

D R A F T

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

Exploratory Analysis of First Year of Monitoring Data

prepared for
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by
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Introduction

Data Reduction

Transparency/Chlorophyll-a Relationships

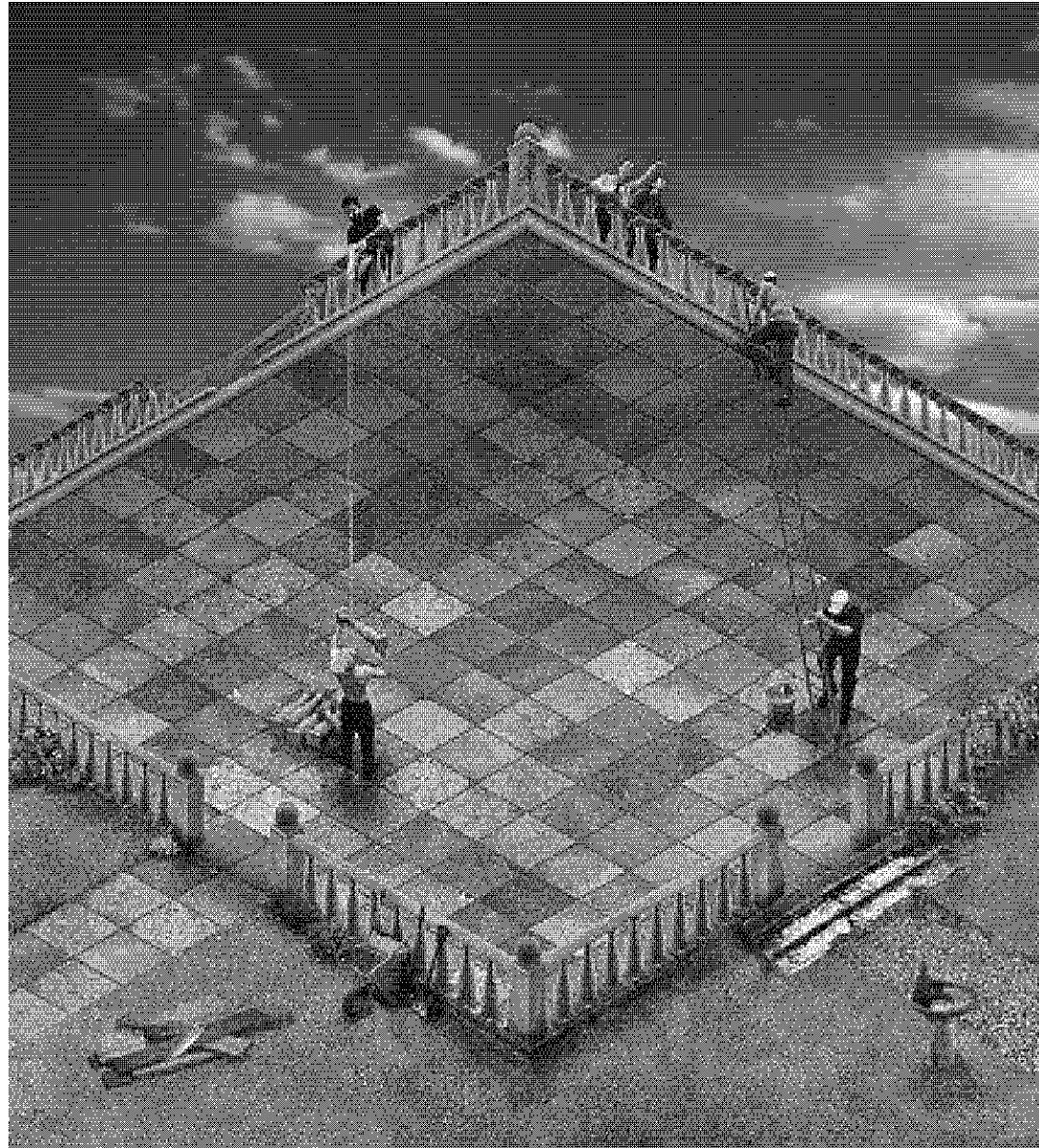
Survey Results vs. Reservoir & Monitoring Site

