

Development of Chlorophyll-a Criteria to Support Recreational Uses of Texas Reservoirs

Exploratory Data Analysis - Year 1 of a 2-Year Study

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Abstract

Numerical nutrient criteria can be based upon a variety of factors, including linkage to other water quality standards for protection of aquatic life (dissolved oxygen, pH), support of specific water uses (fisheries, recreation, water supply), anti-degradation concepts, and regional comparisons with minimally impacted water bodies. This presentation describes an exploratory analysis of data from the first of a two-year study undertaken by regional water authorities in conjunction with Alan Plummer Associates, Inc. to support the development of chlorophyll-a criteria for protecting recreational uses of reservoirs. The study is designed to assess relationships among eutrophication-related water quality conditions, aesthetic qualities, and suitability for recreational uses, as gauged by reservoir user surveys. Similar studies have supported development of regional and lake-specific nutrient criteria in Minnesota, Vermont, New York, Florida, and other states using similar survey forms. This study also collects information on several factors that may influence relationships between algal density and perceived impairment, including: site type (cove vs. open lake), optical properties (relative importance of algae vs. inorganic suspended solids as factors controlling water transparency), trophic state (overall level of enrichment), observer category (lay public vs. sampling crew), type of water use (swimming, boating, fishing, hiking, etc.), and observer visit frequency. The study involves 8 reservoirs and 16 sites reflecting a wide range of nutrient and turbidity levels and biweekly water quality sampling events paired with an average of 7 user survey forms per event. Ranges and patterns in the preliminary data are explored using simple cross-tabulation and graphical techniques. Results indicate the potential power and limitations of the full survey dataset to support statistical modeling and development of chlorophyll/nutrient criteria.

Texas Water Conservation Association

Investigation to Support the Development of Nutrient Criteria
Based on Recreational Uses of Reservoirs

Interim Report - Year 1 of a 2-Year Study

May 2004

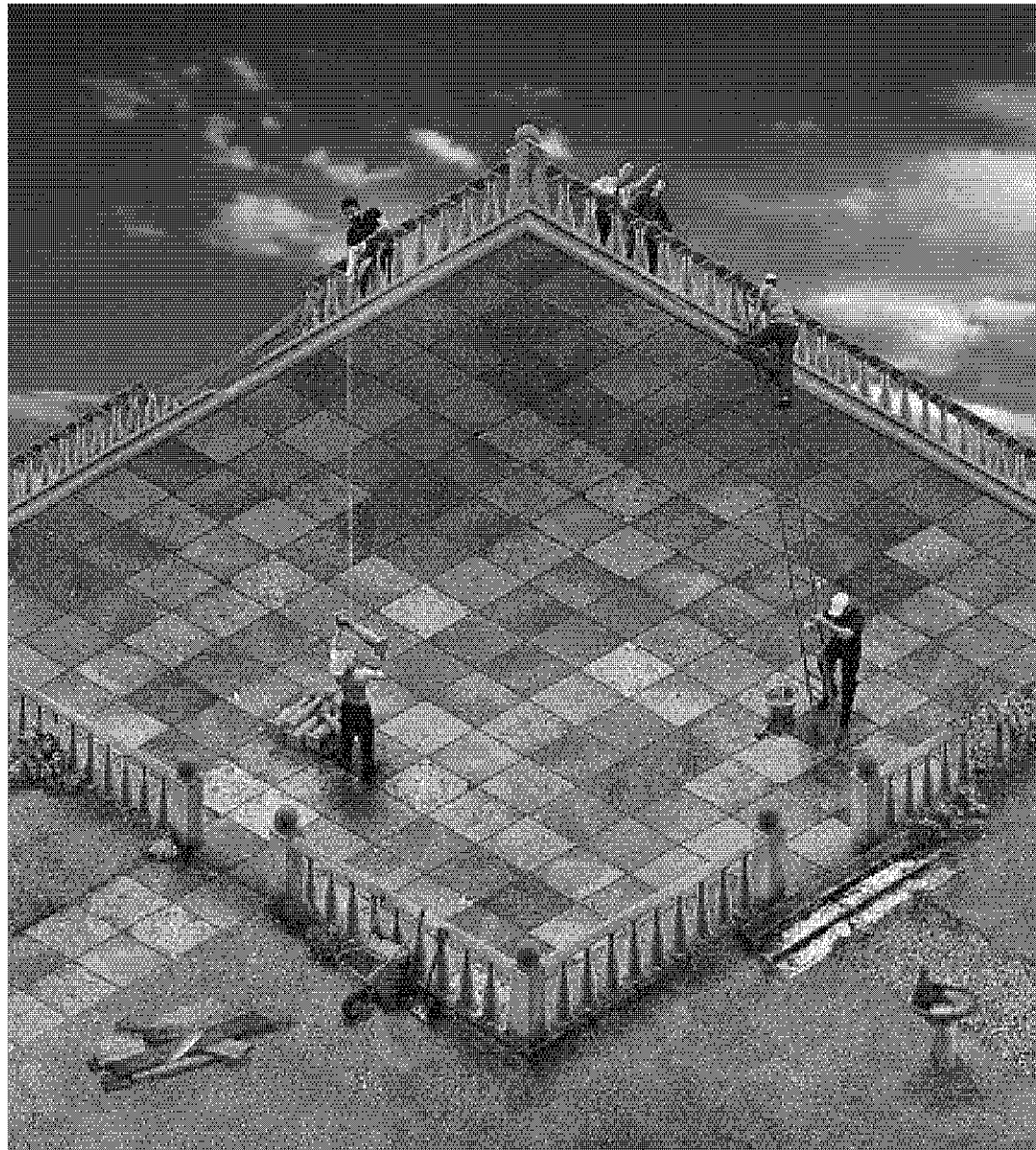
prepared by

Brazos River Authority
Guadalupe-Blanco River Authority
Lower Colorado River Authority
Sabine River Authority
San Antonio River Authority
Tarrant Regional Water District
Trinity River Authority

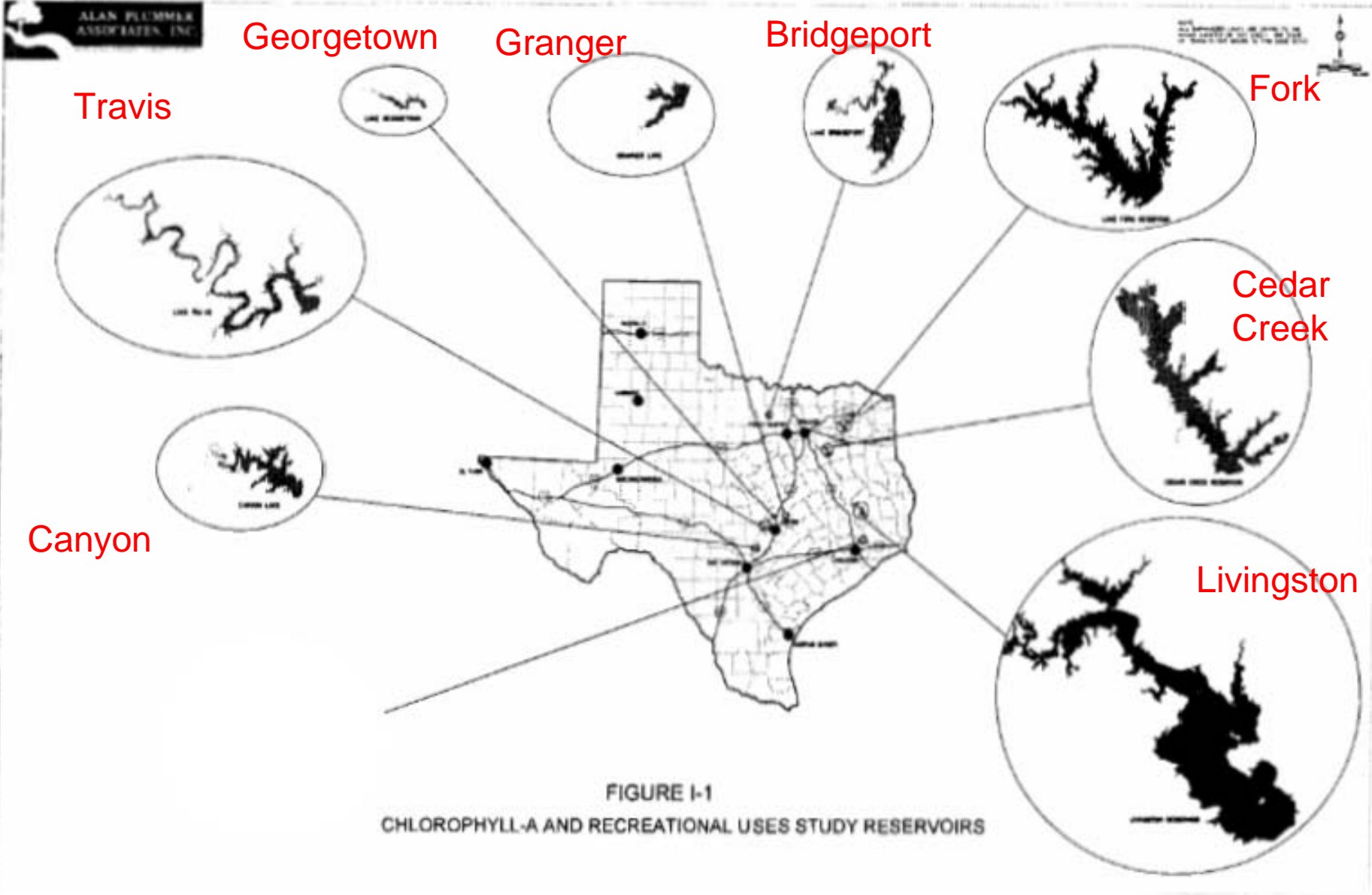
in association with

Alan Plummer Associates, Inc.
William W. Walker, Jr.

