages of discrete samples collected at meter depths 0, 3, and 6. External ammonia loading obtained from historic_loads.xls.

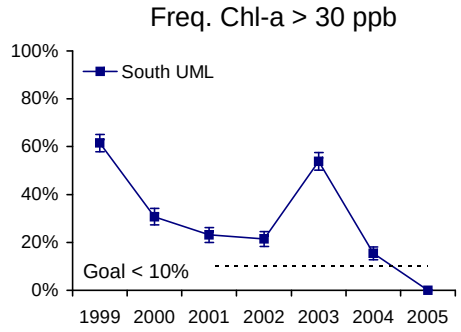
Metro Discharge Concs. & Lake Water Quality Metrics

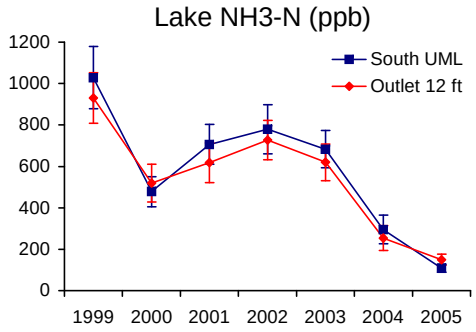


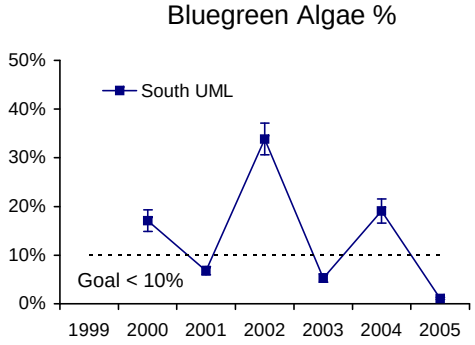


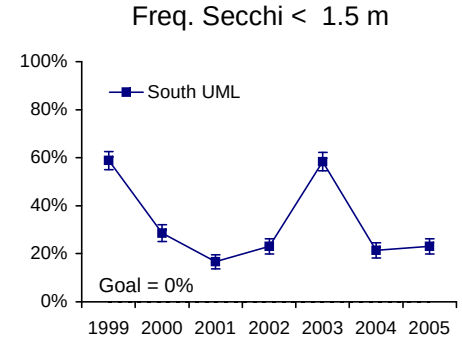


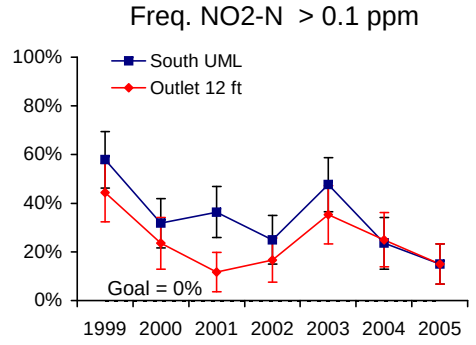












Seasons: June-Aug for Phosphorus, Chlorophyll-a, & Secchi; April-November for NH3 & NO2

Attainment of Transparency Goal in 2005

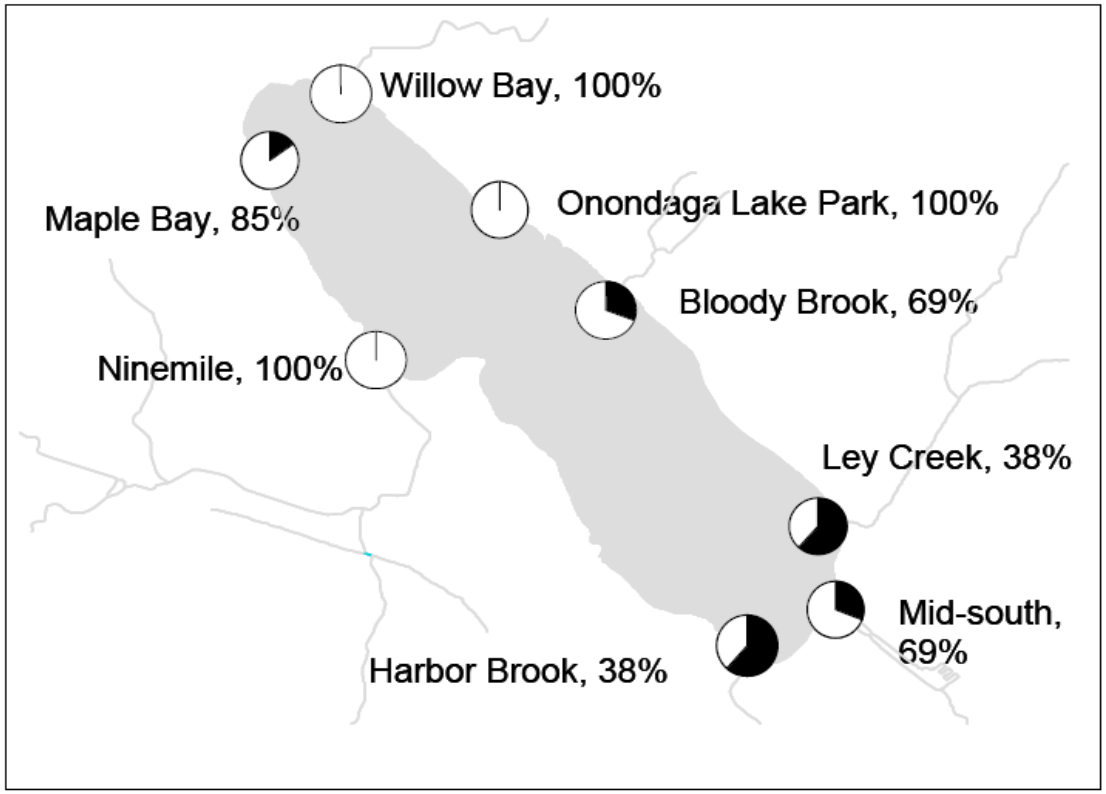
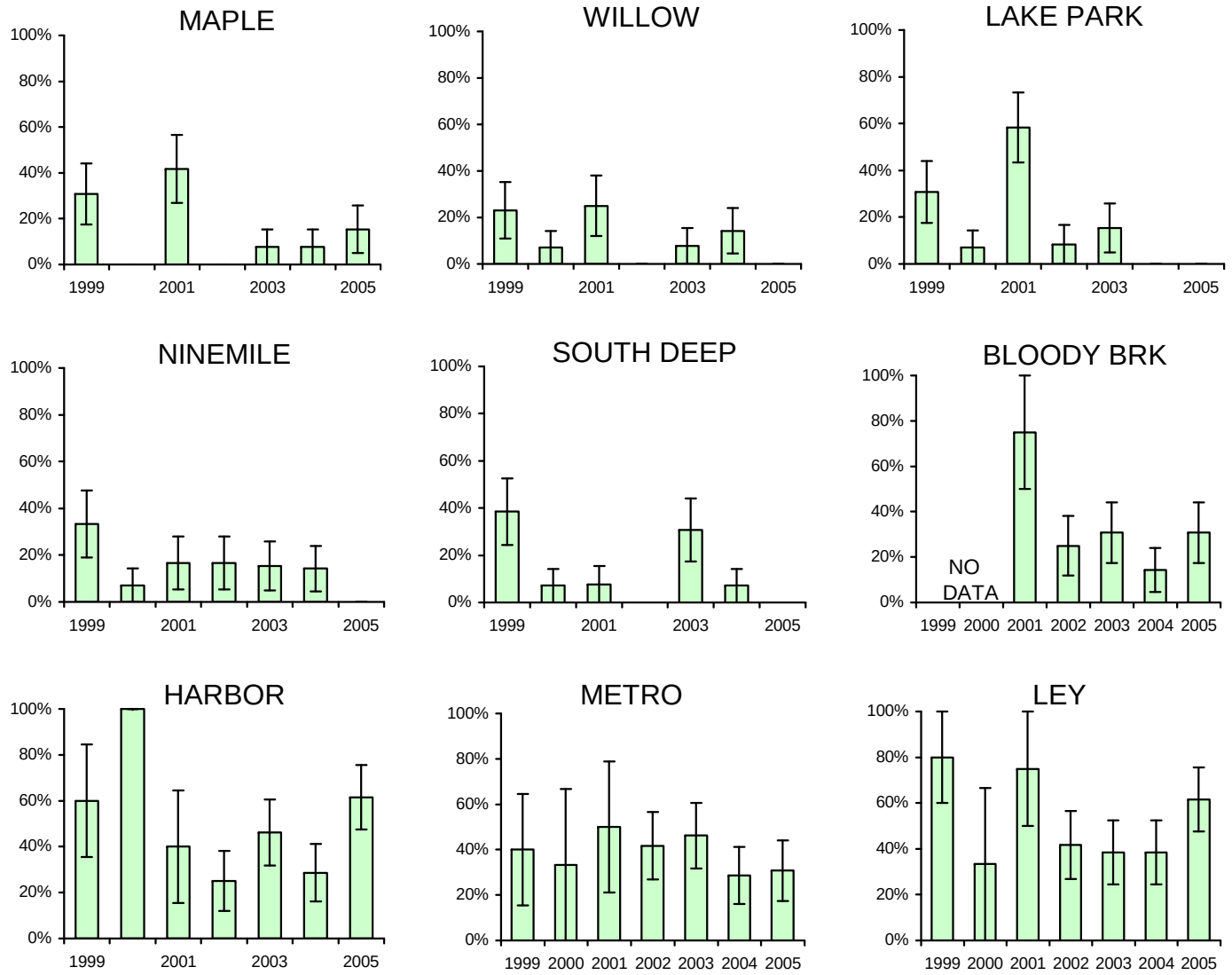


Figure 2-24. Nearshore water clarity conditions in 2005. Percent shown in figure indicates compliance with swimming safety guidance value (1.2 m). Shaded area of pie charts indicates percent of samples where Secchi depth was below guidance value.

Lake Nearshore Data

Frequency of Secchi Depth < 1.2 meters



SECCHI_LT_1.2 June-August

AMP Datasets – Movies

- Yearly Time Series
- Random Yr-to-Yr Variance Measured
- 1-Tailed Null Hypotheses
  - H0: Long-Term Goal Not Achieved
  - H0: No Long-Term Improvement
- Components
  - Water Quality (N, P, DO)
  - South Deep Phyto., Chl-a, Secchi
  - Nearshore Bacteria & Secchi
  - Littoral Adult Fish
  - Pelagic Juvenile Fish

AMP Datasets – Snapshots

- Five-Year Intervals
- Random Year-to-Year Variance Not Measured
- 1-Tailed Null Hypotheses
  - H0: Year N Mean > (or <) Goal
  - H0: Year 6 Mean > (or <) Year 1 Mean
- Components
  - Trib MacroInvertebrates
  - Lake MacroInvertebrates
  - Littoral Macrophytes/Algae

AMP Datasets - Not Analyzed

- Zooplankton
- Littoral Fish Larvae
- Pelagic Fish Larvae
- Pelagic Adult Fish
- Fish Nests
- Angler Surveys

Lake Water Quality

- Precision
- Trends
- Special Topics
  - Correlated with P & NH3 Loads
  - Track Complete Suite of Nutrients in UML & LWL to Reflect Long-Term Changes in Nutrient Cycling
  - Apparent Trends Stronger in LWL vs. UML
  - Outlet Similar to South UML
  - Oxygen Metrics

Lake Water Quality - Precision & Trends

Precision Estimates — Relative Standard Error of Yearly Mean

STATION	DESCRIPTION	TP	TN	TKN	NH3N	ORGN	NO2N	NO3N	TOC	SIO2	CL	DO	TEMP
OUTLET12	OUTLET 12 FT	0.08	0.10	0.08	0.20	0.07	0.10	0.08	0.03	0.17	0.03	0.07	0.03
SOUTH_U	SOUTH - 0-3 m	0.09	0.08	0.06	**0.21**	0.06	0.09	0.08	0.03	0.20	0.02	0.05	0.02
SOUTH_L	SOUTH - 12-18 m	0.11	0.08	0.07	0.10	0.09	**0.23**	**0.28**	0.02	0.12	0.02	**0.20**	0.02

Exceeds AMP Design Goal (RSE < 0.20)

Trends — Trend Slope (% / Year)

STATION	DESCRIPTION	TP	TN	TKN	NH3N	ORGN	NO2N	NO3N	TOC	SIO2	CL	DO	TEMP
OUTLET12	OUTLET 12 FT		-0.10	-0.09	-0.17		-0.10	0.05		0.08	-0.03	0.02	
SOUTH_U	SOUTH - 0-3 m		-0.09	-0.09	-0.15	-0.03	-0.09	0.03			-0.03	0.03	
SOUTH_L	SOUTH - 12-18 m	-0.07	-0.14	-0.13	-0.17	-0.04		0.16	-0.03	0.04	-0.02		

May-October Samples,1999-2005, UML = 0 - 3 meters, LWL = 12 - 18 meters

Seasonal Kendall Test (Version 1), % of Median Value / Yr, p < .10, 1-Tailed Test

Phytoplankton, Chl-a, Secchi

- Precision & Trends
- Special Topics
  - Correlation with P Load
  - Trends vs. Season
  - Photic Samples > EPI/UML Samples
    - Total Biomass ~16%
    - Chlorophyll-a ~11%
    - Bluegreen Biomass, % Bluegreens – No Difference
  - Lake North ~ Lake South Biomass, Chl-a
  - Secchi vs. Zooplankton
  - Trends in Phytoplankton Taxa

Phytoplankton, Chlorophyll-a, Secchi

Precision & Trends, South Deep, 2000-2005

SEASON	CHLA_UML	CHLA_PHO	SECCHI	BLUEGR%	TOTAL_BM	CYANO	CHLORO	CRYPTO	BACILLARIO	CHRYSO	MICRO	DIVERSITY
Precision	**Relative Standard Error of Yearly Mean**											
MAY-SEPT	0.17	0.18	0.10	0.07	0.34	0.62	0.48	0.45	0.64	0.53	0.29	0.13
JULY-AUG	0.22	0.21	0.13	0.12	0.35	0.82	0.50	0.67	1.18	0.70	0.22	0.16

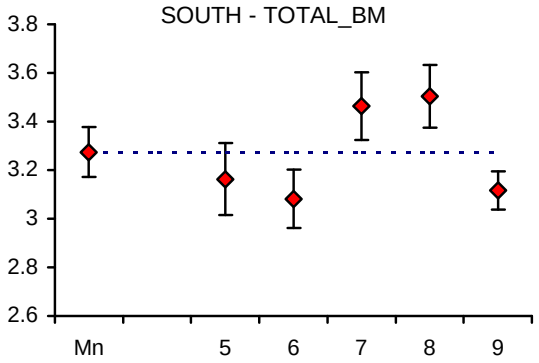
Exceeds AMP Design Objective (RSE < 0.20)

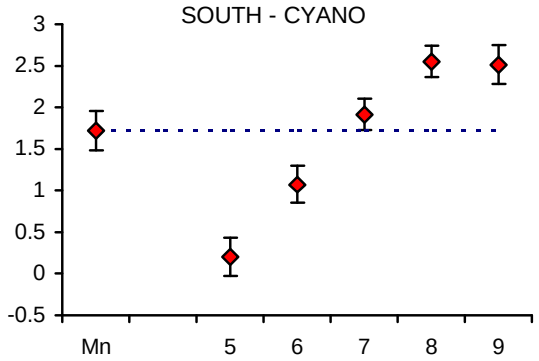
Trends	Trend Slope (% / Year)				2000 - 2005						
MAY-SEPT			-0.01		-0.15	1.02	0.42			-0.27	
JULY-AUG		-0.11	-0.01	-0.25	-0.43	1.15	0.45			-0.26	0.06

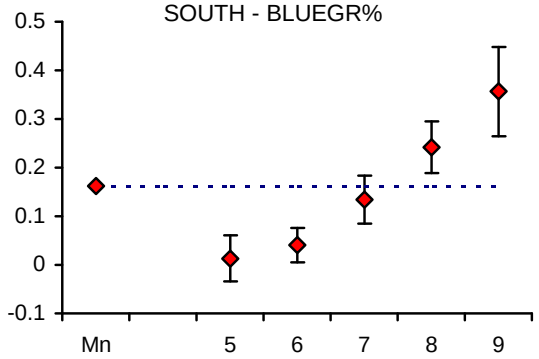
Seasonal Kendall Test (Version 1), % of Median Value / Yr, p < .10, 1-Tailed Test