Survey Results vs. User Categories

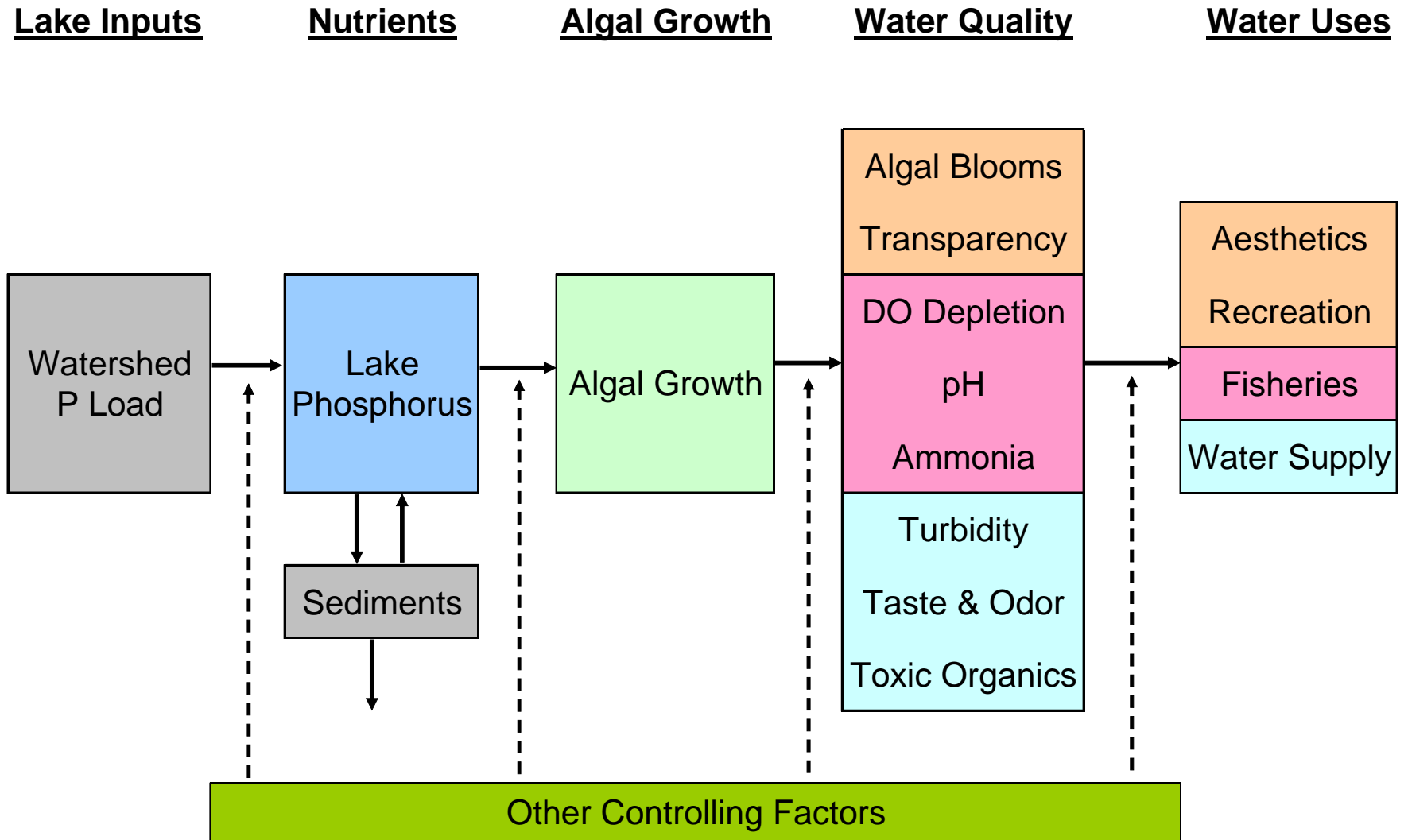
Correlations within Reservoirs

Survey Results vs. Chlorophyll-a Interval

Temporal Variations in Chlorophyll-a



Causal Pathways Linking P Loads to Water Uses



Chlorophyll-a Nuisance Values for South African Impoundments

Instantaneous Chl-a (ppb)

<10

10-20

20-30

> 30

Nuisance Value (Use Impact)

No Problems Encountered

Algal Scums Evident

Nuisance Conditions

Severe Nuisance Conditions

Based upon simultaneous water quality sampling & user surveys

Walmsley, R., "A Chlorophyll-a Trophic State Classification System for South African Reservoirs", J. Environ. Qual., 1984