Exploratory Data Analysis



Cast of Characters



Bases for Nutrient & Chlorophyll-a Criteria

Regional Reference Lakes

Pre-Development Condition

Limnological Concept - "Trophic State"

Linkage to Numeric Water Quality Stds
DO, pH, Ammonia, Secchi

Ecological - Fishery

Water Supply Concerns
Taste & Odor, THM's, Treatment Cost

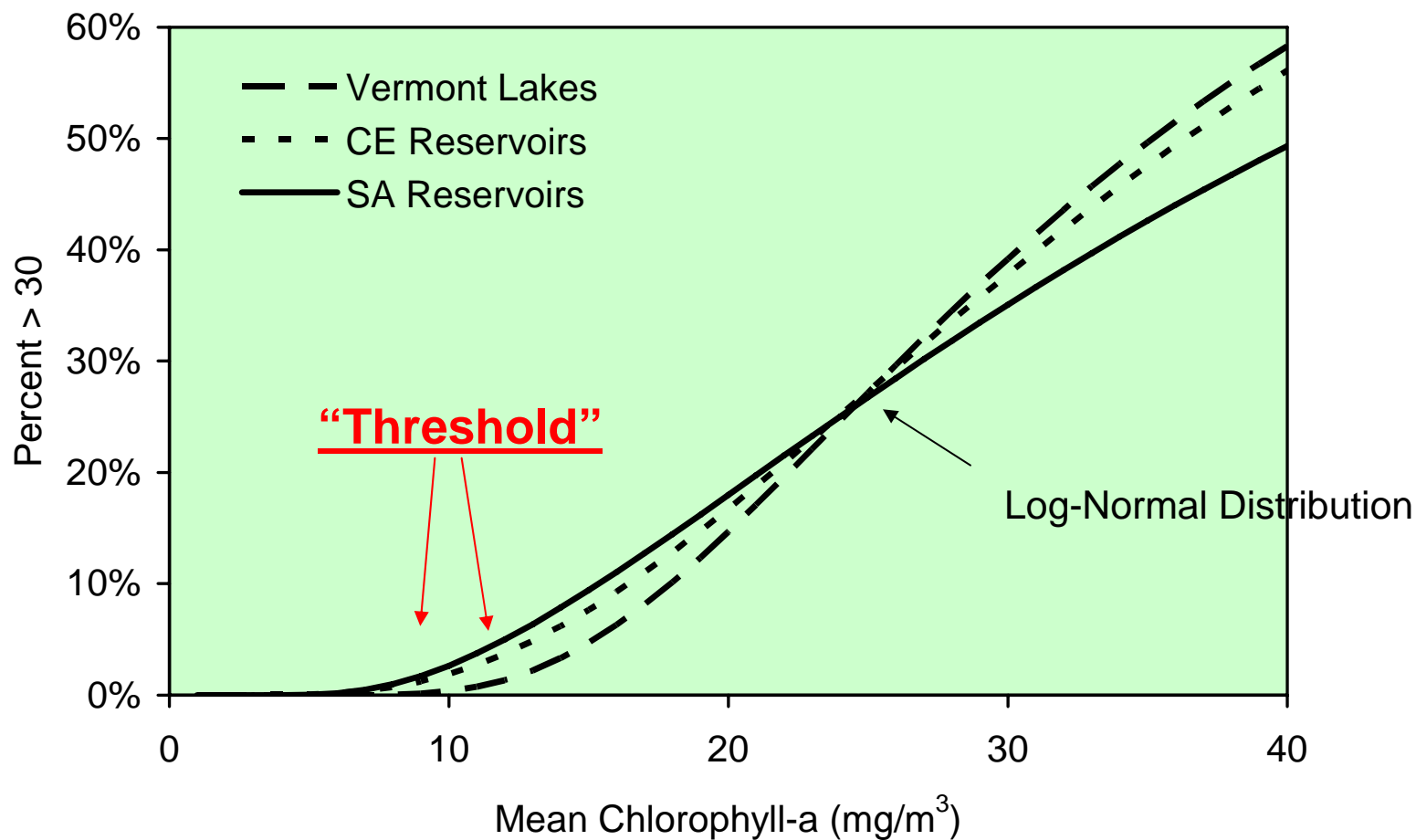
Support of Recreational Uses
Swimming, Boating
Aesthetic Enjoyment

Anti-Degradation





Statistical Basis for Mean Chlorophyll-a Criteria Frequency of Severe Nuisance Blooms vs. Mean Chl-a



Based upon Log-Normal Frequency Distribution Models Calibrated to Various Datasets
Walker, W., "Statistical Bases for Mean Chlorophyll-a Criteria", Lake & Reservoir Mgt, 1985

Previous Applications of the Concept

Regional Criteria

Minnesota

New York

Vermont

Florida *new!!!*

Lake-Specific Criteria

Cherry Creek Reservoir

Colorado

Lake Champlain

Vermont/New York

Lake Okeechobee

Florida

Vadnais Lake

Minnesota

Lake Pepin

Minnesota

Onondaga Lake

New York

Communicating to Public

Meaningful Expression of Lake Condition

Gain Support for Restoration & Management Programs

Study Design

8 Reservoirs, 2 Sites Each (Main Lake, Cove)

Criteria for Site Selection

Depth \geq 10 Feet

Adjacent to Use Areas (Beaches, Marinas, etc)

No Significant Stands of Aquatic Vegetation

Biweekly Sampling, June-Sept (April-Sept in 2004)

0, 3, 6 Foot Composite Samples

Nutrient Species, TSS, VSS, Turbidity, Field Param

Chl-a & Phaeophytin Analyzed by a One Lab (LCRA)

~ 7 Survey Forms Completed on Sampling Date

Target ~ 5 Lay Users

Target ~ 2 Sampling Crew

5 Survey Questions :

Appearance

Visit Frequency

Suitability for Use

User Type

Green vs. Muddy

Recreational User Survey – Questions 1 & 2

- 1) Please circle the **one** response that best describes the **physical condition** of the lake water **today**:
 - a) No algae, or crystal clear water
 - b) A little algae visible
 - c) Definite algal greenness
 - d) Very green; some scum present and/or mild odor apparent
 - e) Pea-soup green with one or more of the following: massive floating scums on lake or washed up on shore, strong foul odor, or fish kill

- 2) Please circle the **one** response that best describes your **perception** of how suitable the lake water is for recreation and aesthetic enjoyment **today**:
 - a) Beautiful, could not be any nicer
 - b) Very minor aesthetic problems; excellent for swimming, boating enjoyment
 - c) Swimming and aesthetic enjoyment slightly impaired
 - d) Desire to swim and level of enjoyment of the lake substantially reduced
 - e) Swimming and aesthetic enjoyment of the lake nearly impossible

Recreational User Survey – Questions 3-5

- 3) If you circled c, d, or e in Question No. 2 above, please indicate the factor that most affected your answer:
- a) Muddiness
 - b) Algae/greenness
 - c) Other (please specify)
- 4) How many times a year do you visit the lake? (Circle one response)
- a) Permanent resident
 - b) More than six times per year
 - c) Two to six times per year
 - d) Typically every year
 - e) This is my first visit
- 5) Please circle the activity that best describes your primary recreational activity today:
- a) Swimmin
 - b) Fishing
 - c) Boating
 - d) Skiing/Windsurfing
 - e) On-Shore Activity (camping, picnicking, etc.)
 - f) Other or non-recreational (Please specify)

Survey Cross-Tabs

Question 1 - Appearance

Count of Date		Question1					Grand Total
ResLabel	Cove_Main	a	b	c	d	e	
Bridgeport	Cove	5	32	14	3		54
	Main	11	40	4	1		56
Bridgeport Total		16	72	18	4		110
Canyon	Cove	16	17	12	1		46
	Main	8	31	6	1		46
Canyon Total		24	48	18	2		92
Cedar Creek	Cove	1	27	27	2	1	58
	Main	6	36	13	1		56
Cedar Creek Total		7	63	40	3	1	114
Fork	Cove	3	14	14	3		34
	Main	12	20	18			50
Fork Total		15	34	32	3		84
Georgetown	Cove	20	12	1			33
	Main	20	18	1			39
Georgetown Total		40	30	2			72
Granger	Cove	2	6	5			13
	Main	6	32	21			59
Granger Total		8	38	26			72
Livingston	Cove	3	33	19	6		61
	Main	11	24	26	2		63
Livingston Total		14	57	45	8		124
Travis	Cove	8	23	9		1	41
	Main	14	29	6			49
Travis Total		22	52	15		1	90
Grand Total		146	394	196	20	2	758