Seasonal Variations - Phytoplankton

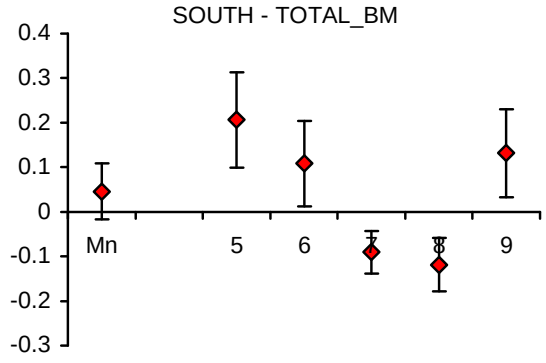
Seasonal Variations in Means

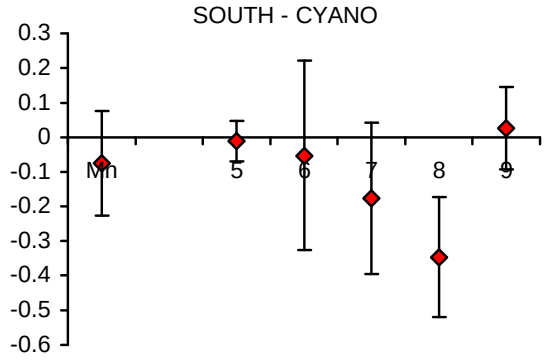


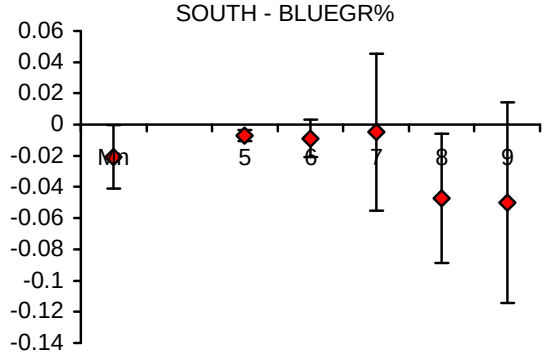




Seasonal Variations in Trend Slopes

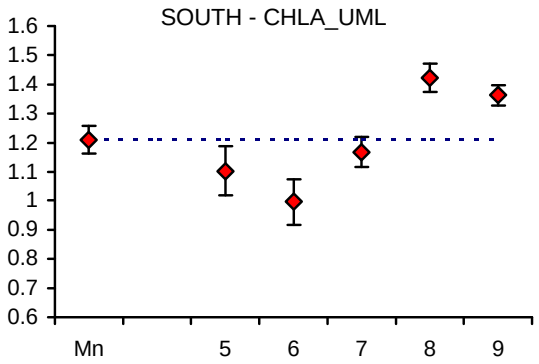


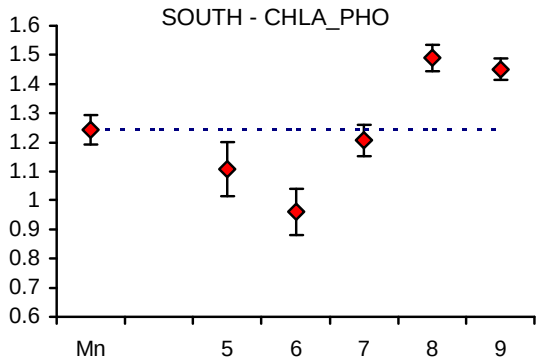


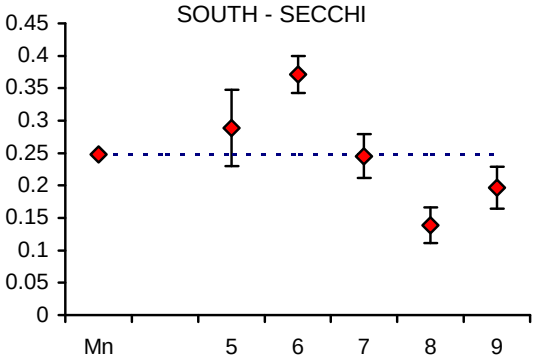


Seasonal Variations – Chl-a & Secchi

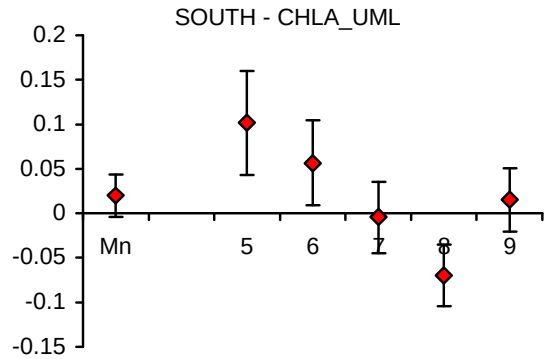
Seasonal Variations in Means

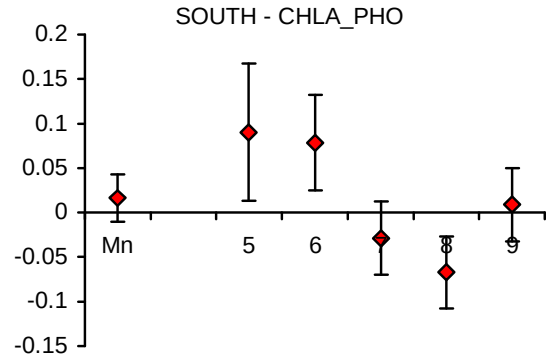


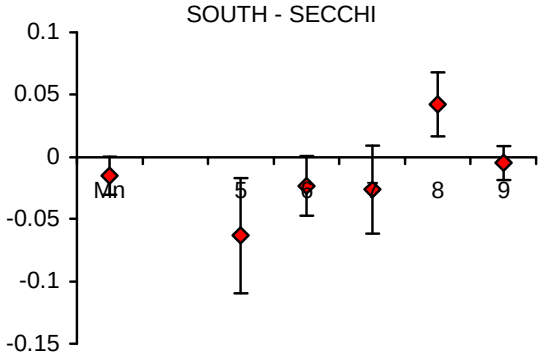




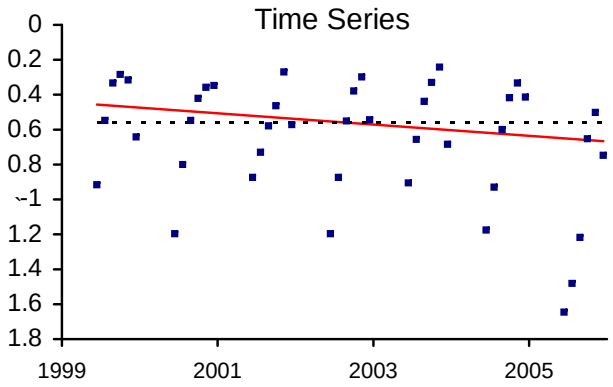
Seasonal Variations in Trend Slopes

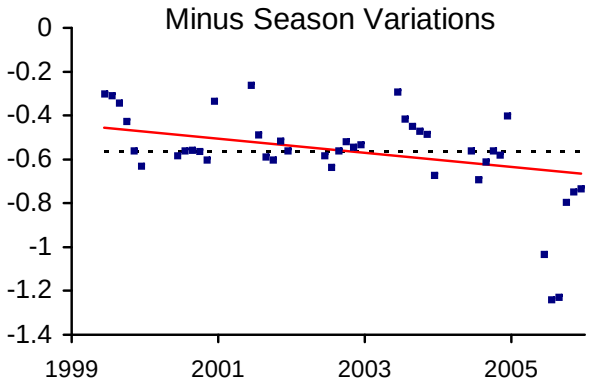


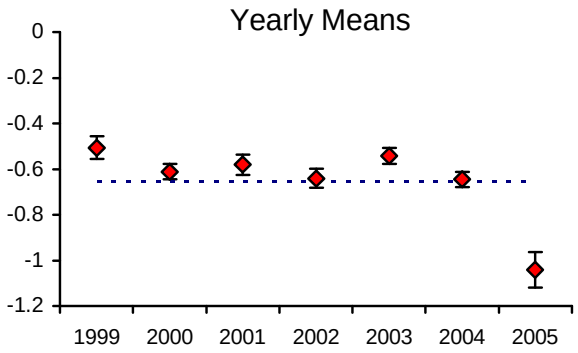


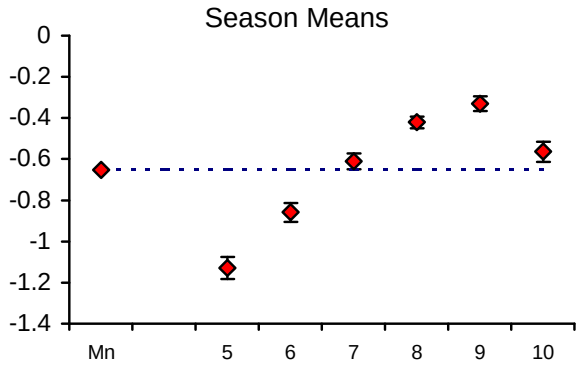


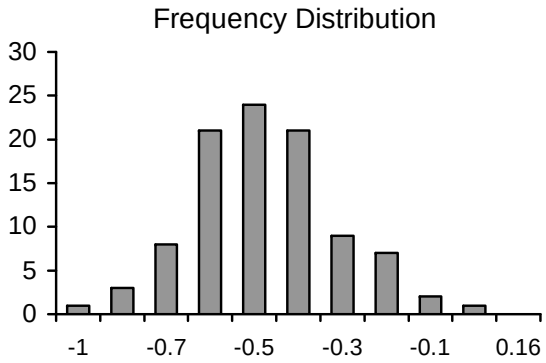
Diagnostic Output – LWL TP

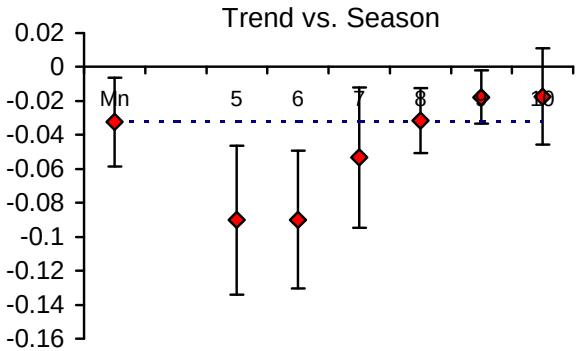












Adjustment of Secchi Depth Time Series to Account for Covariance with Zooplankton Size

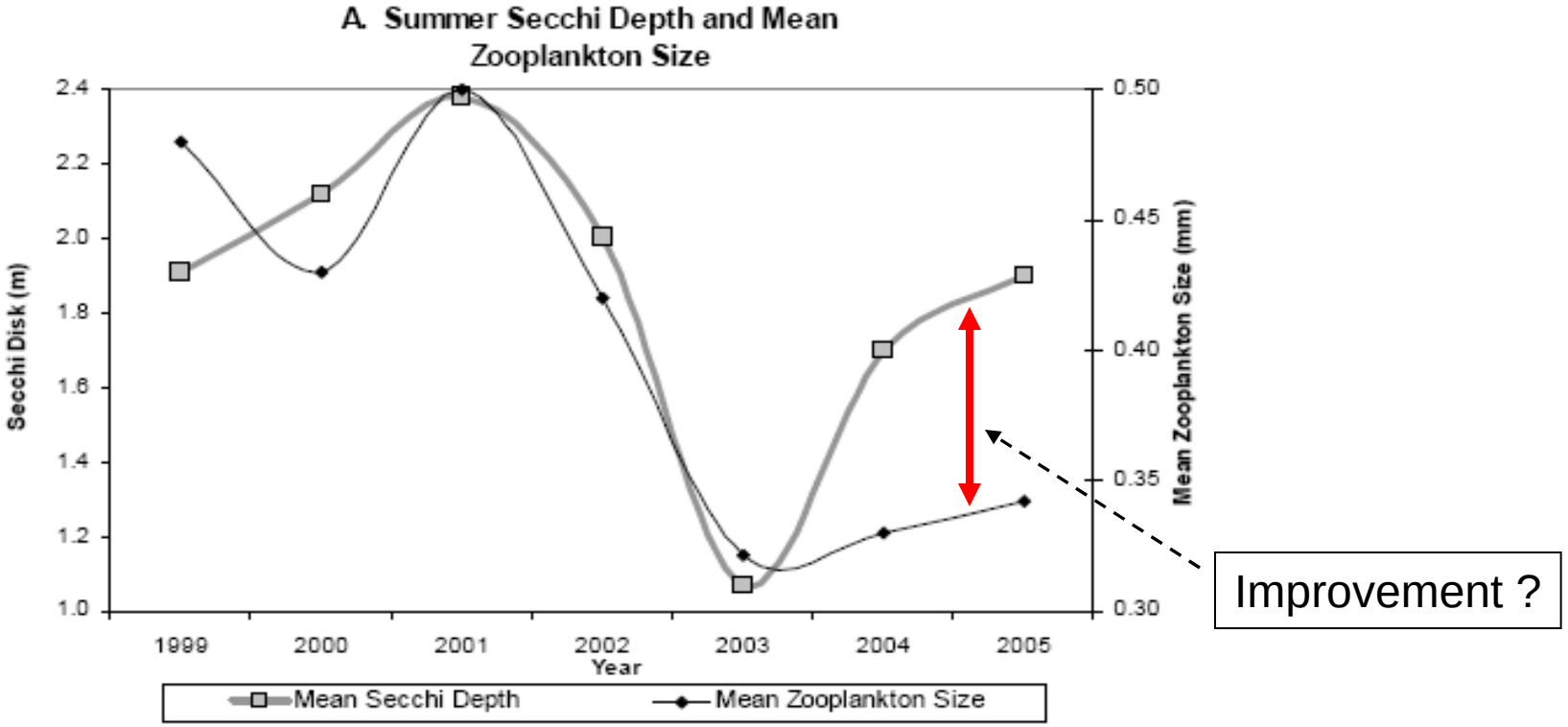
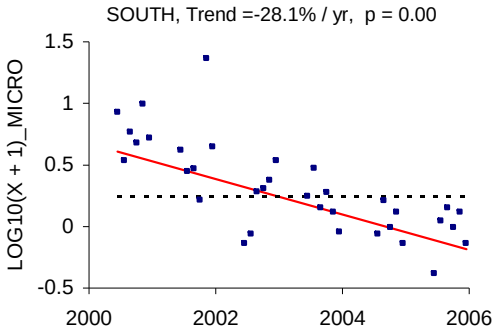


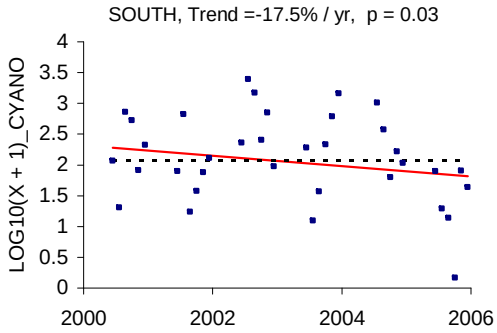
Figure 3-6. A) Mean summer Secchi disk measurements and mean zooplankton size from Onondaga Lake, 1999 to 2005. B) Regression of mean summer Secchi disk measurements and mean zooplankton size in Onondaga Lake 1999 to 2005, labels are the year.

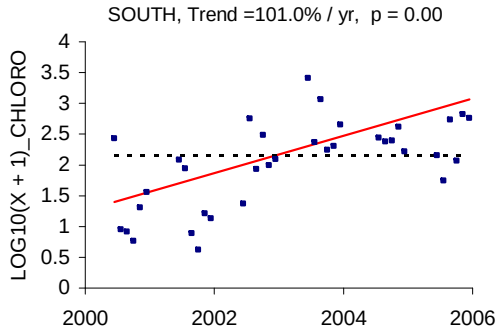
Trends in Phytoplankton Taxa

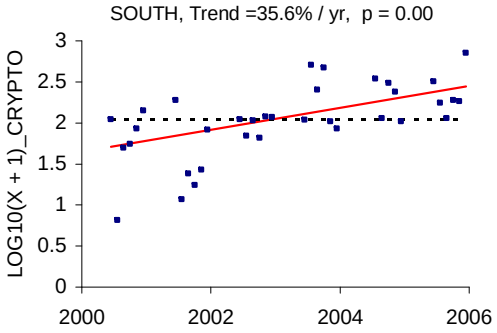
Seasonally Adjusted Time Series

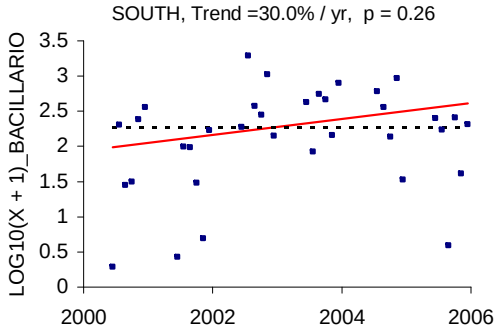
Dataset: Lake Phytoplankton Site: SOUTH Lake South

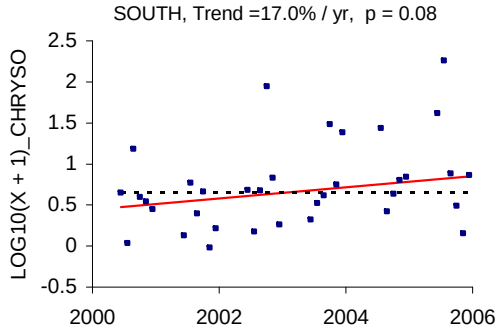


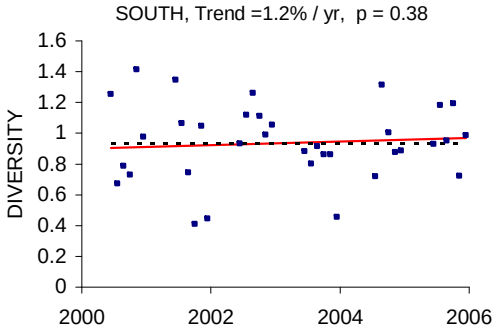


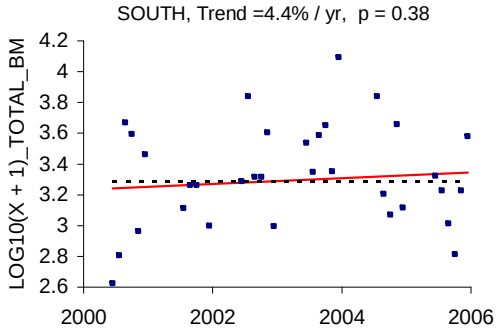


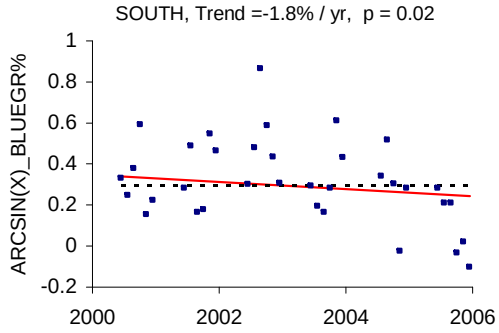












Shoreline Bacteria & Transparency

- Precision
- Notes
  - Analyzed Weekly Data (Not Storm Events)
  - Pooling Sites Increases Precision
  - Messy Bacteria Data
- Recommendations
  - Further Review & Analysis of Bacteria Data
  - Add Bacteria Monitoring at Outlet 12 ft

Lake Near-Shore Bacteria & Secchi - Precision

Precision Estimates — RSE

STATION	DESCRIPTION	SECCHI	FCOLI	ECOLI
MAPLE	MAPLE BAY	0.09	0.20	**0.21**
WIL	WILLOW BAY	0.08	**0.23**	**0.25**
LKPK	LAKE PARK	0.10	0.11	0.14
BLBRK	BLOODY BROOK	0.10	**0.35**	**0.36**
9MILE	NINEMILE CREEK	0.08	**0.23**	**0.27**
LEY	LEY CREEK	0.16	**0.71**	**0.72**
METRO	METRO	0.10	**0.63**	**0.62**
HARB	HARBOR BROOK	0.09	**0.57**	**0.58**
SOUTH	SOUTH DEEP	0.12	**0.27**	**0.30**
NORTH_C	NORTH BASIN	0.04	0.10	0.11
SOUTH_C	SOUTH BASIN	0.06	**0.25**	**0.27**

June-August, Storm Event Data Excluded

Exceeds AMP Design Objective (< 0.20)

Inventory of Near-Shore Fecal Coliform Data

June-August - Routine / "Dry"?

Year	MAPLE	WIL	LKPK	BLBRK	9MILE	LEY	HARB	METRO	SOUTH
1999	13	13	13		12	3	3	3	13
2000	14	14	14		14	3	3	3	14
2001	12	12	12	4	12	4	5	4	13
2002	12	12	12	12	12	12	12	12	13
2003	13	13	13	13	13	13	13	13	13
2004	13	14	14	14	14	13	14	14	14
2005	13	13	13	13	13	13	13	13	13

June-August - Storm Event ?

Year	MAPLE	WIL	LKPK	BLBRK	9MILE	LEY	HARB	METRO	SOUTH
1999	3	3	3		3	3	2	3	
2000	3	3	3		3	3	3	3	
2001	3	3	3	3	3	3	3	3	
2002	3	3	3	3	3	3	3	3	3
2003	20	20	20	20	20	20	20	20	20
2004									
2005									

Percent of June-August Samples with 3-Day Antecedent Rain > 0.5 inches

Year	MAPLE	WIL	LKPK	BLBRK	9MILE	LEY	HARB	METRO	SOUTH
1999	0	0	0		0	0	0	0	0
2000	18	18	18		18	0	0	0	21
2001	20	20	20	29	20	29	38	29	15
2002	20	20	20	20	20	20	20	20	19
2003	30	30	30	30	30	30	30	30	30
2004	46	43	43	43	43	46	43	43	43
2005	23	23	23	23	23	23	23	23	23

Limitations of Shoreline Bacteria Data

- Routine (~Weekly-Monthly) vs. Storm Event Programs
- Weekly Samples “Dry” or Random ?
- Sensitive to Antecedent Storm Events
- Not Random if Different Programs Are Pooled
- Variations in “Dry” Sampling Frequency
- Values Not Quantified (< , >)
- Highly Variable & Skewed Distributions
- Difficult to Detect Outliers
- Trend Analysis Sensitive To
  - Monthly vs. Weekly Intervals for Summarizing Data
  - Means vs. Medians within Intervals
  - Season Boundaries (May-Sept vs. June-Aug)
  - Pooling of Stations
- Questions on Database - Sample Assignments to Programs
- Recommend Additional QA/QC on Database
- Recommend Analysis vs. Storm Events etc.

Pelagic Juvenile Fish

- Precision & Trends
- Special Topics
  - Data Inventory
  - Strong Seasonality
  - Focused on July-Sept Samples
  - Increasing Trend in Bass CPUE

Pelagic Juvenile Fish – Data Inventory

Common Name	2000*	2001	2002	2003	2004	2005	Total
Banded killifish	4	5	27	56	5	49	146
Bluegill	0	13	21	0	29	15	78
Bluntnose minnow	0	0	0	4	0	0	4
Brook Silverside	45	24	10	0	0	0	79
Carp	1	0	28	76	58	30	193
Emerald shiner	0	4	0	0	0	0	4
Gizzard shad	1790	1559	2	321	178	2	3852
Golden shiner	1	0	0	11	0	2	14
Largemouth bass	30	248	261	182	618	1529	2868
Lepomis sp.	591	5150	2719	4942	1419	2715	17536
Pumpkinseed	0	43	13	0	3	272	331
Smallmouth bass	78	193	56	82	140	361	910
White perch	30	34	2	10	3	0	79
Yellow perch	28	329	2	0	0	12	371
Johnny darter	0	0	1	0	0	0	1
White sucker	0	11	1	0	0	0	12
Tesselated darter	0	0	0	0	0	2	2
Logperch	7	3	0	0	0	0	10
Longnose gar	0	0	0	0	1	0	1
Rock bass	0	0	0	0	0	6	6
Brown bullhead	0	2	1	3	0	18	24
Channel catfish	0	0	1	0	0	0	1
Total	2605	7618	3145	5687	2454	5013	26522

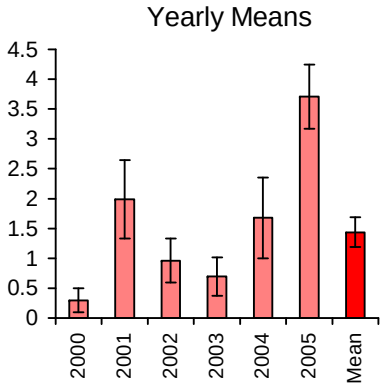
Pelagic Juvenile Fish - Precision & Trends

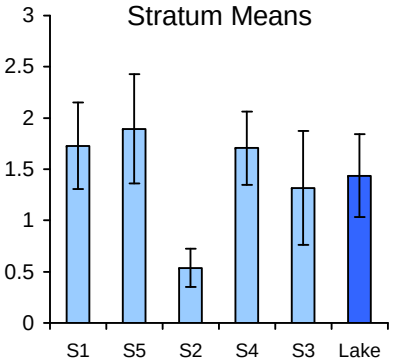
STRATUM	DESCRIPTION	CPUE	CPUE_BASS	RICHNESS	DIVERSITY
Precision Estimates		Relative Std Error of Yearly Mean			
S1	STRATUM 1	0.70	0.54	0.24	0.39
S2	STRATUM 2	1.16	0.93	0.28	0.36
S3	STRATUM 3	0.85	0.81	0.28	0.42
S4	STRATUM 4	0.67	0.67	0.26	0.29
S5	STRATUM 5	0.66	0.51	0.19	0.28
NORTH	NORTH (S1, S5)	0.55	0.36	0.16	0.21
SOUTH	SOUTH (S2, S3, S4)	0.56	0.62	0.15	0.19
LK	LAKE	0.44	0.32	0.11	0.14
Exceeds AMP Design Objective (< 0.20)					
Trends		Trend Slope (% / Year)			
S1	STRATUM 1		0.76		
S2	STRATUM 2		0.54		0.13
S3	STRATUM 3		0.60		
S4	STRATUM 4		0.58		
S5	STRATUM 5	0.28	0.75		
NORTH	NORTH (S1, S5)	0.39	0.66		
SOUTH	SOUTH (S2, S3, S4)		0.44		
LK	LAKE		0.75		

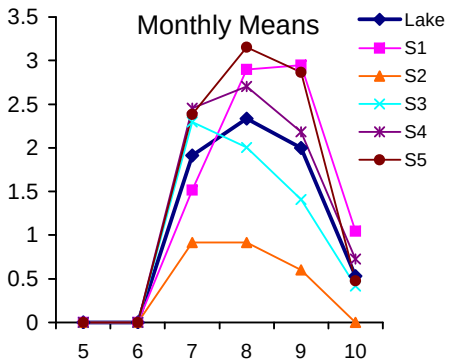
July-September Samples,2000-2005

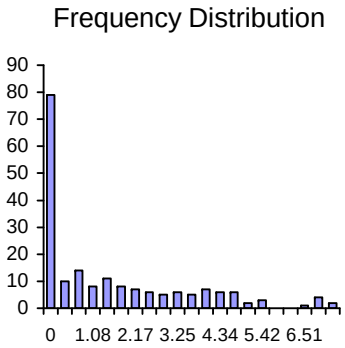
Seasonal Kendall Test (Version 1), % of Median Value / Yr, p < .10, 1-Tailed Test

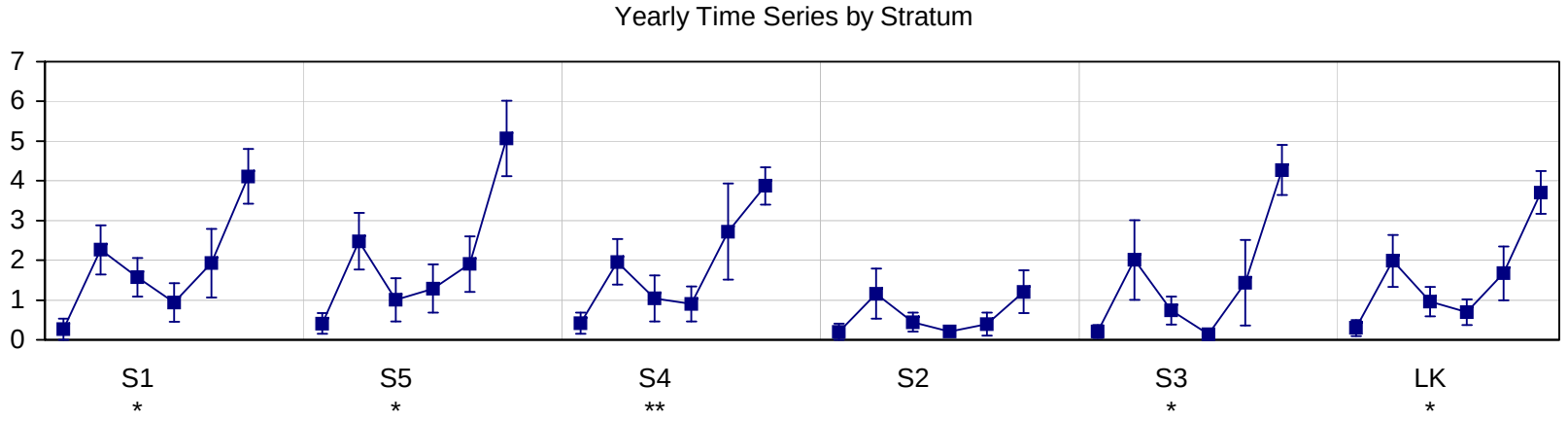
Pelagic Juvenile Fish
Spatial & Temporal Variations in Bass CPUE











Linear Regression * p<.10, ** p<.05, 1 tailed

Strata ordered North to South

CPUE_BASS_SQRT

Pelagic Larval Fish - Data Inventory

Common Name	2000	2002	2003	2004	2005	Total
Gizzard shad	8	213	21	14		256
Alewife				2	17	19
Herring Family (Cluepeidae)	387			2	2	391
Lepomis sp.	77		17	1	1	96
Pumpkinseed		1	1			2
Bluegill		90				90
Sunfish Family (Centrarchidae)	1					1
Banded killifish					1	1
Brook Silverside				1		1
Carp		1			1	2
Freshwater drum	64	7				71
Minnow Family (Cyprinadae)	1					1
White perch	4	11				15
Yellow perch	2	4			1	7
Species Unknown	12					12
Total	556	327	39	20	23	965

Littoral Zone Adult Fish

- Precision & Trends
- Special Topics
  - Precision Sufficient to Detect Trends (Clupeids, Bass)
  - Trends Vary with Season & Stratum
  - Effects of Pooling Samples on Species Richness
  - Estimated vs. Direct Counts
  - Handling of High Clupeid Counts
  - CPUE Square Root Transformation
  - Suggested Formats for Displaying Data

Adult Fish Transects

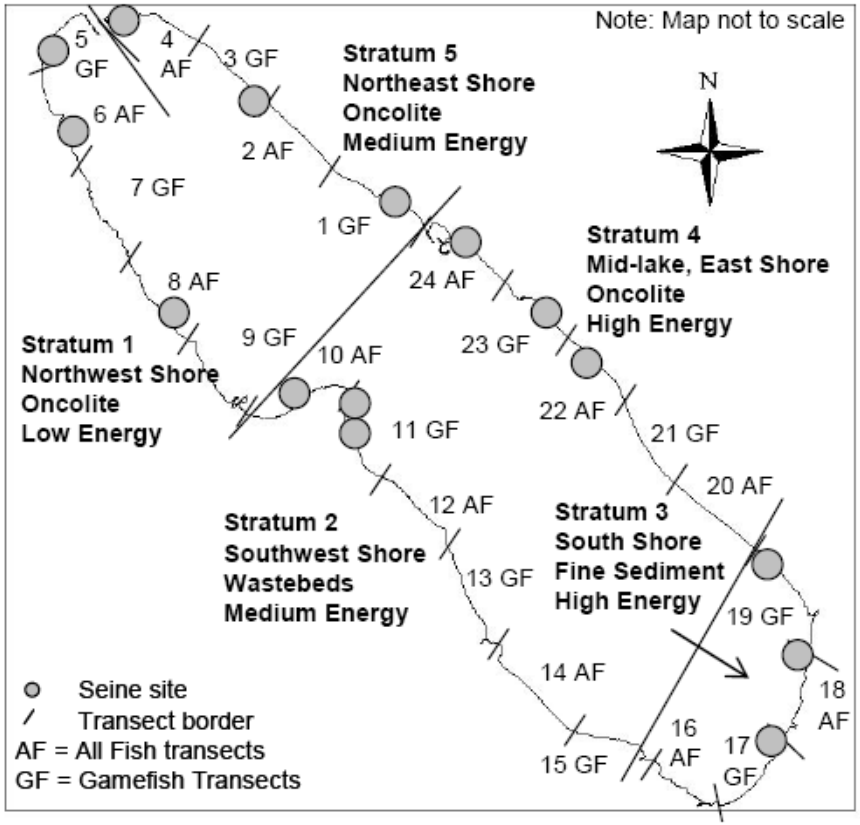


Figure A8-1. Location and description of strata, boat electrofishing transects, and seining sites in Onondaga Lake.