Question 4 - Type of Use

Count of Date		Question4					Grand Total
ResLabel	Cove_Main	a	b	c	d	e	
Bridgeport	Cove	4	26	10	3	11	54
	Main	7	29	13	1	6	56
Bridgeport Total		11	55	23	4	17	110
Canyon	Cove	16	15	9	1	5	46
	Main	12	15	7	5	7	46
Canyon Total		28	30	16	6	12	92
Cedar Creek	Cove	26	29	3			58
	Main	17	25	3	4	7	56
Cedar Creek Total		43	54	6	4	7	114
Fork	Cove	21	5	4		4	34
	Main	26	9	5	2	8	50
Fork Total		47	14	9	2	12	84
Georgetown	Cove	3	22	4	2	2	33
	Main		16	18	3	2	39
Georgetown Total		3	38	22	5	4	72
Granger	Cove	9	3			1	13
	Main	8	25	14	6	6	59
Granger Total		8	34	17	6	7	72
Livingston	Cove	39	15	3	1	3	61
	Main	18	18	9	6	12	63
Livingston Total		57	33	12	7	15	124
Travis	Cove	4	34	3			41
	Main	5	27	10		7	49
Travis Total		9	61	13		7	90
Grand Total		206	319	118	34	81	758

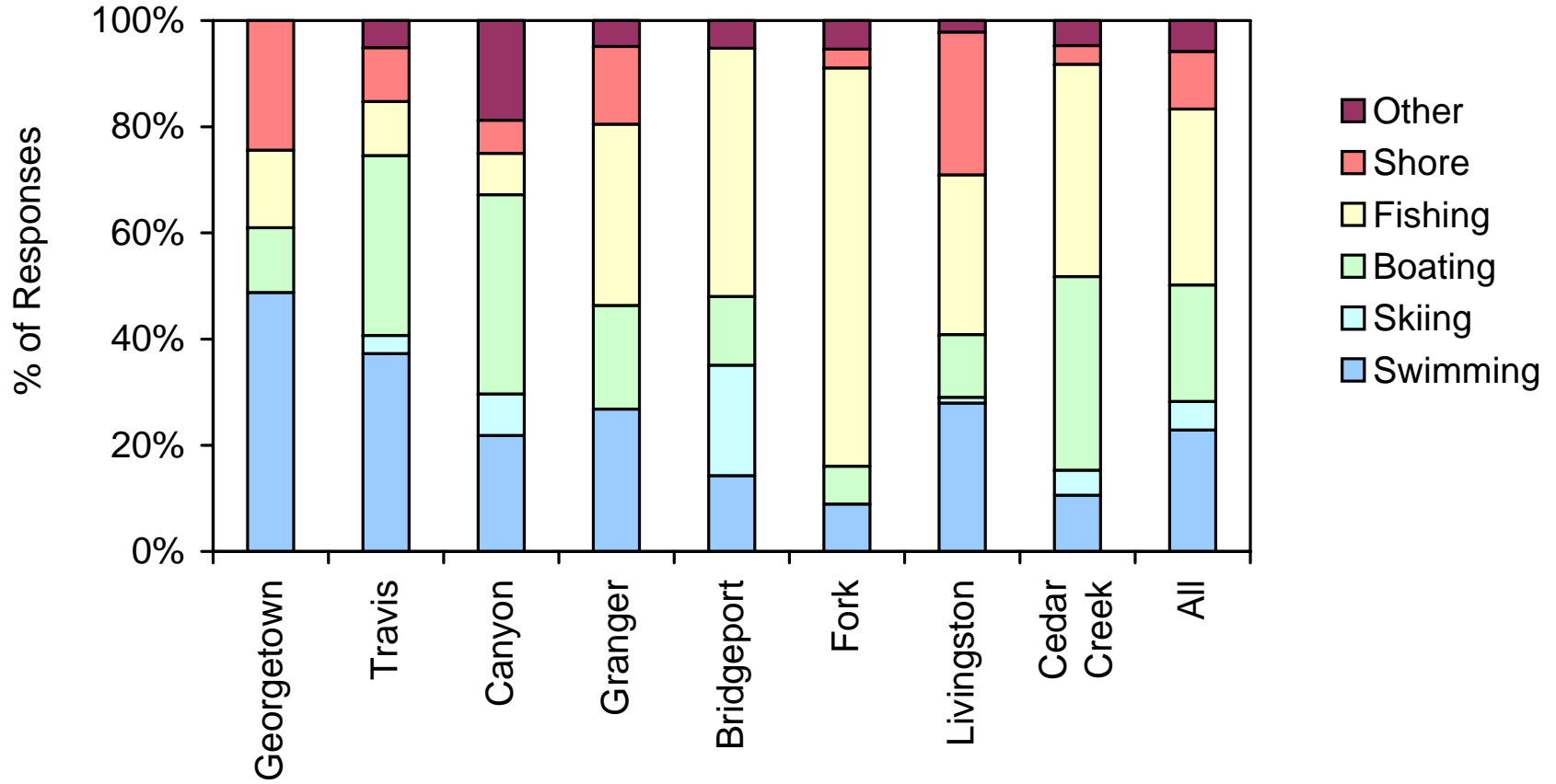
Question 2 - Use Impairment

Count of Date		Question2					Grand Total
ResLabel	Cove_Main	a	b	c	d	e	
Bridgeport	Cove	13	29	9	3		54
	Main	33	20	3			56
Bridgeport Total		46	49	12	3		110
Canyon	Cove	15	27	4			46
	Main	22	23		1		46
Canyon Total		37	50	4	1		92
Cedar Creek	Cove	8	35	13	2		58
	Main	14	37	5			56
Cedar Creek Total		22	72	18	2		114
Fork	Cove	7	12	12	2	1	34
	Main	17	27	6			50
Fork Total		24	39	18	2	1	84
Georgetown	Cove	19	13	1			33
	Main	17	20	2			39
Georgetown Total		36	33	3			72
Granger	Cove		3	8	2		13
	Main	6	27	21	5		59
Granger Total		6	30	29	7		72
Livingston	Cove	1	2	43	12	3	61
	Main		11	36	15	1	63
Livingston Total		1	13	79	27	4	124
Travis	Cove	16	23	2			41
	Main	24	24	1			49
Travis Total		40	47	3			90
Grand Total		1	224	399	114	19	758

Question 5 - Visit Frequency

Count of Date		Question5						Grand Total	
ResLabel	Cove_Main	a	b	c	d	e	f		
Bridgeport	Cove	9	7	5	14		19	54	
	Main	4	33	8	3		23	71	
Bridgeport Total		13	40	13	17		42	125	
Canyon	Cove	4	4	22	3	1	20	54	
	Main	10	4	6	4	4	20	48	
Canyon Total		14	8	28	7	5	40	102	
Cedar Creek	Cove	8	20	16	2	1	21	68	
	Main	1	2	19	21	3	2	16	64
Cedar Creek Total		1	10	39	37	5	3	132	
Fork	Cove	3	12	4		2	16	37	
	Main	2	32	4	1		15	54	
Fork Total		5	44	8	1	2	31	91	
Georgetown	Cove	15	2				1	16	34
	Main	5	6	6	1	13	15	46	
Georgetown Total		20	8	6	1	14	31	80	
Granger	Cove		1					12	13
	Main	11	17	15	1	12	21	77	
Granger Total		11	18	15	1	12	33	90	
Livingston	Cove	1	16	14	10	4	12	16	73
	Main		10	24	10	4	18	17	83
Livingston Total		1	26	38	20	8	30	33	156
Travis	Cove	8	3	16	3	2	19	51	
	Main	1	14	5	13	4	7	15	59
Travis Total		1	22	8	29	7	9	34	110
Grand Total		3	121	203	156	47	75	281	886

Q5 - Use Type



Increasing Mean Chlorophyll-a →

Exploratory Analysis

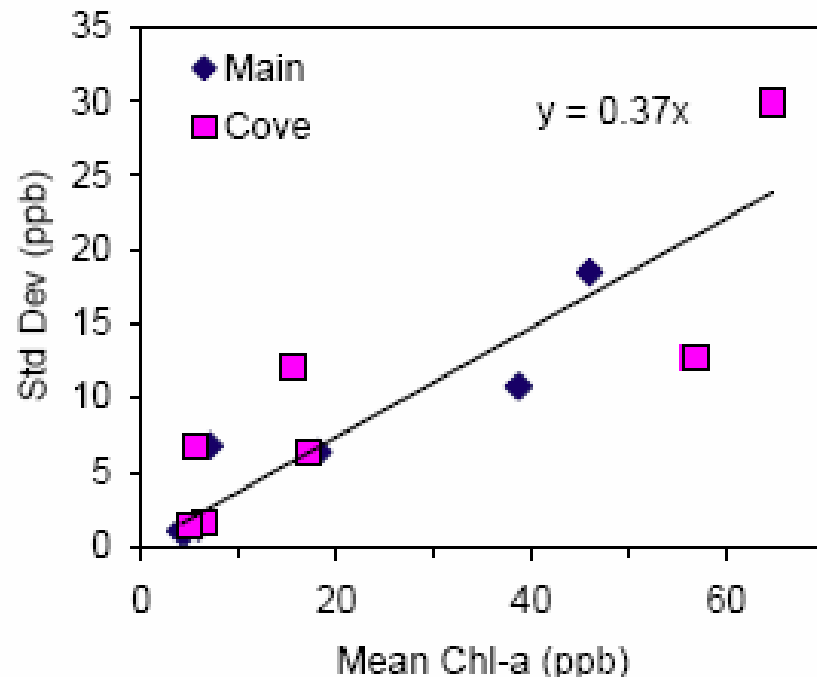


Bloom Frequency vs Seasonal Mean Chl-a
Statistical Model

Survey Responses vs. Sample Chl-a
Within Reservoirs
Across Reservoirs

Responses vs. Observer Category
Sampling Crew
Contact Users
Noncontact Users

Calibration of Bloom Frequency Model



Log-Normal Freq. Distribution

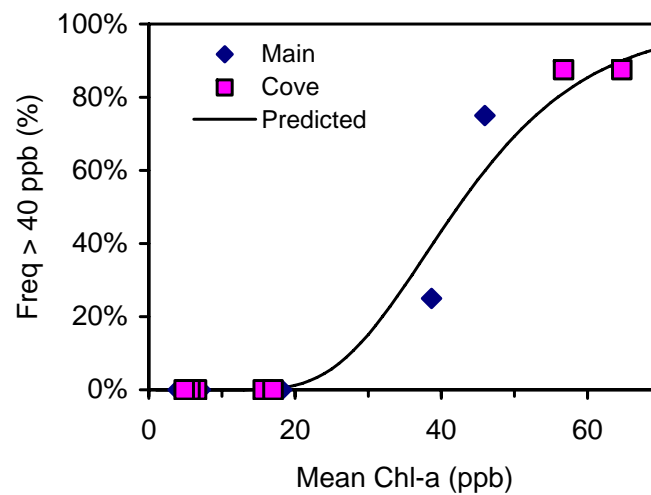
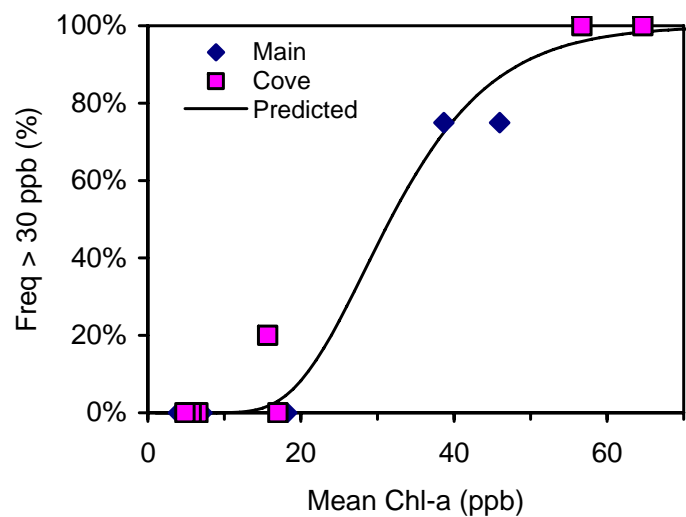
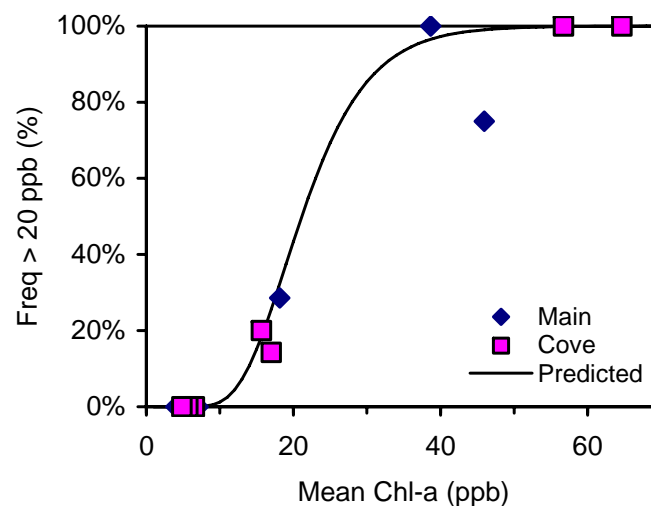
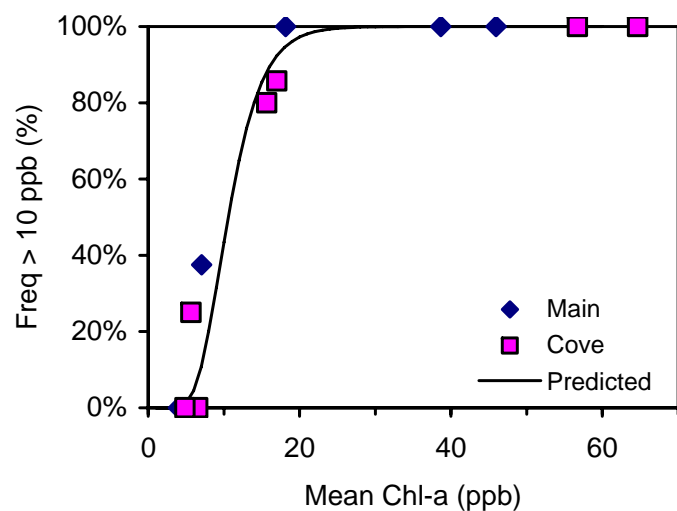
Temporal Coef. of Variation

This Study ~ 0.37

Historical Data (Same Res.) ~0.67

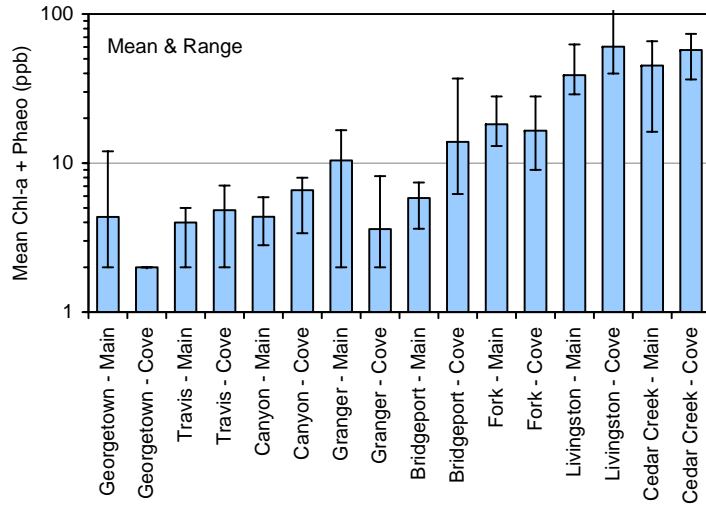
Other Lakes & Reserv. 0.4 – 0.7

Observed & Predicted Bloom Frequencies vs Mean Chl-a Mean Threshold $\sim 0.5 \times$ Bloom Criterion

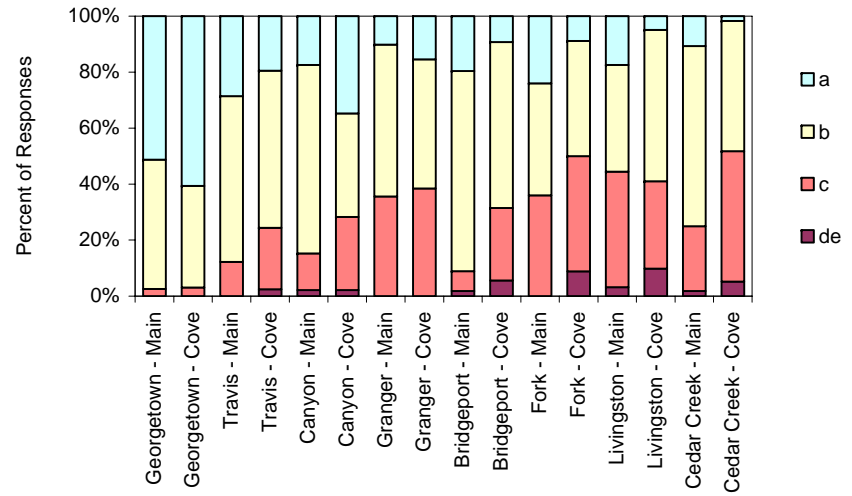


Response Frequencies by Site, Sorted by Mean Chl-a

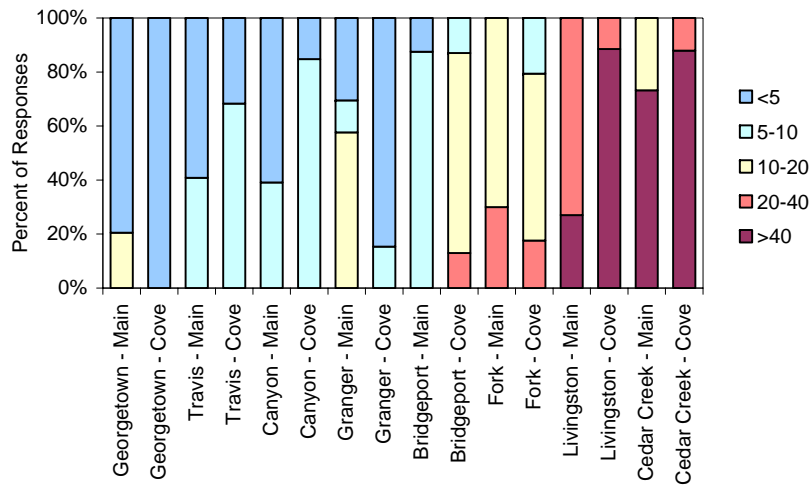
Mean Chl-a + Phaeophytin (ppb)