Adult Fish Precision

Precision Estimates — Relative Standard Error of Yearly Mean

STRATUM	CPUE_ALLFISH	CPUE_GAME	CPUE_CLUP	CPUE_NONCLUP	CPUE_BASS	RICH_ALLFISH	RICH_GAME	DIV_ALLFISH	DIV_GAME	PCT_INTOL
S1	0.17	**0.26**	**0.33**	**0.24**	**0.32**	0.10	0.10	0.08	0.06	0.04
S2	0.20	**0.27**	**0.29**	**0.26**	**0.36**	0.10	0.11	0.08	0.08	0.03
S3	**0.23**	**0.40**	**0.47**	**0.26**	**0.60**	0.17	0.19	0.15	0.15	0.02
S4	**0.35**	**0.26**	**0.58**	**0.32**	**0.33**	0.11	0.09	0.09	0.08	0.04
S5	**0.28**	**0.20**	**0.66**	**0.29**	**0.26**	0.10	0.09	0.07	0.09	0.02
NORTH_SPR	0.18	0.18	**0.44**	**0.21**	**0.25**	0.09	0.08	0.08	0.06	0.03
SOUTH_SPR	0.20	**0.21**	**0.34**	**0.20**	**0.31**	0.10	0.09	0.08	0.07	0.02
LAKE_SPR	0.14	0.15	**0.28**	0.16	**0.23**	0.07	0.06	0.06	0.05	0.02
NORTH_FAL	0.17	**0.25**	**0.35**	**0.22**	**0.27**	0.09	0.09	0.07	0.08	0.05
SOUTH_FAL	**0.21**	**0.22**	**0.34**	**0.25**	**0.32**	0.11	0.11	0.09	0.09	0.04
LAKE_FAL	0.14	0.17	**0.26**	0.17	**0.21**	0.07	0.07	0.06	0.06	0.03

Exceed AMP Design Objective (< 0.20)

Adult Fish Trends

Trends

Trend Slope (% / Year)

STRATUM	CPUE_ALLFISH	CPUE_GAME	CPUE_CLUP	CPUE_NONCLUP	CPUE_BASS	RICH_ALLFISH	RICH_GAME	DIV_ALLFISH	DIV_GAME	PCT_INTOL
S1	0.14		0.63							0.01
S2	0.21		0.74		0.48			-0.06	0.05	0.01
S3	0.18		0.43				0.09		0.09	
S4			0.52		0.35		0.08	-0.04		
S5			0.44							
NORTH_SPR			0.69	-0.17						
SOUTH_SPR	0.11		0.24		0.58		0.11	-0.04	0.05	
LAKE_SPR			0.39	-0.09			0.10	-0.05	0.05	
NORTH_FAL	0.31		0.38	0.17						
SOUTH_FAL	0.22		0.91					-0.03		
LAKE_FAL	0.22		0.71		0.12					0.01

Seasonal Kendall Test (Version 1), Percent of Median Value / Year, $p < .10$, 1-Tailed Test

Adult Fish Power

Power — Change Detectable with 90% Confidence

STRATUM	CPUE_ALLFISH	CPUE_GAME	CPUE_CLUP	CPUE_NONCLUP	CPUE_BASS	RICH_ALLFISH	RICH_GAME	DIV_ALLFISH	DIV_GAME	PCT_INTOL
S1	19	26	54	23	31	10	10	8	7	5
S2	22	27	39	26	37	10	11	10	11	4
S3	24	40	50	38	83	17	22	16	20	3
S4	35	25	75	32	38	16	15	11	10	4
S5	28	20	78	28	26	13	9	10	11	3
NORTH_SPR	18	47	88	22	49	14	15	11	12	3
SOUTH_SPR	26	60	49	36	46	12	11	12	8	3
LAKE_SPR	20	53	57	24	40	7	11	8	7	
NORTH_FAL	36	25	69	25	56	17	21	10	17	5
SOUTH_FAL	25	30	40	29	31	15	18	10	10	4
LAKE_FAL	25	25	48	16	37	10	17	7	11	3

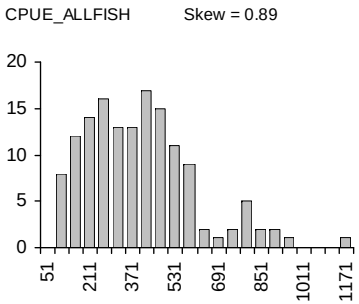
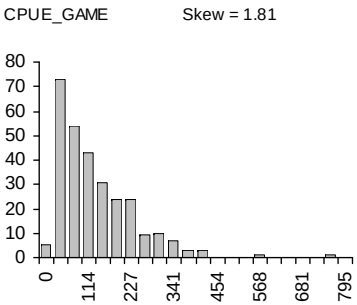
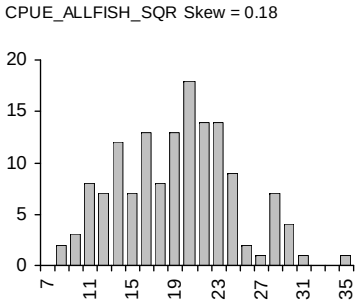
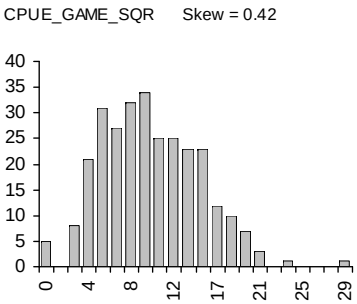
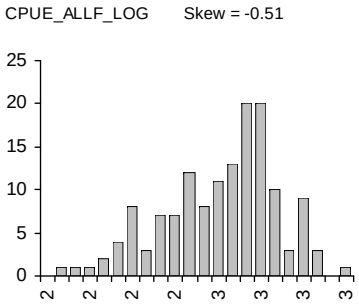
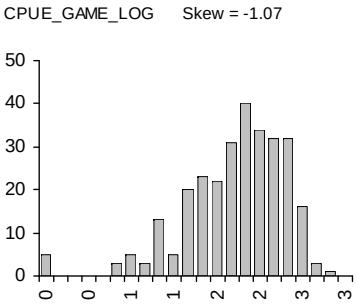
Monitored yearly for 10 years; Students t test comparing means of years 1-5 with years 6-10
Test significance level = 0.10 (1-tailed) ; Risk of Type II error is < 10% if change >= value in table
Change expressed as percent of 10-year mean

Counted vs. Estimated Adult Fish by Year

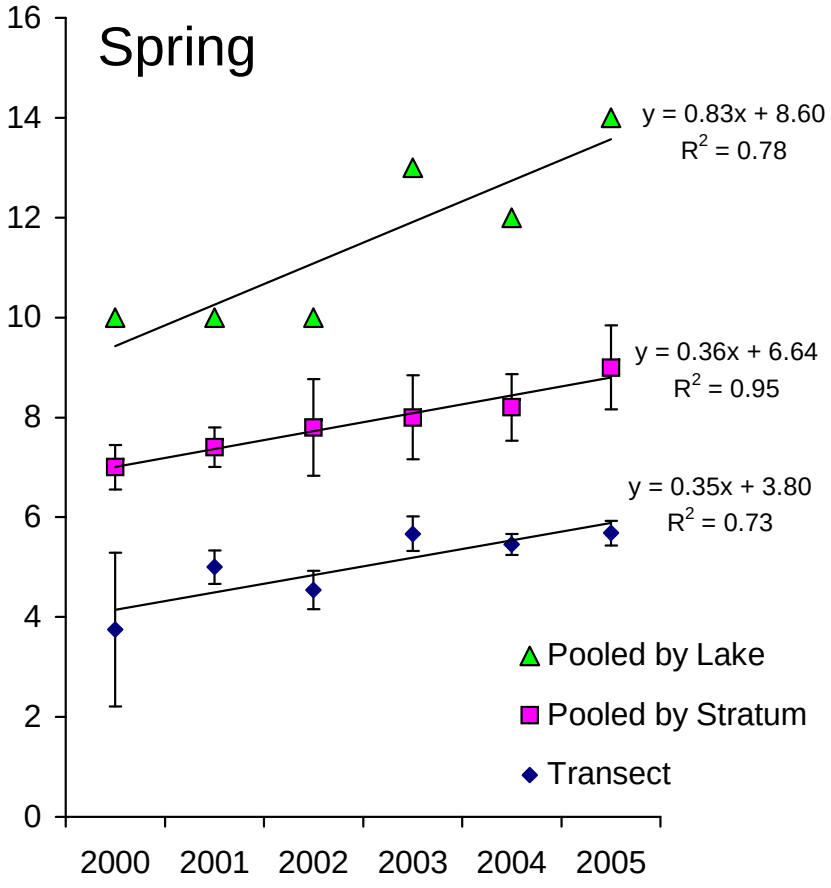
	2000	2001	2002	2003	2004	2005
Fish Counted						
Clupeid	361	237	417	269	1443	926
Non Game	695	716	487	456	566	486
Game	830	1018	1372	1542	1275	1004
Total	1886	1971	2276	2267	3284	2416
Fish Estimated						
Clupeid	1500	200	4200	1540	13862	8070
Non Game *	6	0	17	311	1167	635
Game *	0	0	65	1434	1616	999
Total	1506	200	4282	3285	16645	9704

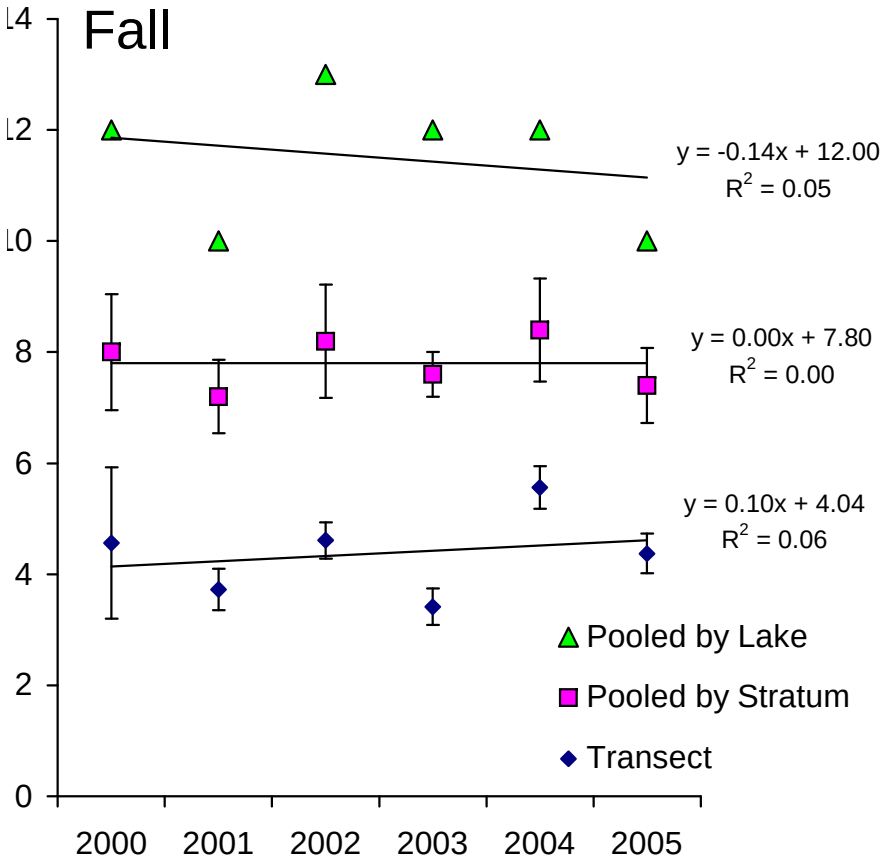
* Excluded from analysis in AMP Yearly & AMPSF Reports

Square Root Transformation of CPUE Data to Reduce Skewness

	All Fish	Game Fish
N		
$N^{.5}$		
LOG (N + 1)		

Trends in Gamefish Richness vs. Season & Sample Pooling Method





Gamefish Counted in Spring vs. Year

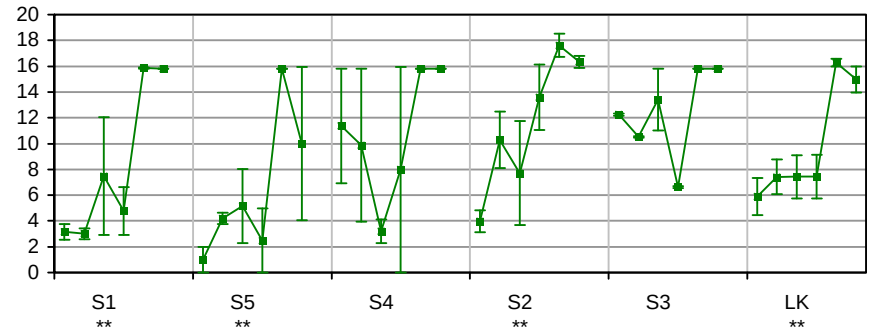
Common Name	2000	2001	2002	2003	2004	2005
Black crappie*	1			1	1	
Bluegill*	140	229	315	434	164	27
Bowfin*			6	4	9	5
Brown bullhead*	8	25	20	15	15	30
Brown trout	1				1	2
Channel catfish*		5	3	4	7	1
Largemouth bass*	44	48	59	93	87	87
Lepomis sp.				1		
Northern pike		1		1		2
Pumpkinseed*	72	209	263	416	280	140
Rock bass	1		2	1	1	5
Smallmouth bass	28	124	40	83	48	40
Tiger muskellunge	0	1				2
Walleye*	22	11	9	4	1	6
Yellow bullhead*						1
Yellow perch*	13	166	29	139	129	186
Total Fish	330	819	746	1196	743	534
Total Species	11	11	11	14	13	15
Shannon-Weaver	1.62	1.69	1.44	1.50	1.65	1.74

* Pollution Tolerant or Moderately Tolerant

Trends in Clupeid CPUE

Strata Ordered North to South

Yearly time series, significant trends (* p<.10, **p<.05, 1-tailed)