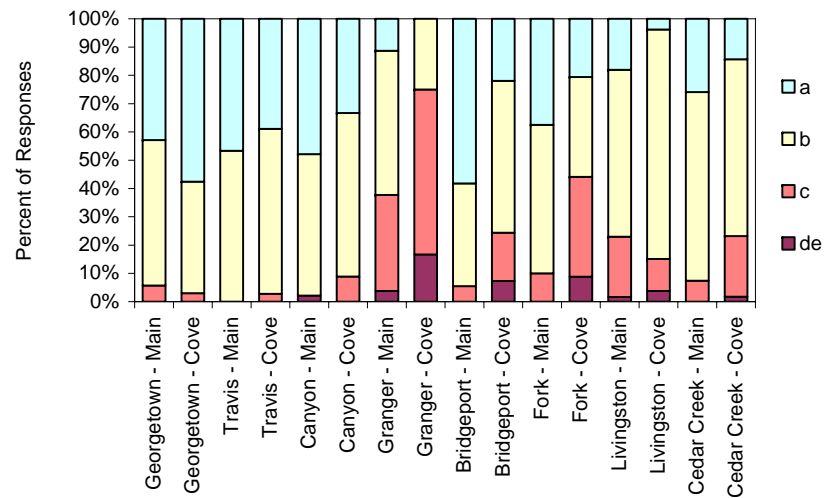
Question 1 - Physical Appearance



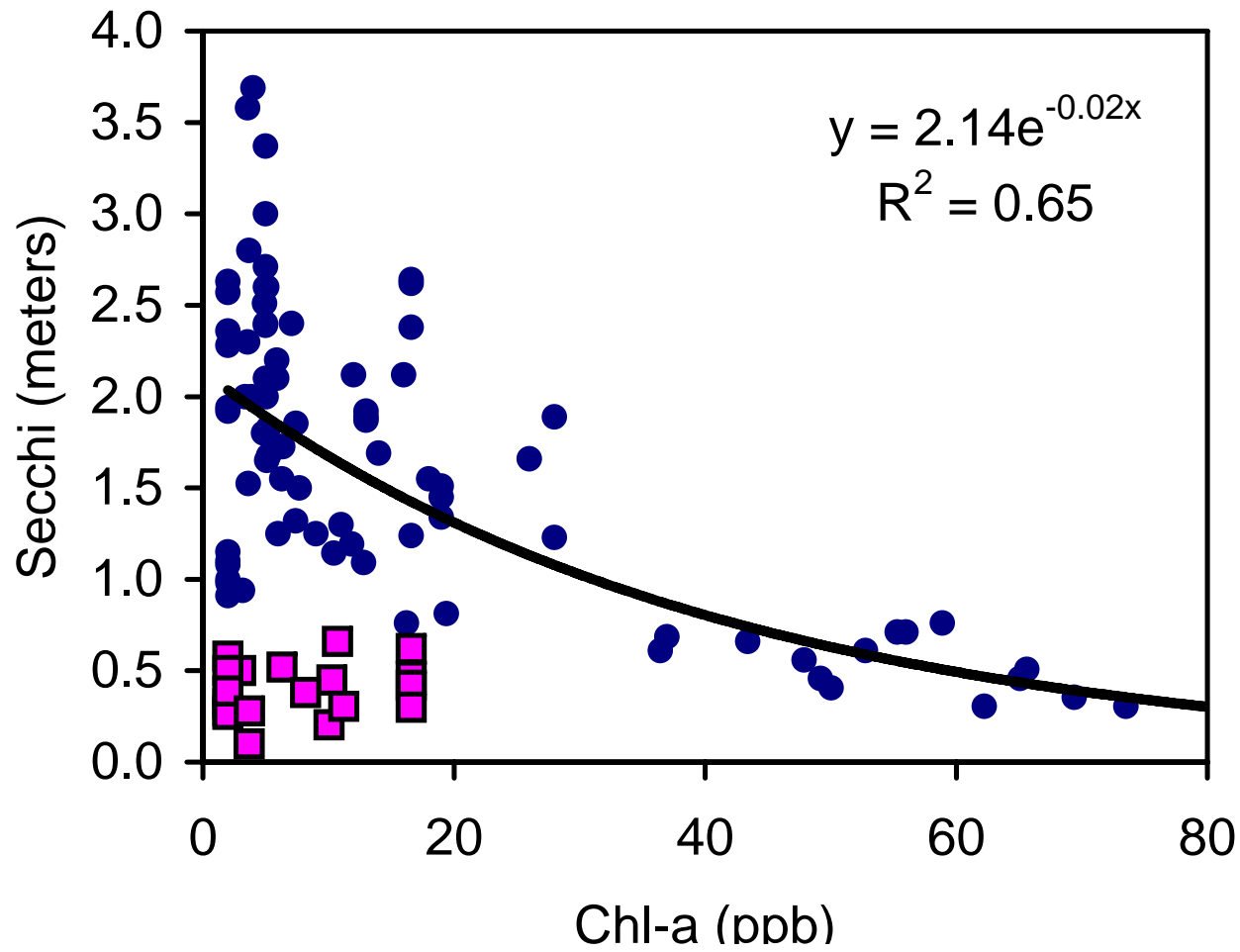
Bloom Frequencies



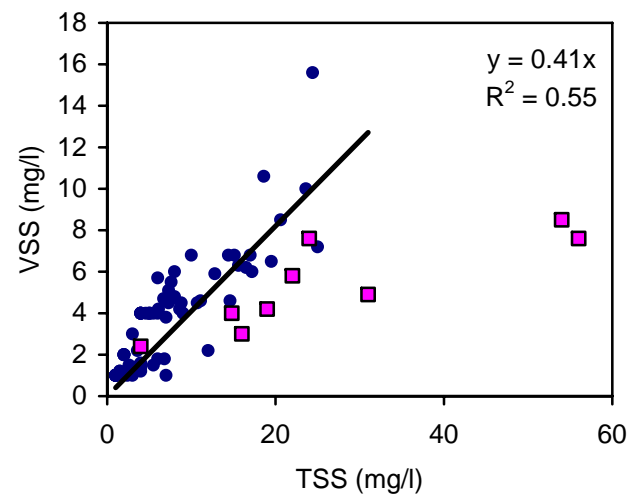
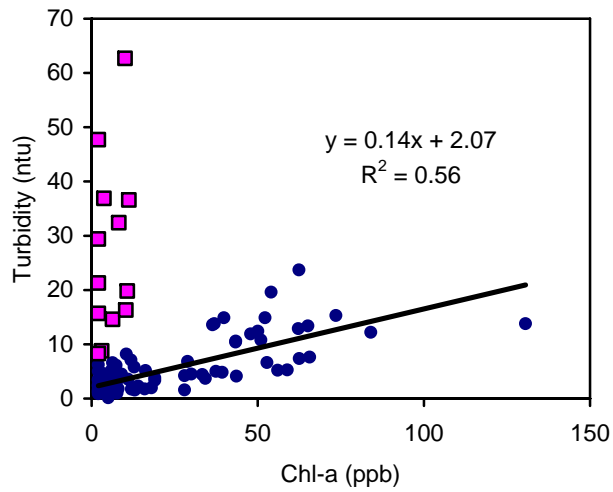
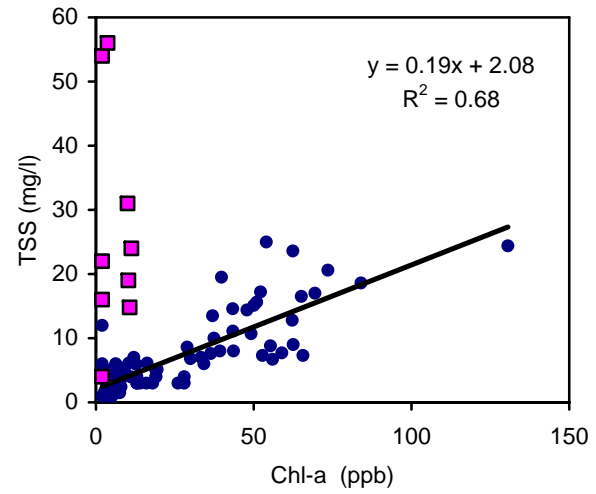
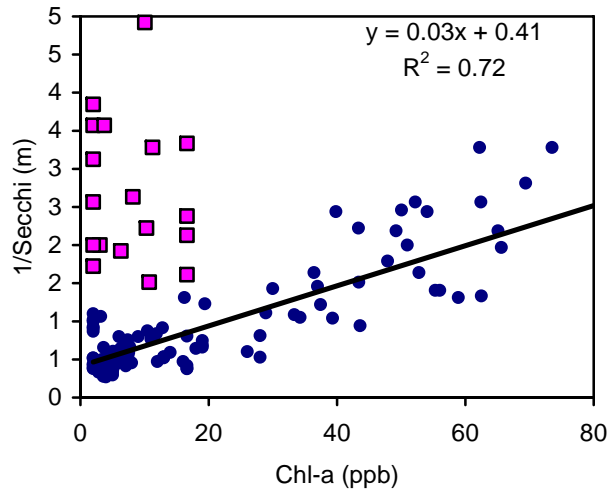
Question 2 - Use Impact



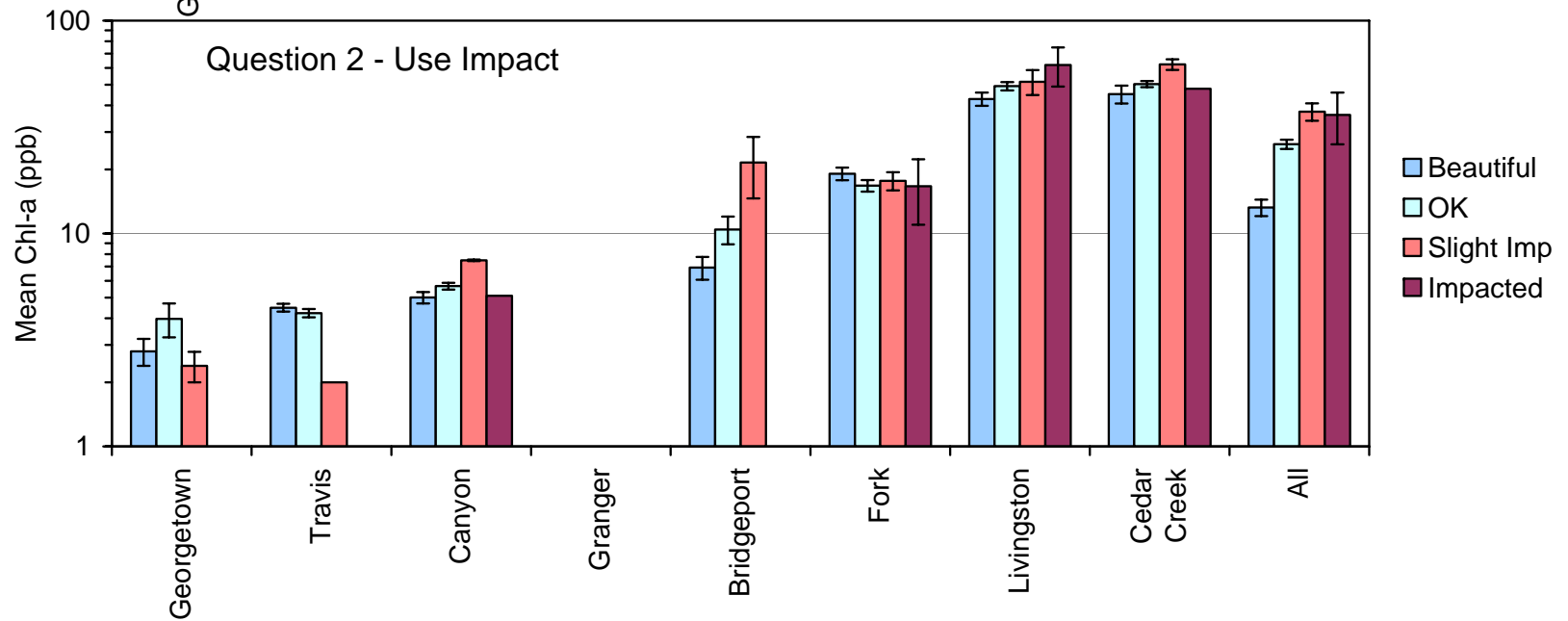
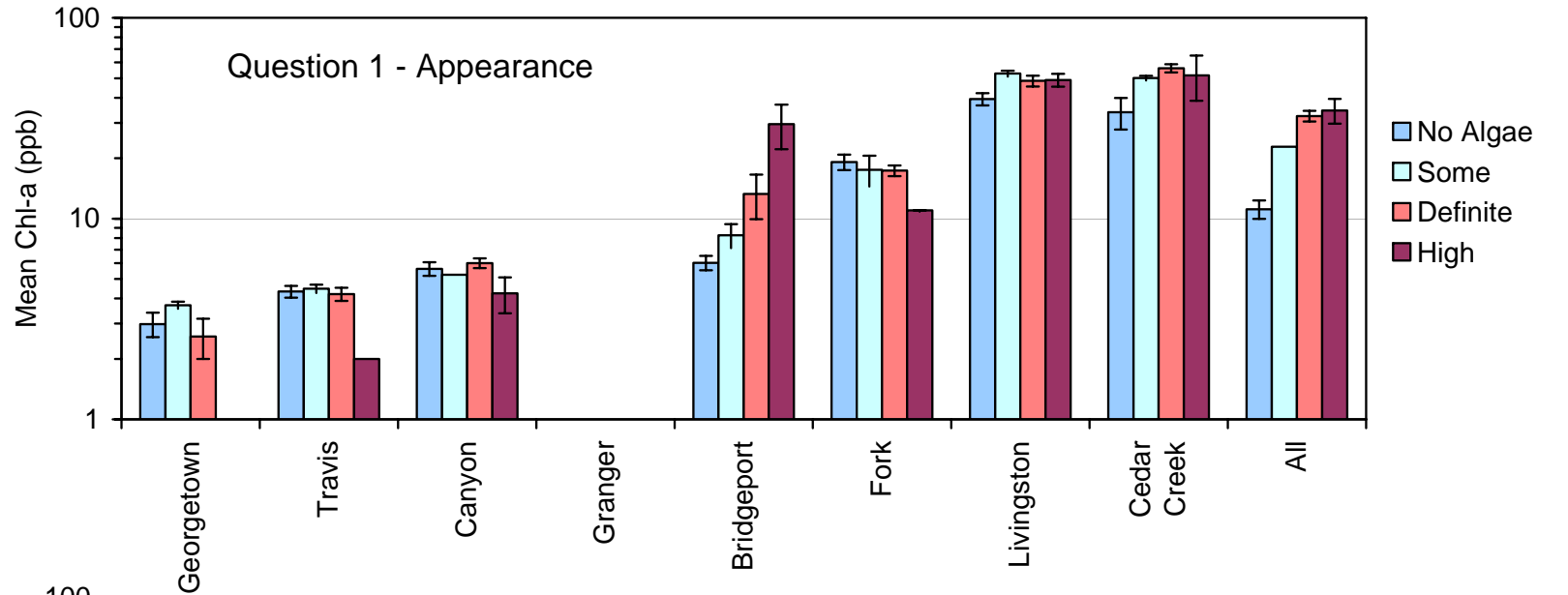
Data Screening Based upon Non-Algal Turbidity



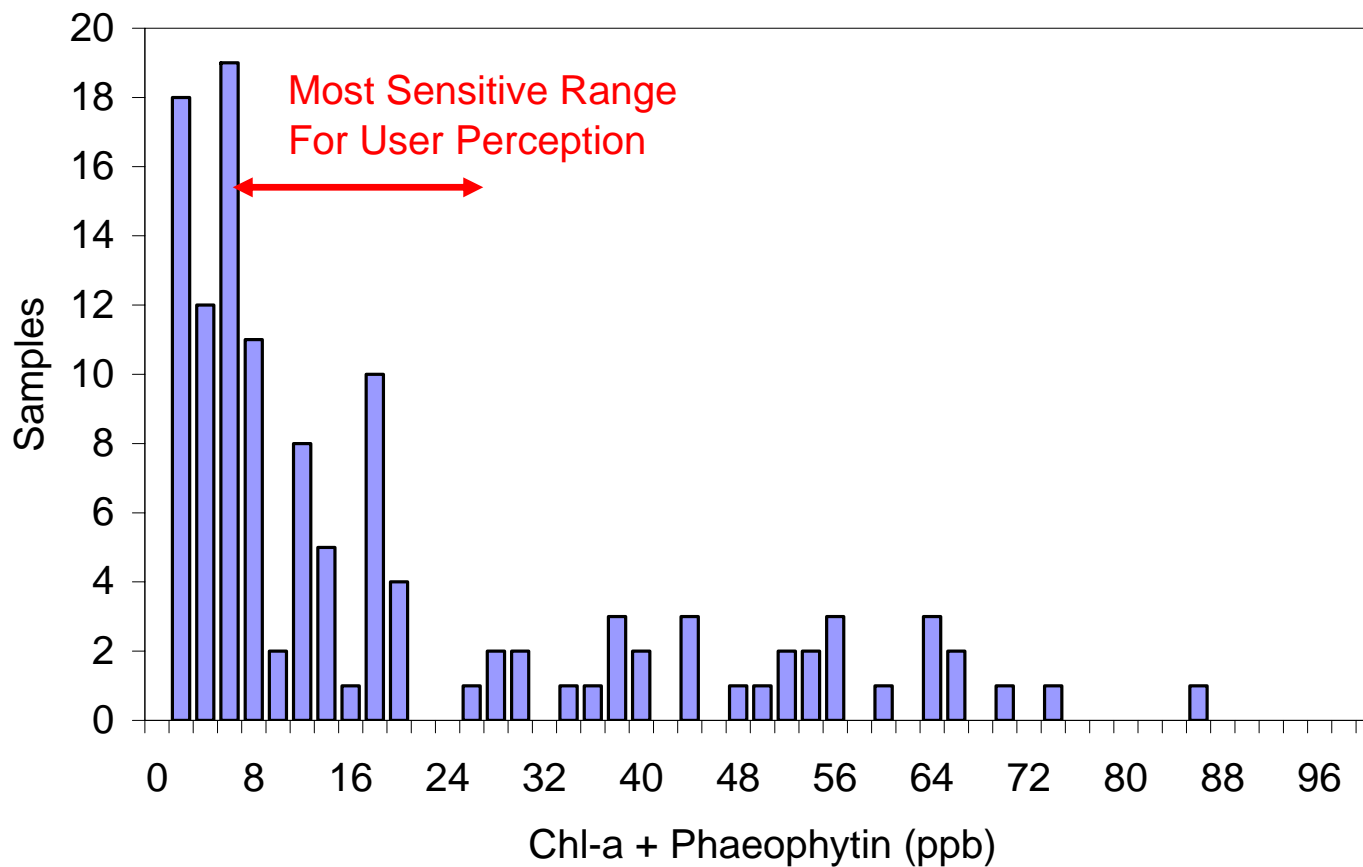
Data Screening Based upon Non-Algal Turbidity