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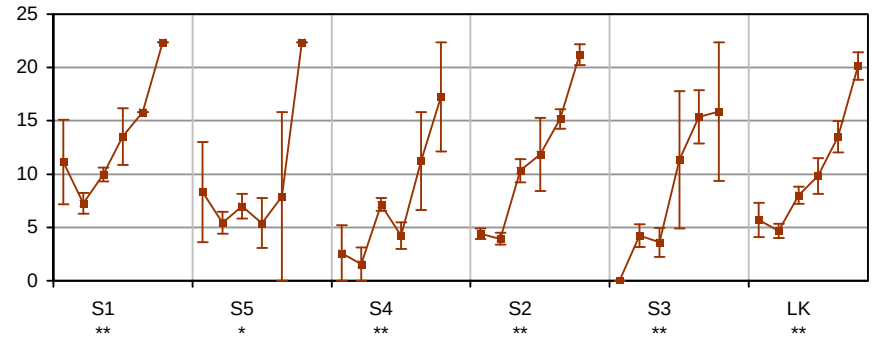
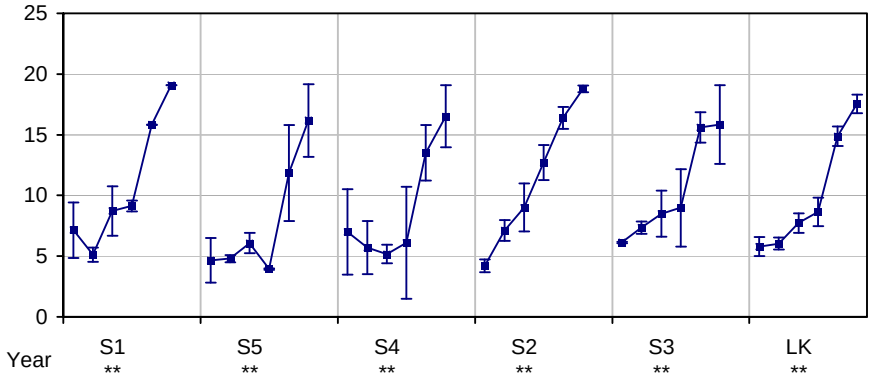
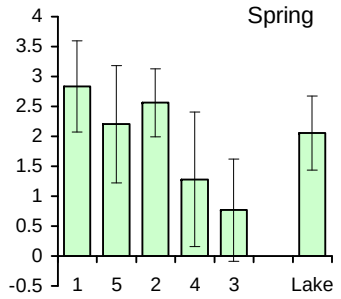
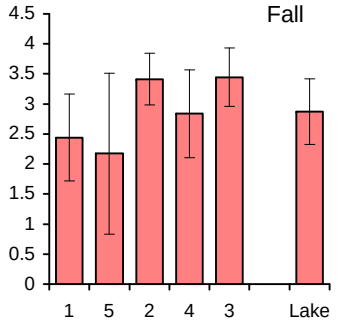


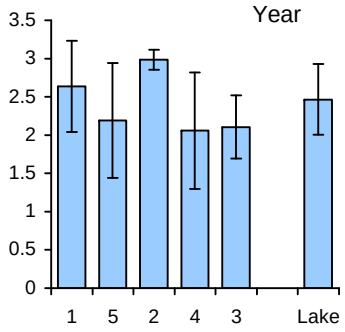
Fall



Trend Slopes



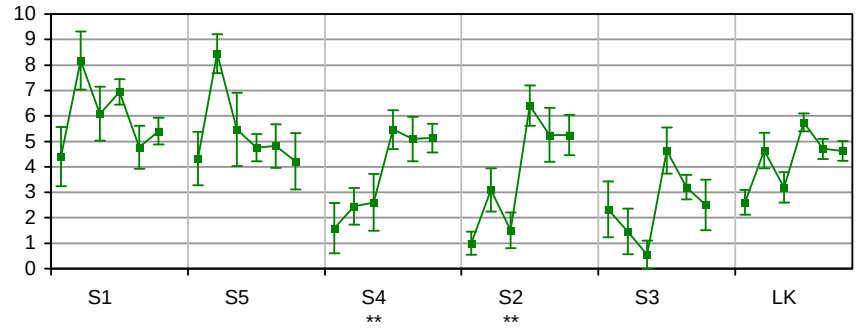




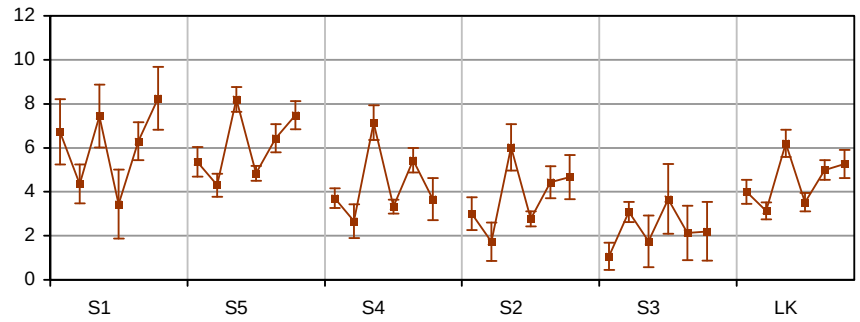
Trends in Bass CPUE

Strata Ordered North to South

Yearly time series, significant trends (* p<.10, **p<.05, 1-tailed)



Spring



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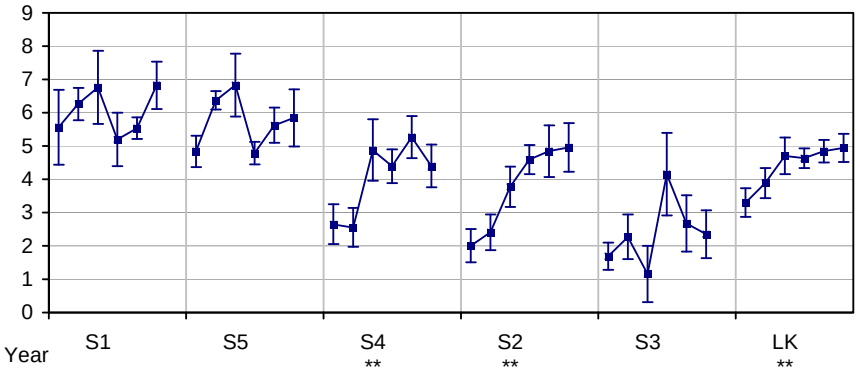
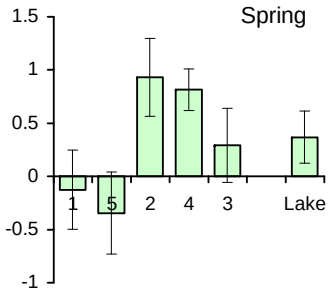
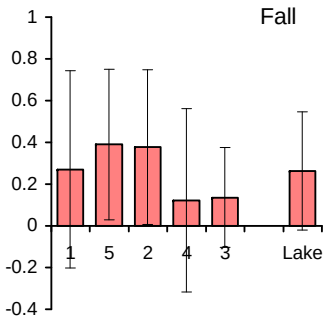
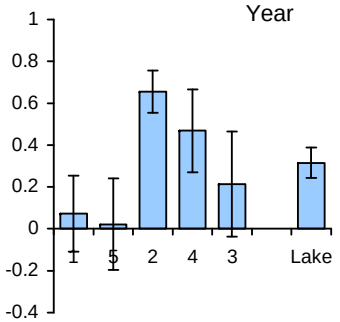


Year

Trend Slopes



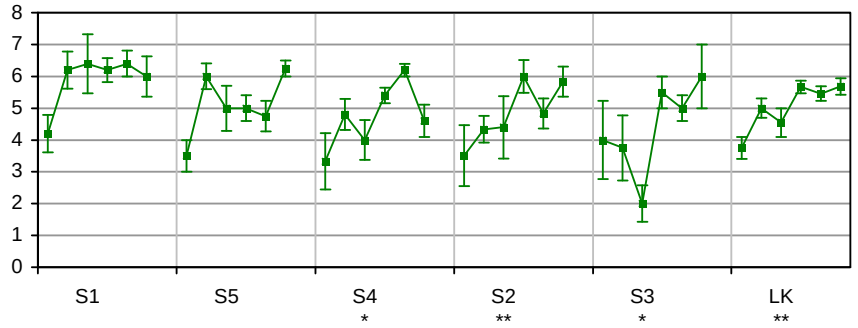




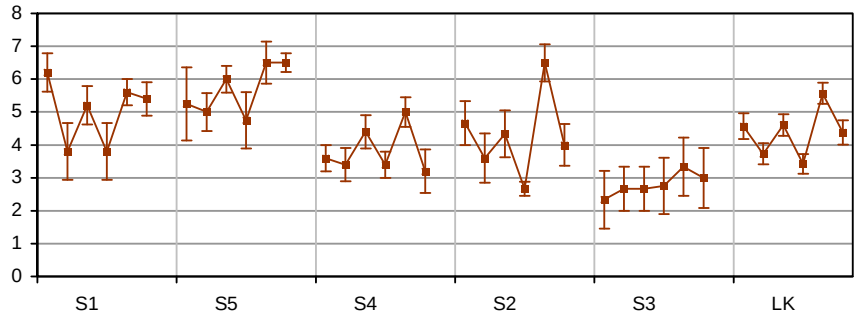
Trends in Gamefish Richness

Strata Ordered North to South

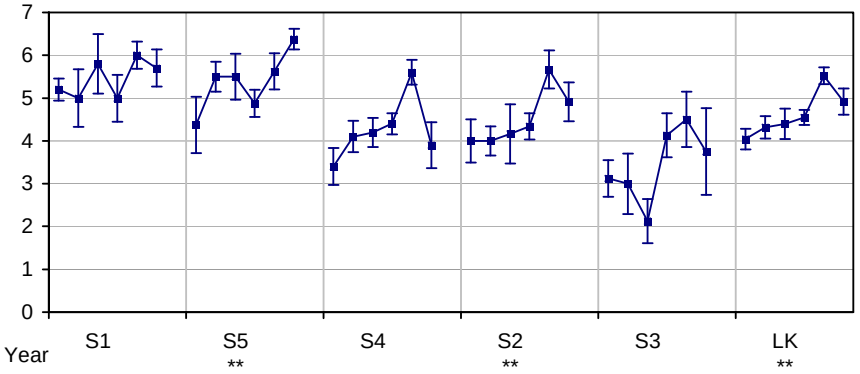
Yearly time series, significant trends (* p<.10, **p<.05, 1-tailed)



Spring

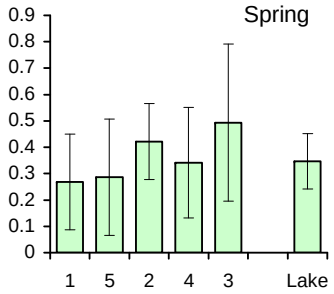


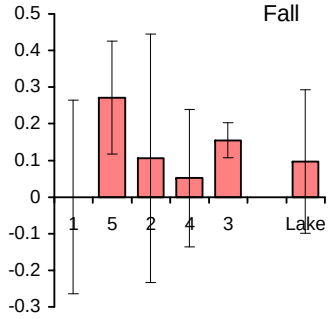
Fall

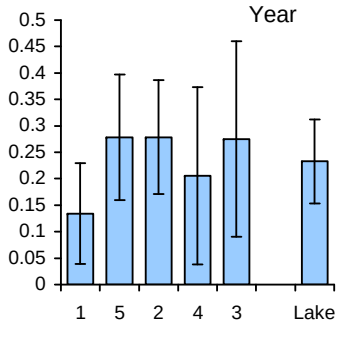


Year

Trend Slopes



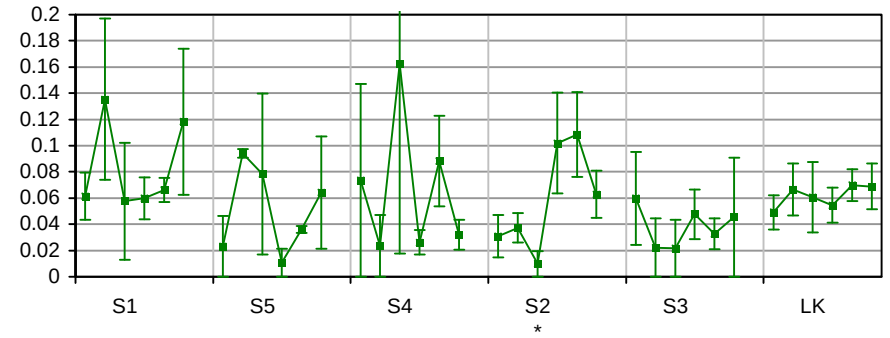




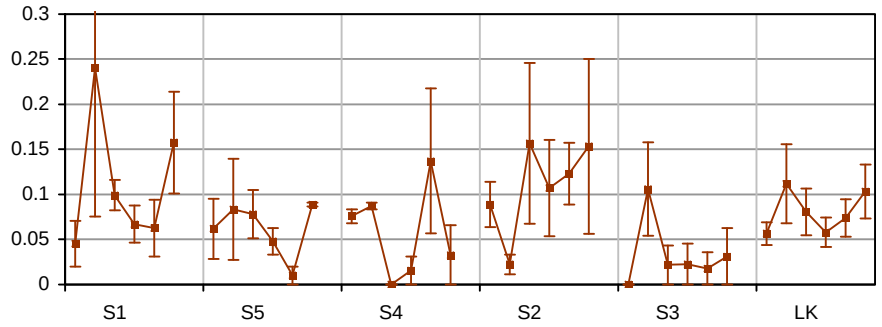
Trends in % Pollution Intolerant Fish

Strata Ordered North to South

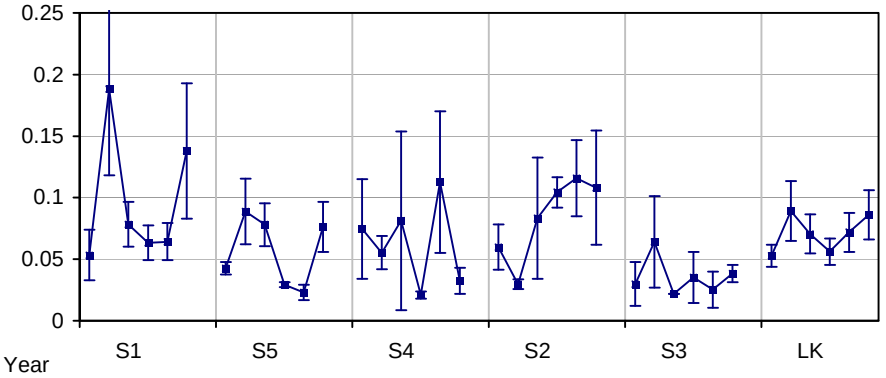
Yearly time series, significant trends (* p<.10, **p<.05, 1-tailed)



Spring



Fall



Year

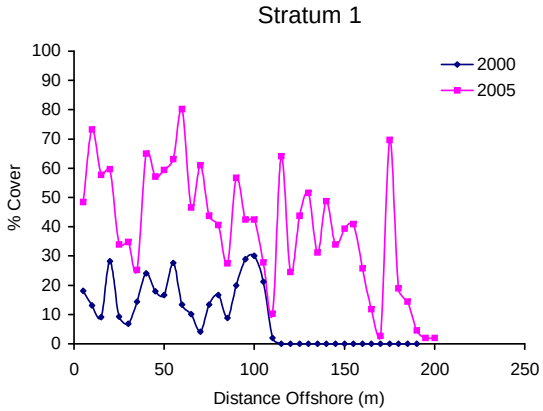
Littoral Macrophytes & Algae

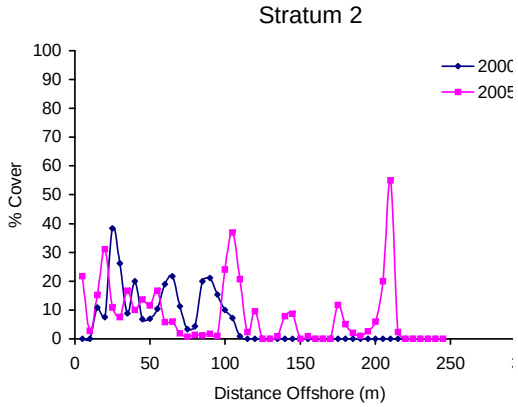
Precision Estimates — Relative Std Error of Yearly Mean

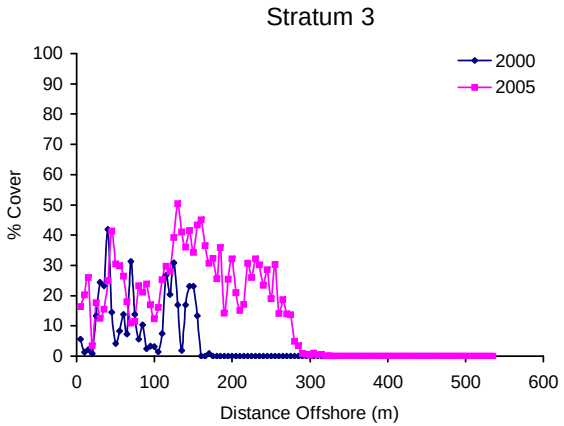
STRATUM	P_Species	P_Cover%	P_Freq%	P_Biomass	A_Cover%	A_Biomass	A_Freq%
S1	0.19	0.04	0.02	0.53	0.11	3.03	0.14
S2	0.44	0.07	0.14	0.70	0.01	0.00	0.07
S3	0.24	0.06	0.04	1.45	0.03	2.82	0.00
S4	0.20	0.05	0.12	1.00	0.11	1.62	0.14
S5	0.29	0.06	0.12	0.42	0.04	0.31	0.06
LAKE	0.11	0.03	0.04	0.50	0.03	1.58	0.05
LAKE_S	0.10	0.03	0.04	0.49	0.03	0.92	0.05