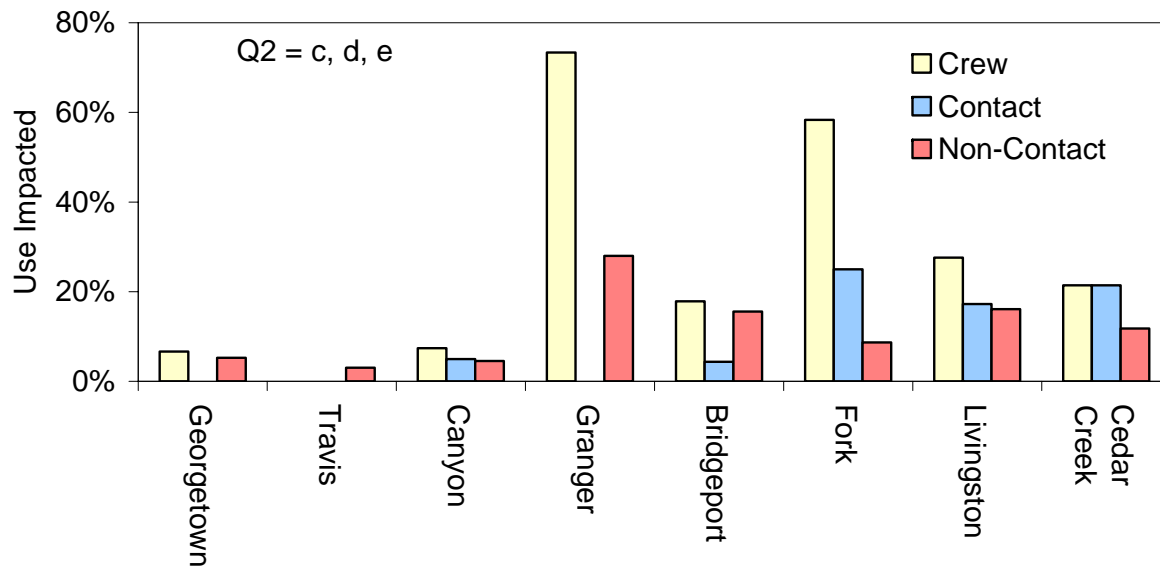
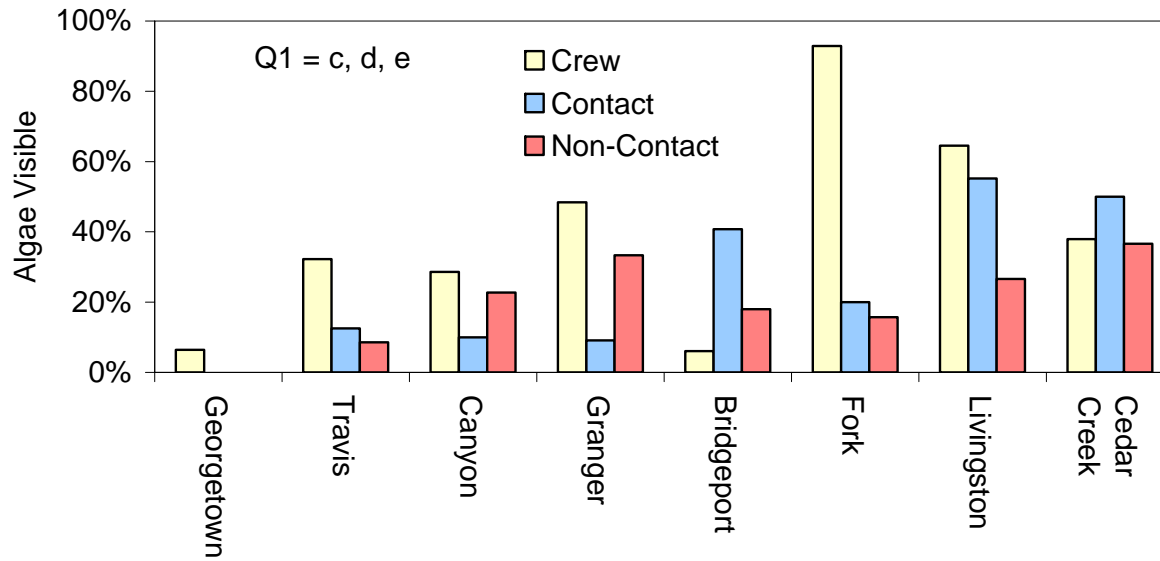
Mean Chl-a vs. Survey Response by Reservoir



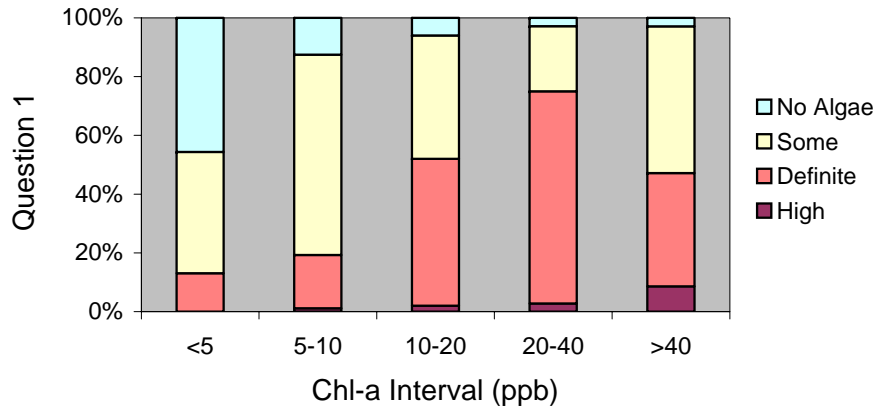
Chl-a Frequency Distribution



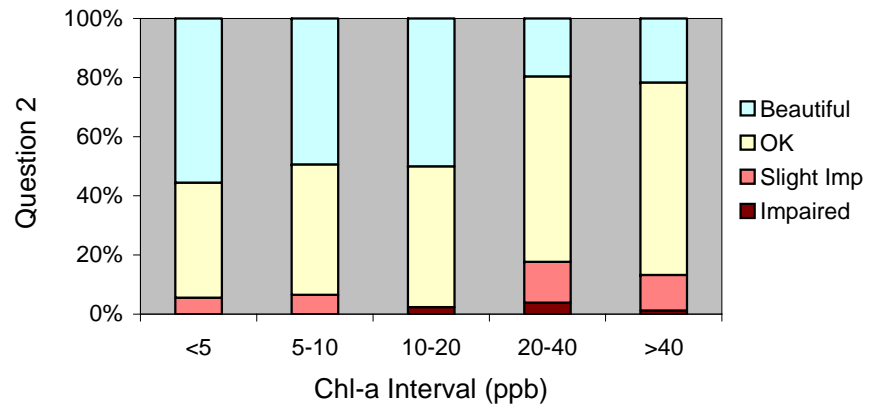
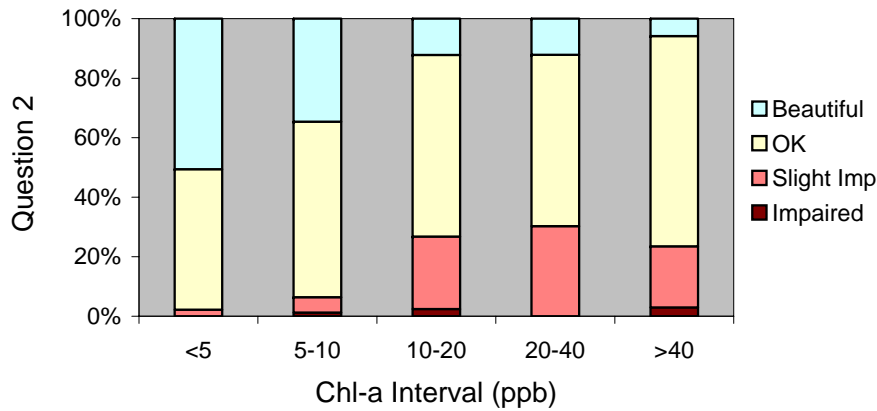
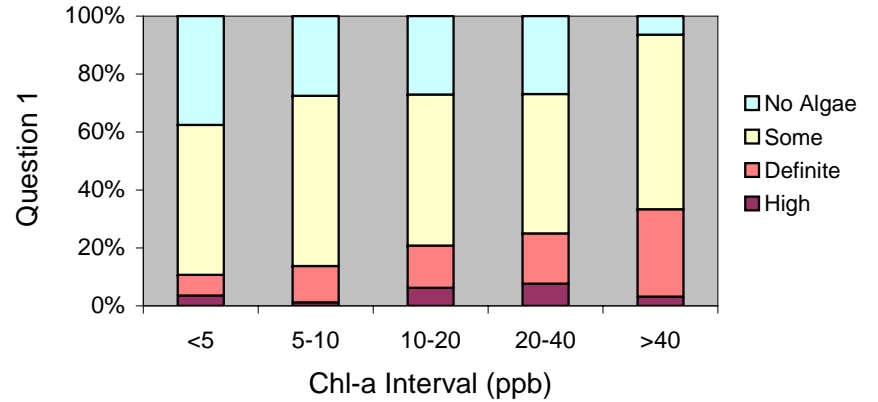
Responses vs. Reservoir & Observer Category