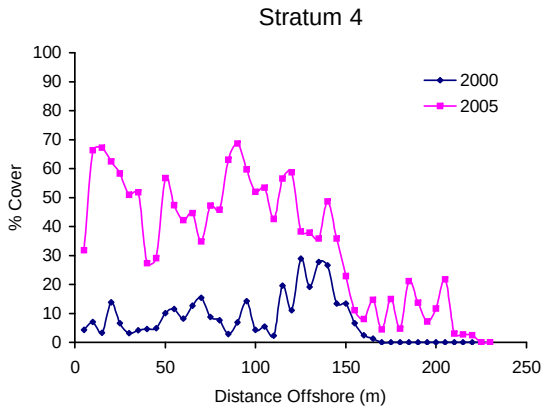
Exceeds AMP Design Objective (< 0.20)

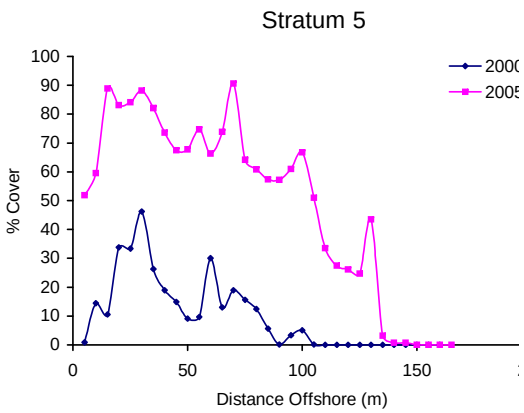
Littoral Macrophytes
% Cover vs. Distance From Shore

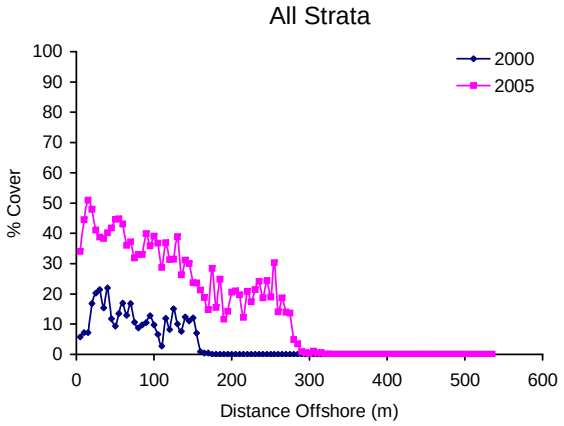












Some Conclusions

- Hypotheses Have Three Dimensions
- Power for Detecting Long-Term Trends
  - Insensitive to Precision of Yearly Means
  - Potentially Increased by Correlating Year-to-Year Variations With External Factors
- Trends Vary with Season & Location (Phytoplankton, Nutrients, Macrophytes, Fish)
- Averaging May Obscure Trends
- Recent Variations in Nutrients & Phytoplankton Correlated with Metro Loads
- Outlet 12 ft Similar to Lake UML
- Fish CPUE Precision Sufficient to Detect Trends in Some Species
- Sensitivity of Richness to Single Catch

Some Recommendations

- Concise Plots to Convey Status, Trends, & Correlations with Load
- Sharpen Hypotheses vs. Season
- Consensus on Averaging Methods for Metrics
- What to Do with Estimated Fish Counts
- Bass CPUE as Potential Metric
- Refine Pollution Tolerance Index For Adult Fish
- One-Tailed Hypotheses / SK 1 for Trend Analysis
- Scrub & Analyze Near-Shore Bacteria Database
- Confidence Intervals for Frequency Statistics
- Correlate with External Factors to Increase Power

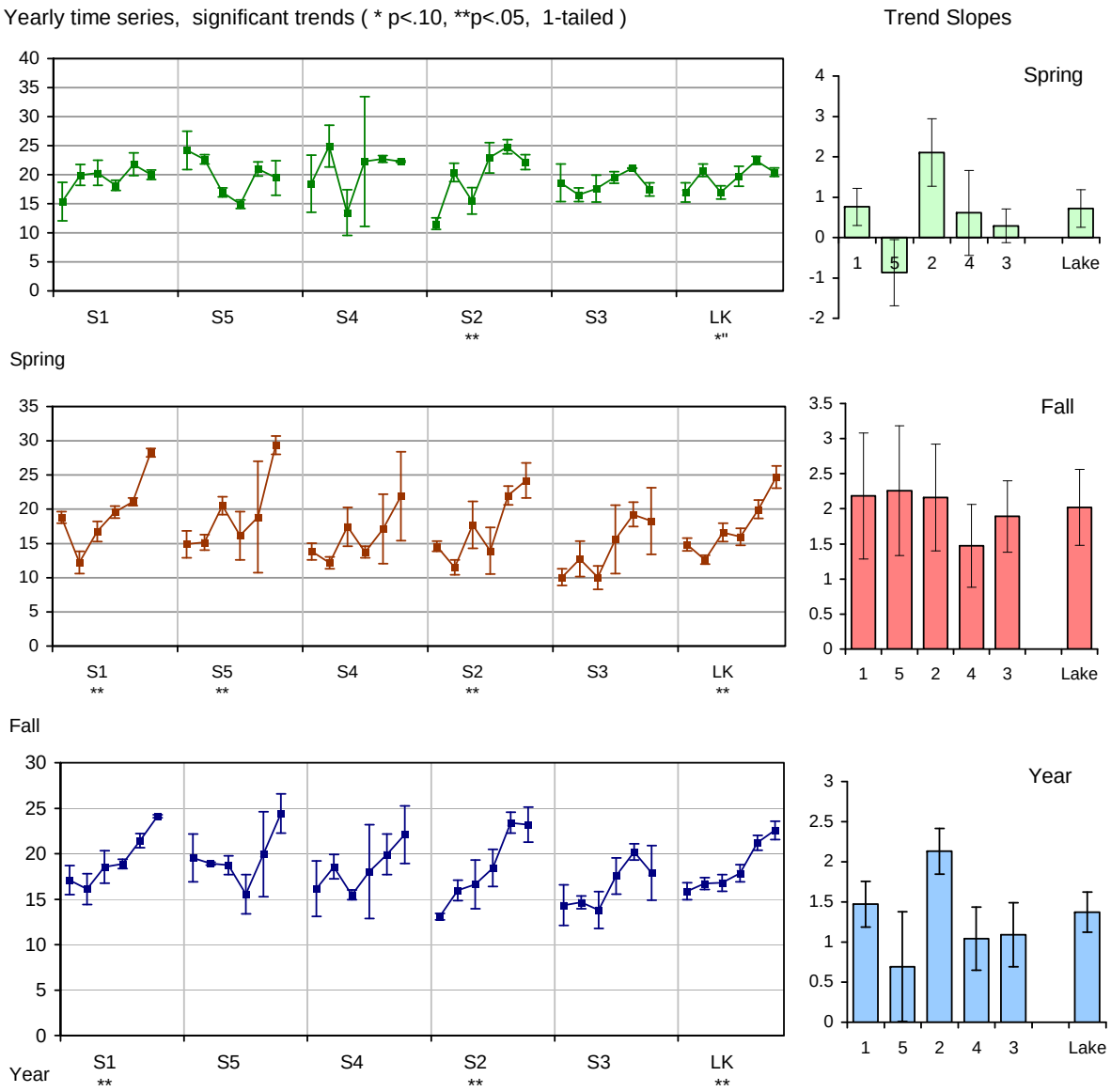
QA/QC Recommendations

- Additional QA/QC on WQ & Biological DB
  - Analytical Results
  - Systematic Errors(Sample Codes, Depths, etc.)
- Power of Statistical Outlier Detection Limited
- More Likely to Identify Systematic Errors Thru Data Inventories and Analysis
- Tune Up Trend Analysis Software
- Tune Up Outlier Detection Algorithms
- Fish Habitat & Vol Days of Anoxia Metrics

THE
END

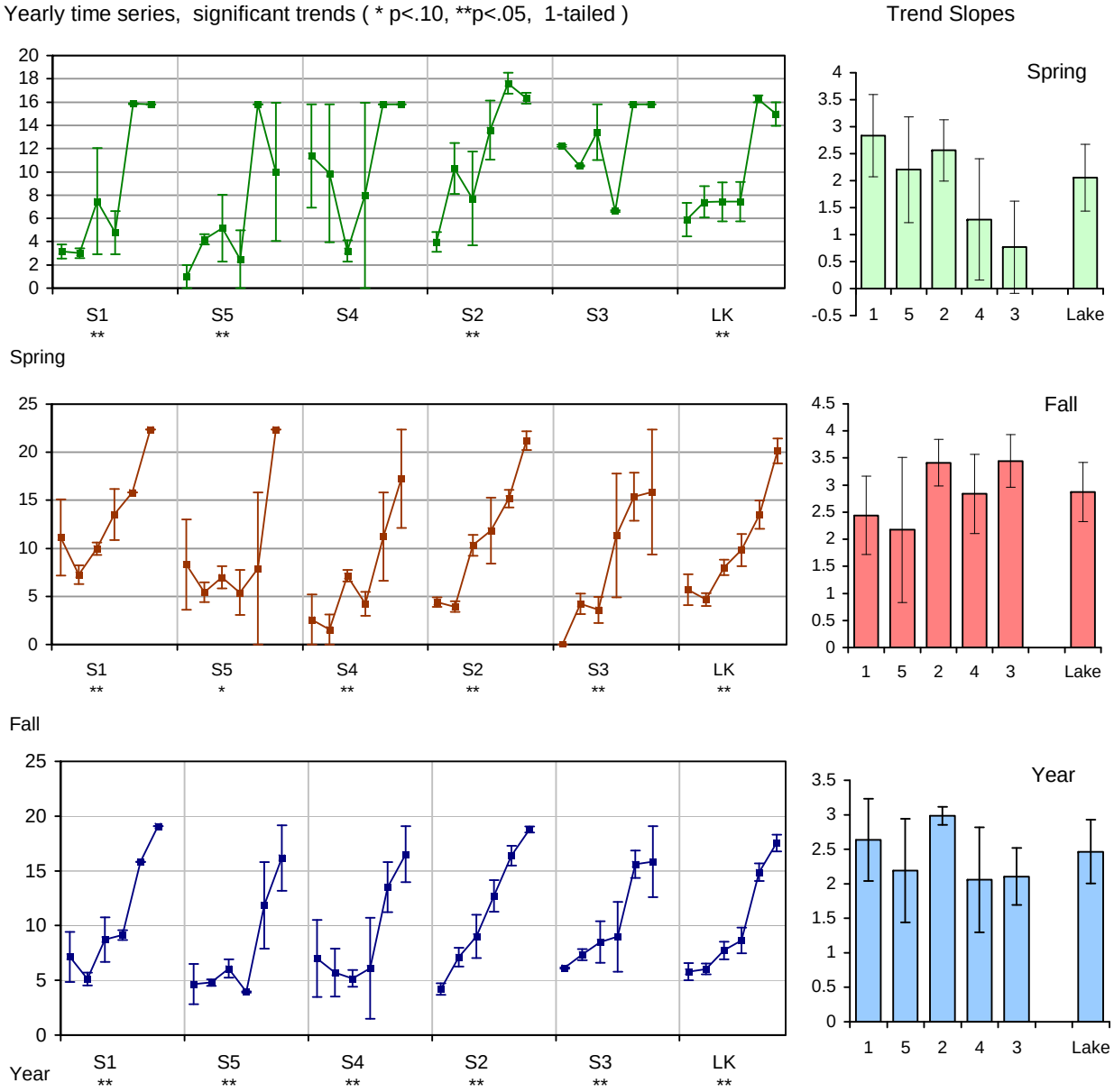
Trends in Total Fish CPUE

Strata Ordered North to South



Trends in Clupeid CPUE

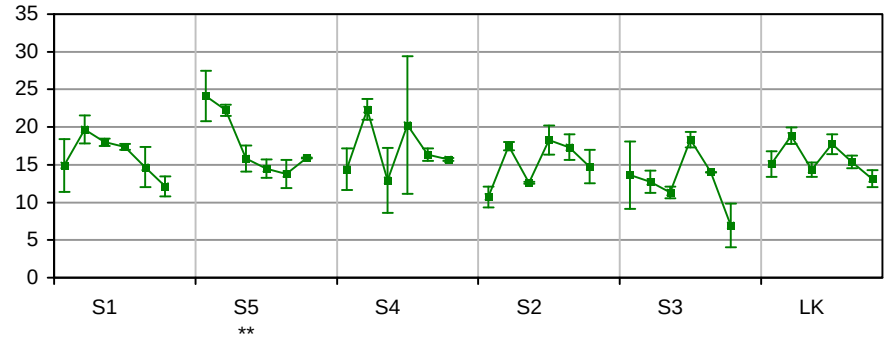
Strata Ordered North to South



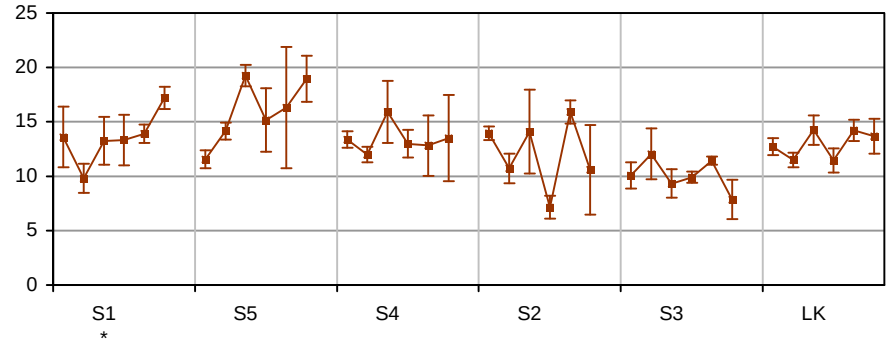
Trends in Non-Clupeid Fish CPUE

Strata Ordered North to South

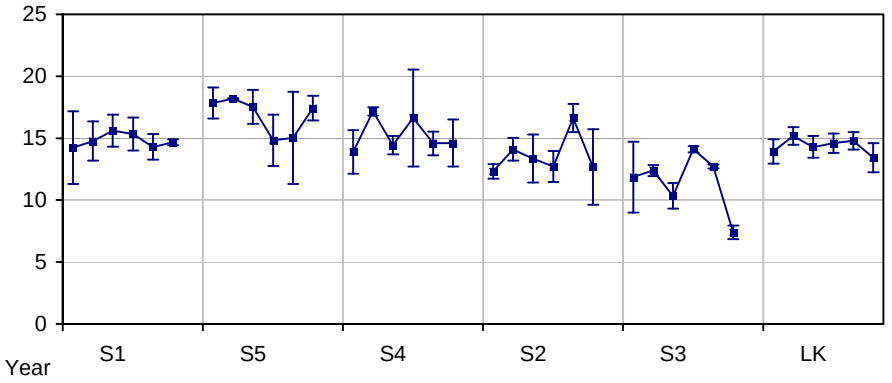
Yearly time series, significant trends (* p<.10, **p<.05, 1-tailed)