Survey Responses vs Chl-a Interval
Sampling Crews & Contact Users

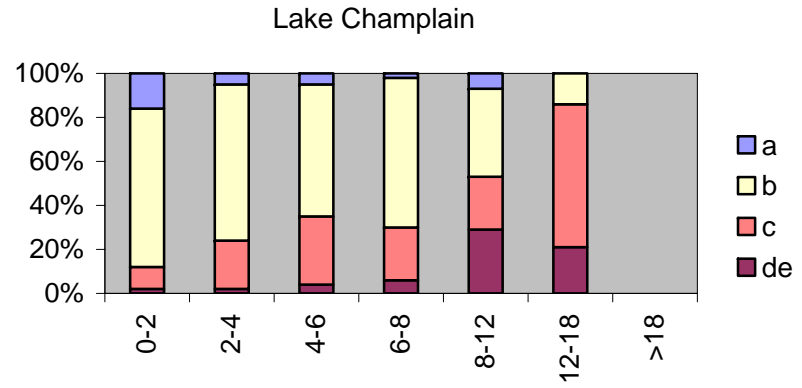
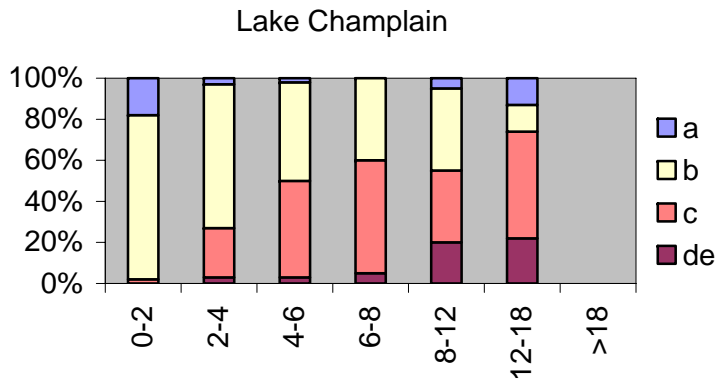


Survey Responses vs Chl-a Interval
Non-Contact Water Users

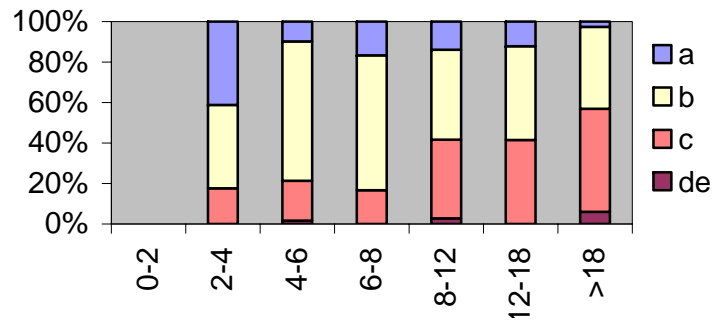


Survey Responses - Lake Champlain vs. Texas Reservoirs

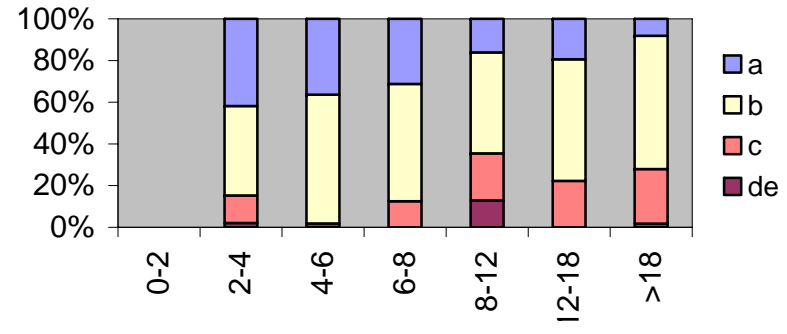
Question 1 - Appearance



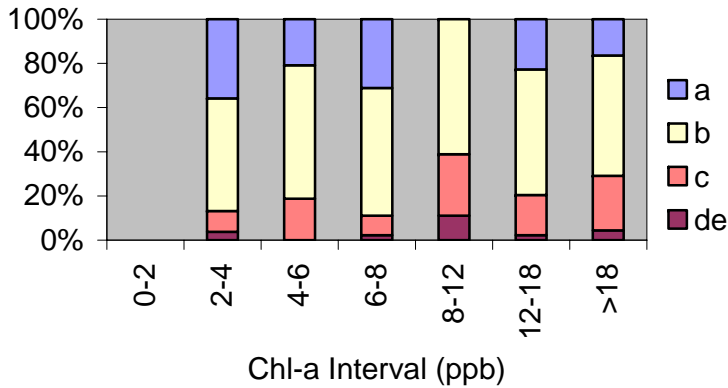
Texas Reserv - Crew or Contact User



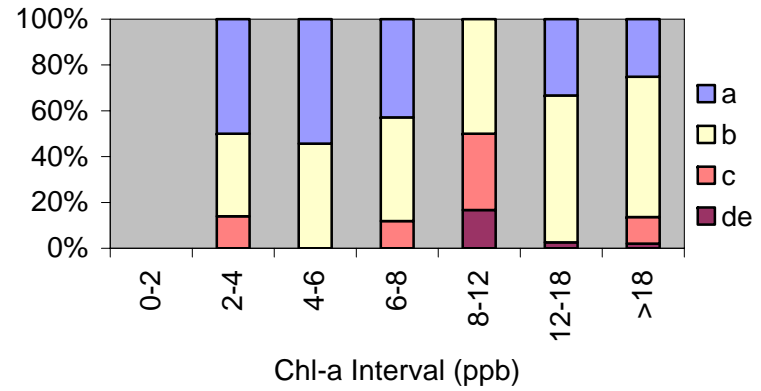
Texas Reserv - Crew or Contact User

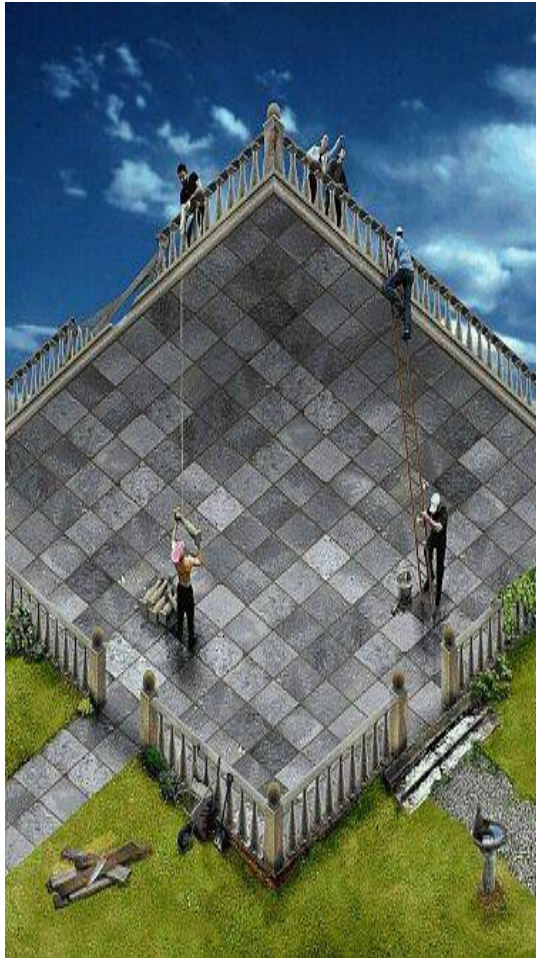


Texas Reserv - Other Observer



Texas Reserv - Other Observer





Factors Potentially Influencing Correlations Between Survey Responses & Chlorophyll-a

Exploratory Analysis - First of Two Survey Years

- yes Level of Enrichment (Oligo-Meso vs. Hypereutrophic)
- yes Observer Category (Sampling Crew vs. Lay Observer)
- yes Water Use (Contact vs. Noncontact)
- yes Non-Algal Turbidity (Low-Moderate vs. Extremely High)
- yes Site Type (Cove vs. Open Lake)
- yes Spatial/Temporal Variance in Reservoir (High vs. Low)
- no Observer Visit Frequency
- no Season (June-July vs.. Aug-Sept)
- no Include or Exclude Phaeophytin