Spring

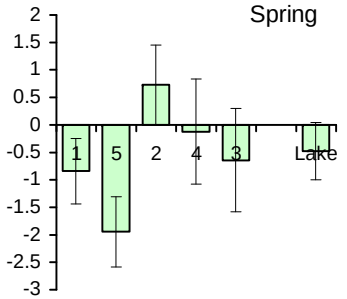


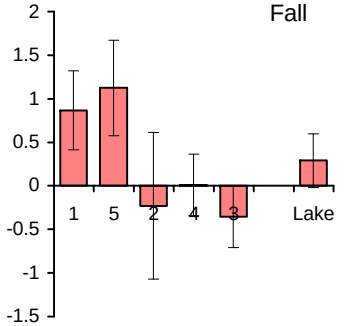
Fall

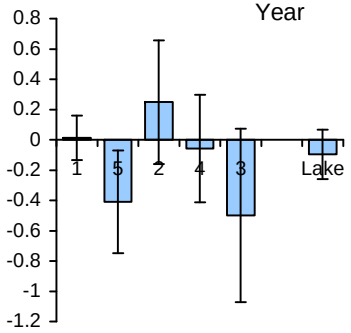


Year

Trend Slopes



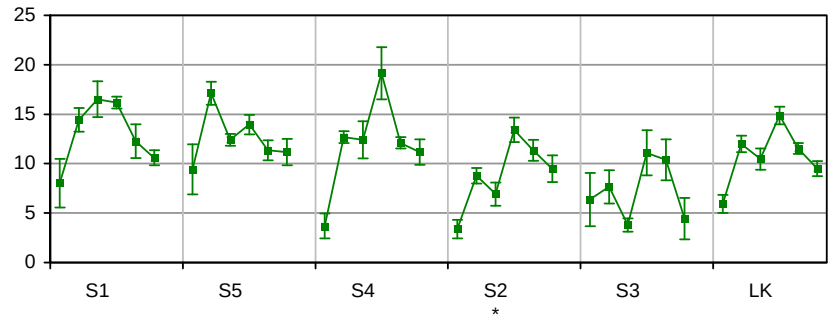




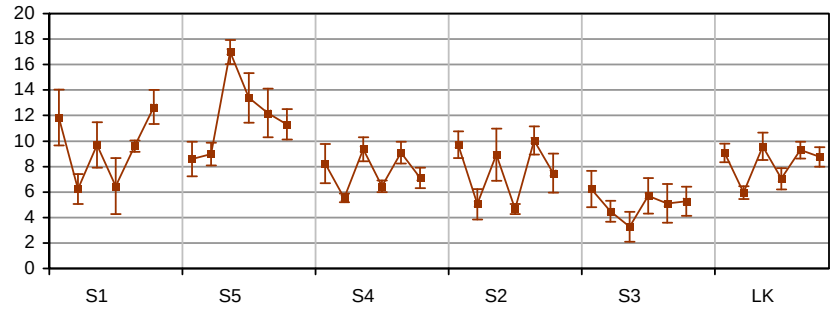
Trends in Gamefish CPUE

Strata Ordered North to South

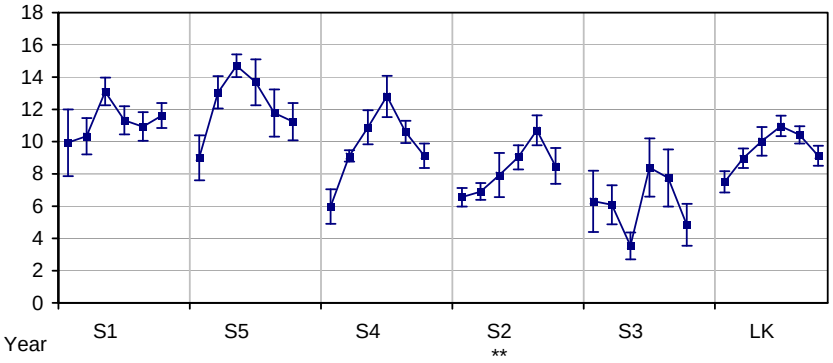
Yearly time series, significant trends (* p<.10, **p<.05, 1-tailed)



Spring

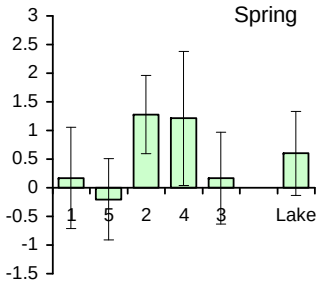


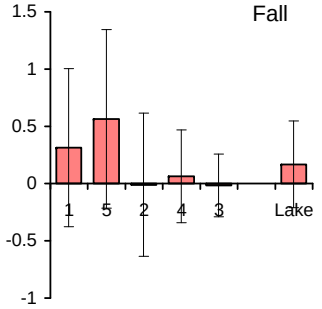
Fall

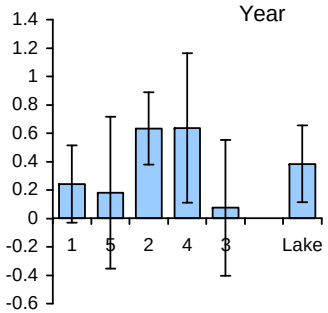


Year

Trend Slopes

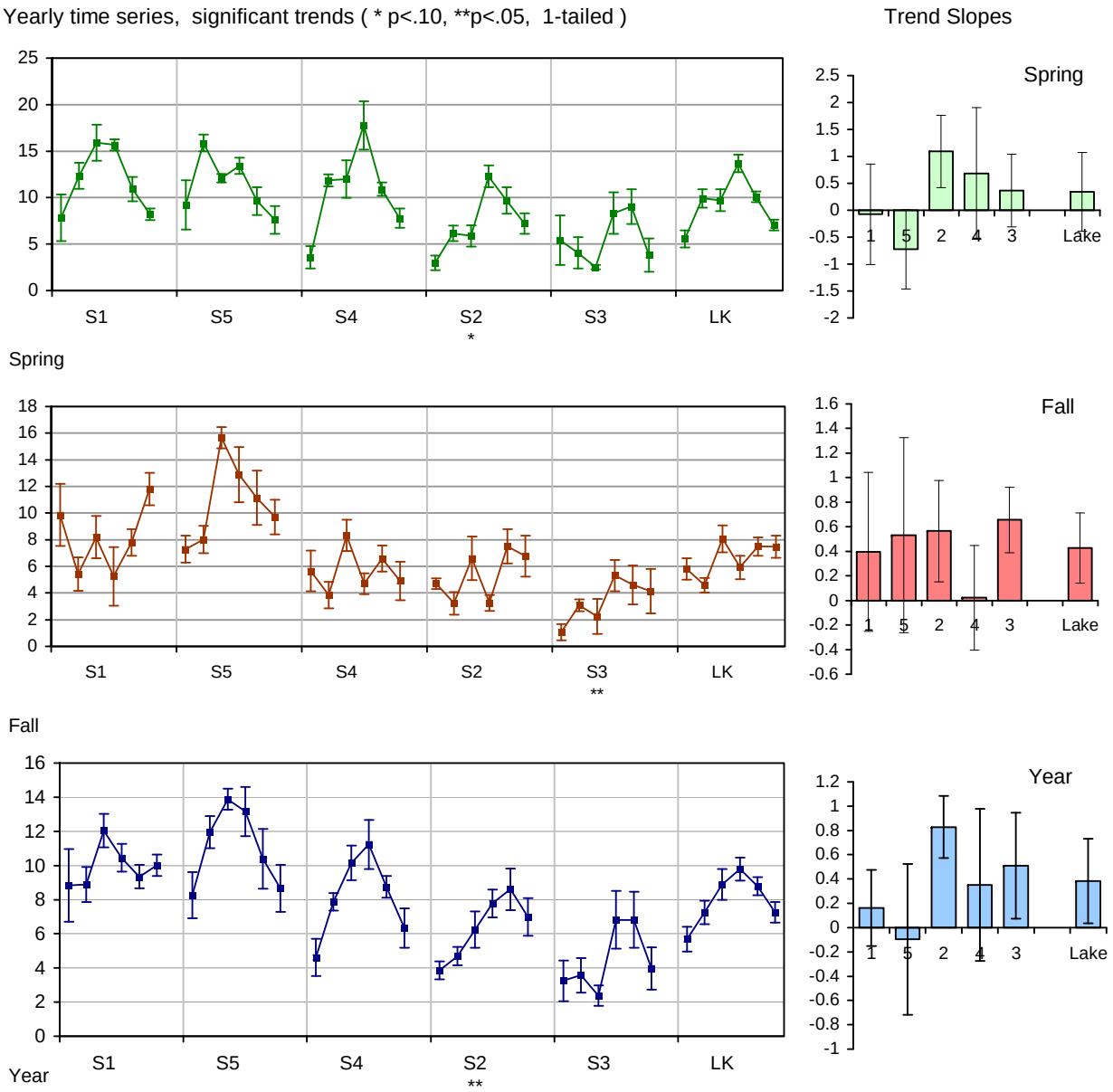






Trends in ACJ Species CPUE

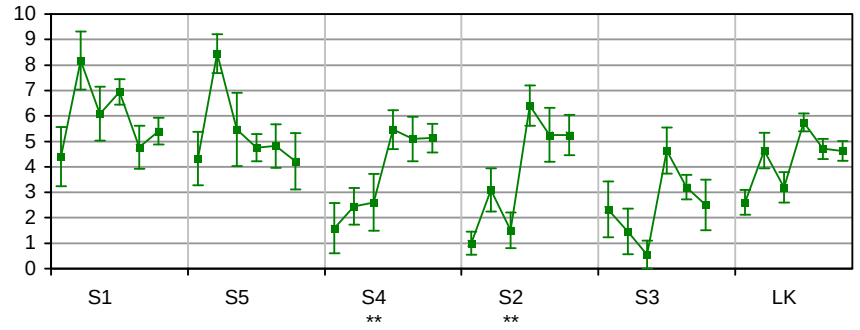
Strata Ordered North to South



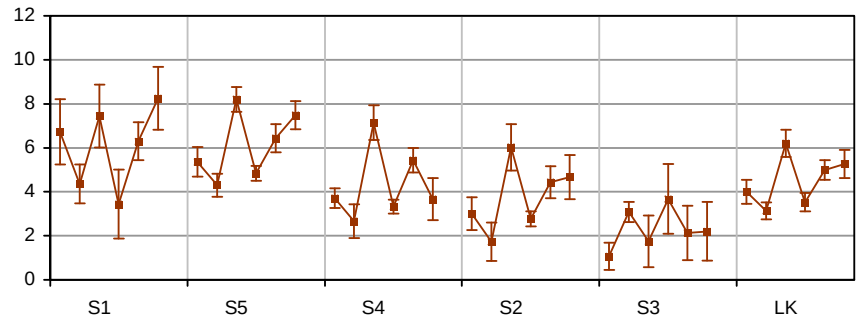
Trends in Bass CPUE

Strata Ordered North to South

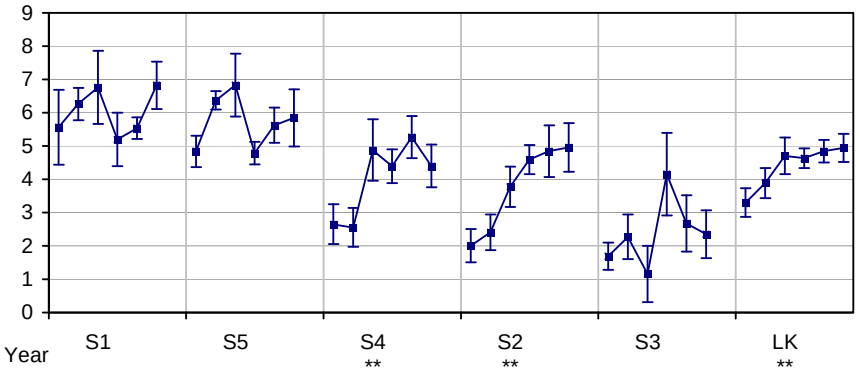
Yearly time series, significant trends (* p<.10, **p<.05, 1-tailed)



Spring

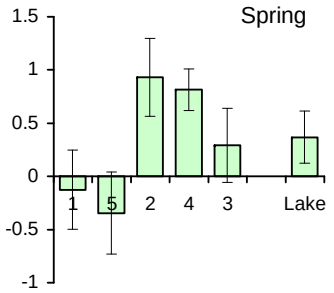


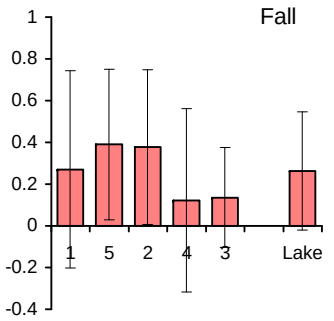
Fall

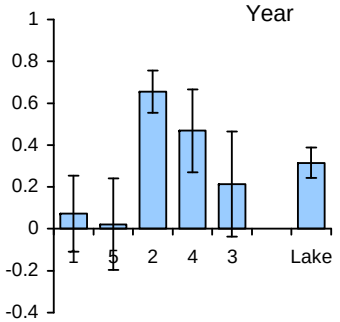


Year

Trend Slopes



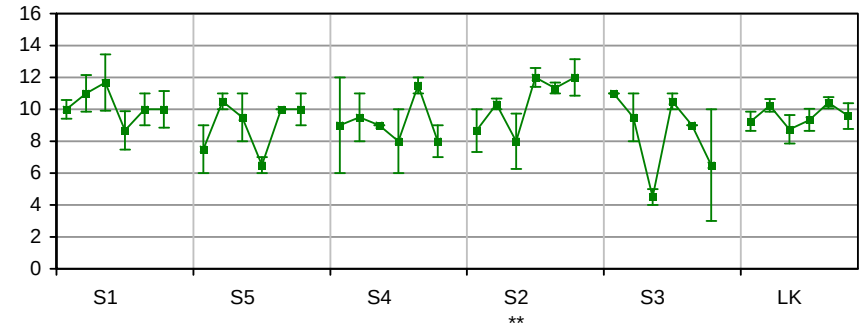




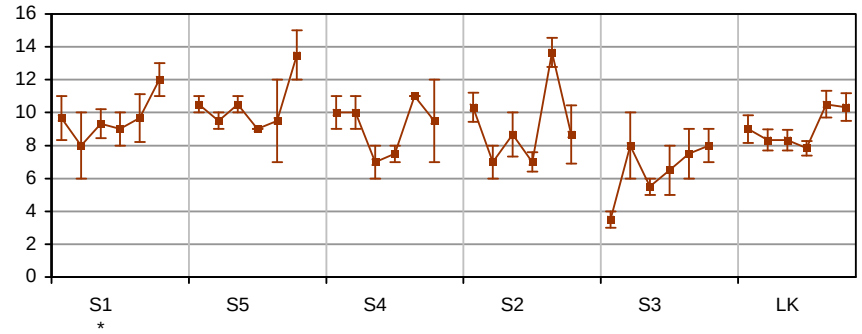
Trends in Total Fish Richness

Strata Ordered North to South

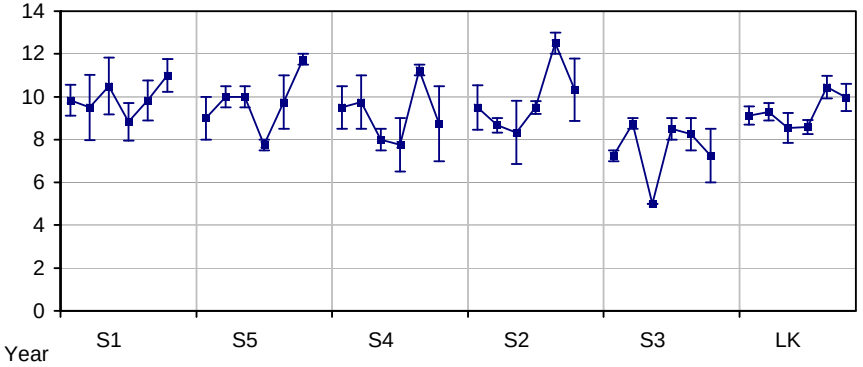
Yearly time series, significant trends (* p<.10, **p<.05, 1-tailed)



Spring

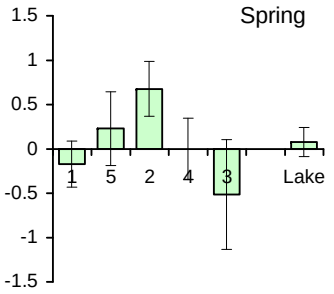


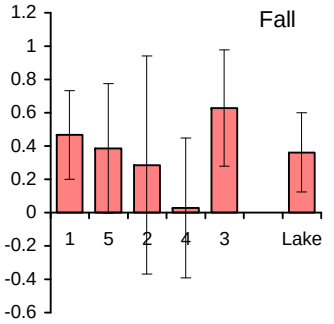
Fall

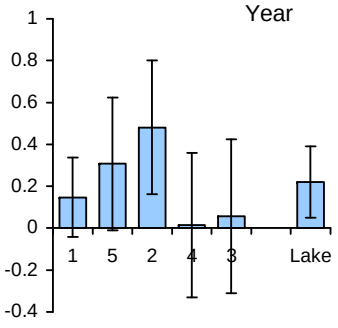


Year

Trend Slopes

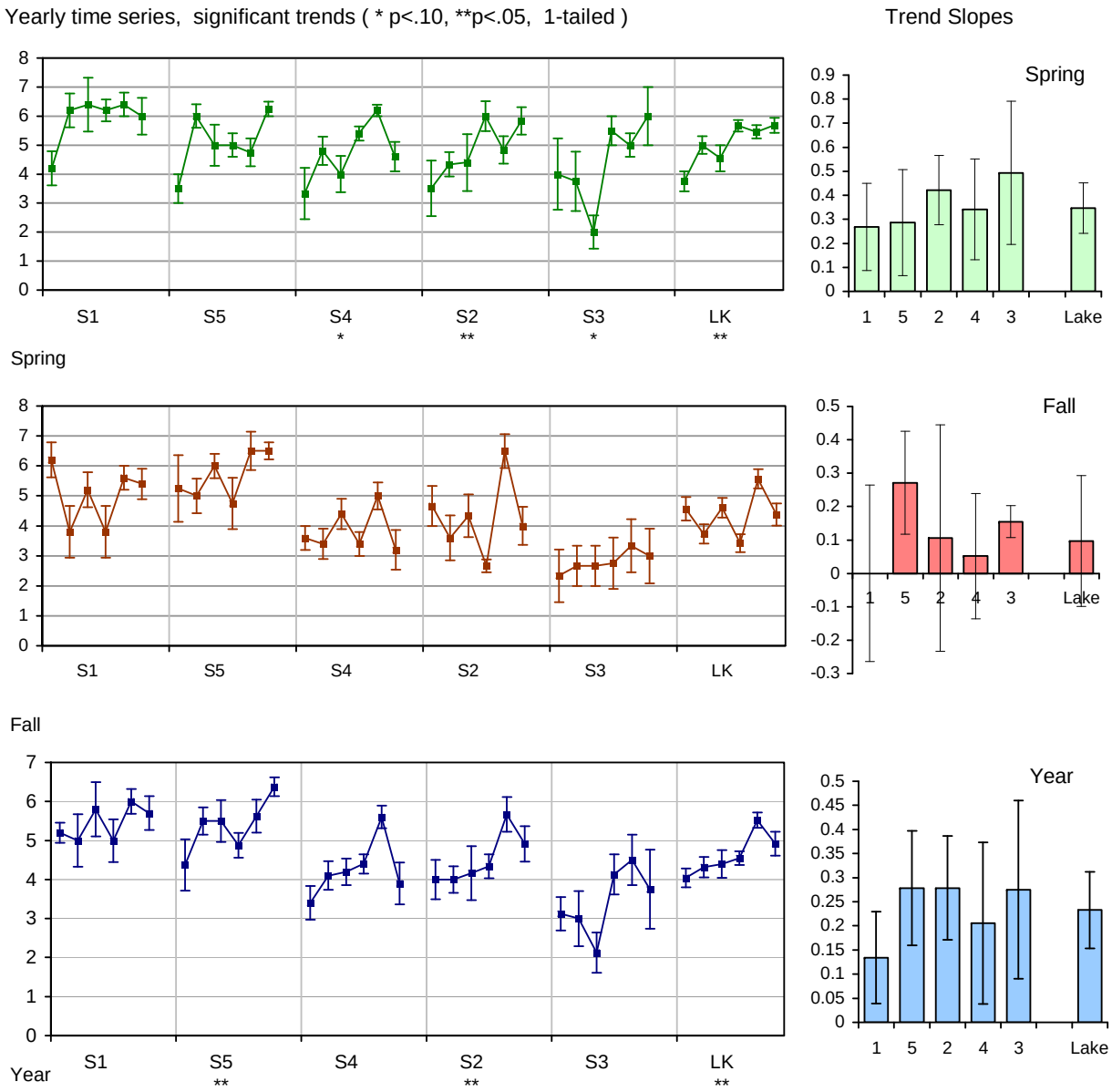






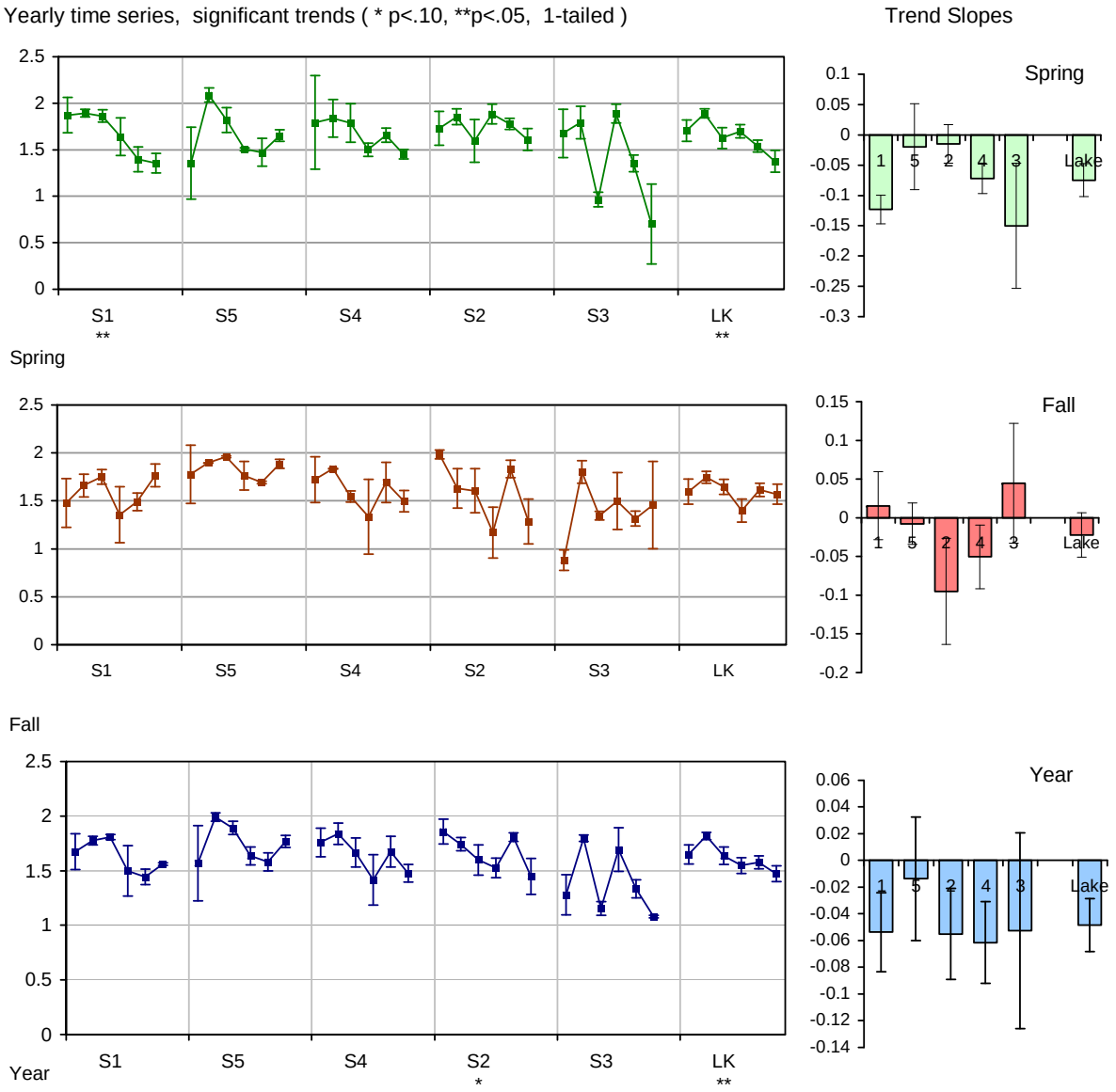
Trends in Gamefish Richness

Strata Ordered North to South



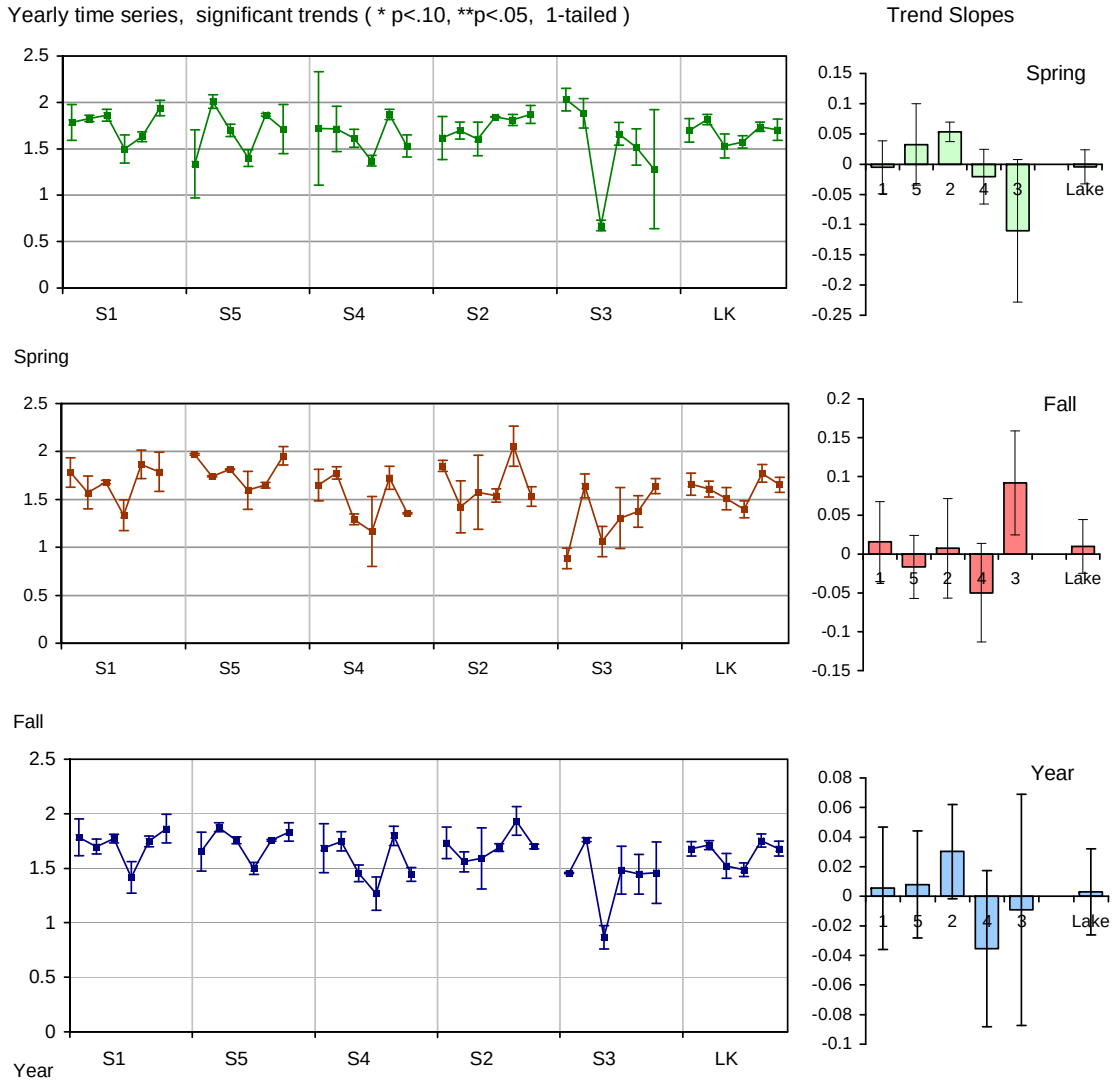
Trends in Total Fish Shannon-Weaver Diversity

Strata Ordered North to South



Trends in Non-Clupeid Fish Shannon-Weaver Diversity

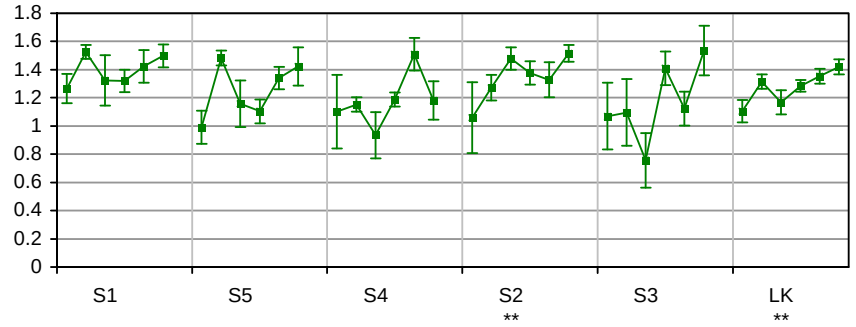
Strata Ordered North to South



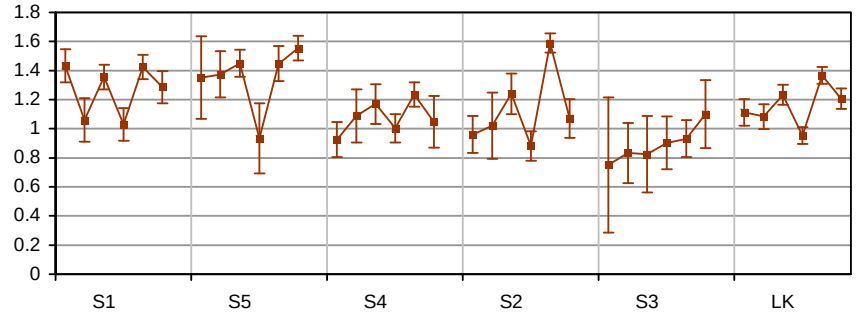
Trends in Gamefish Shannon-Weaver Diversity

Strata Ordered North to South

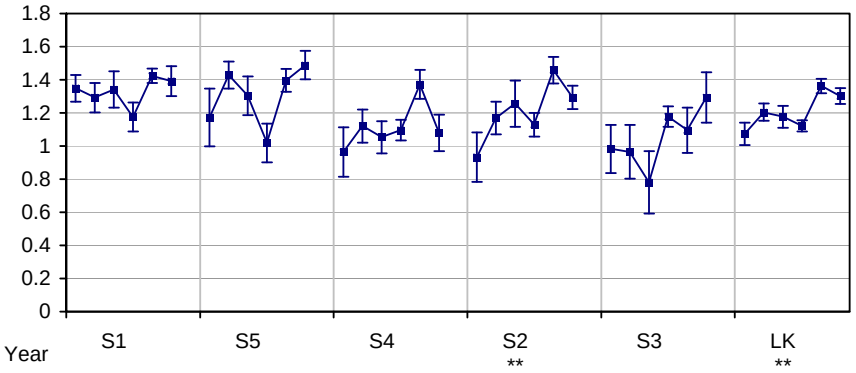
Yearly time series, significant trends (* p<.10, **p<.05, 1-tailed)



Spring

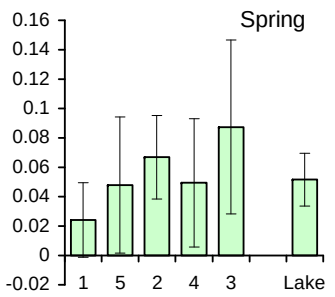


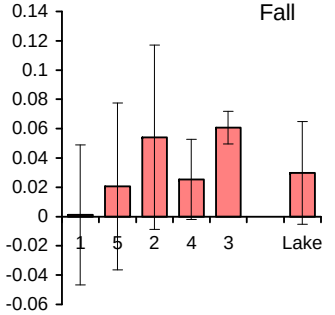
Fall

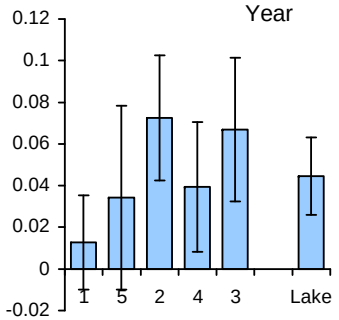


Year

Trend Slopes







Trends in % Pollution Intolerant Fish

Strata Ordered North to South