Recreation Potential vs. TP, Chl-a, & Secchi Minnesota Lakes

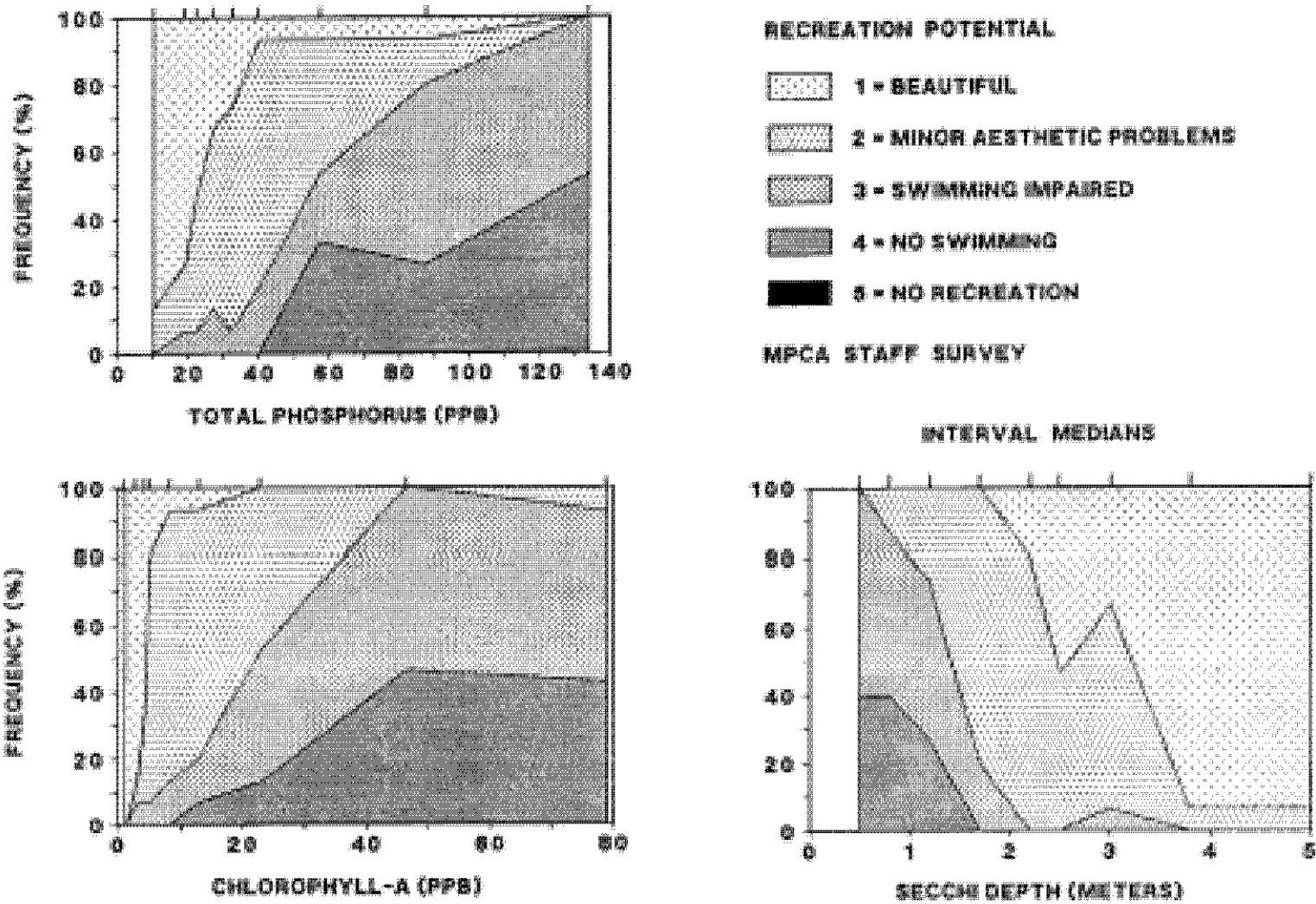


Figure 5. – Recreation potential ratings vs. lake water quality measurements.

- 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) High algae levels and/or mild odor apparent
 - e) Severely high algae levels 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

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) Swimming

b) Fishing

c) Boating

d) Skiing/Windsurfing

e) On-Shore Activity (camping, picnicking, etc.)

f) Other or non-recreational (Please specify)

Question 1 - Appearance

ResLabel	Cove_Mai	No Algae	Some	Definite	High	Severe	Total
		a	b	c	d	e	
Bridgeport	Cove	5	32	14	3		54
	Main	11	40	4	1		56
Canyon	Cove	16	17	12	1		46
	Main	8	31	6	1		46
Cedar Creek	Cove	1	27	27	2	1	58
	Main	6	36	13	1		56
Fork	Cove	3	14	14	3		34
	Main	12	20	18			50
Georgetown	Cove	20	12	1			33
	Main	20	18	1			39
Granger	Cove	2	6	5			13
	Main	6	32	21			59
Livingston	Cove	3	33	19	6		61
	Main	11	24	26	2		63
Travis	Cove	8	23	9		1	41
	Main	14	29	6			49
Grand Total		146	394	196	20	2	758

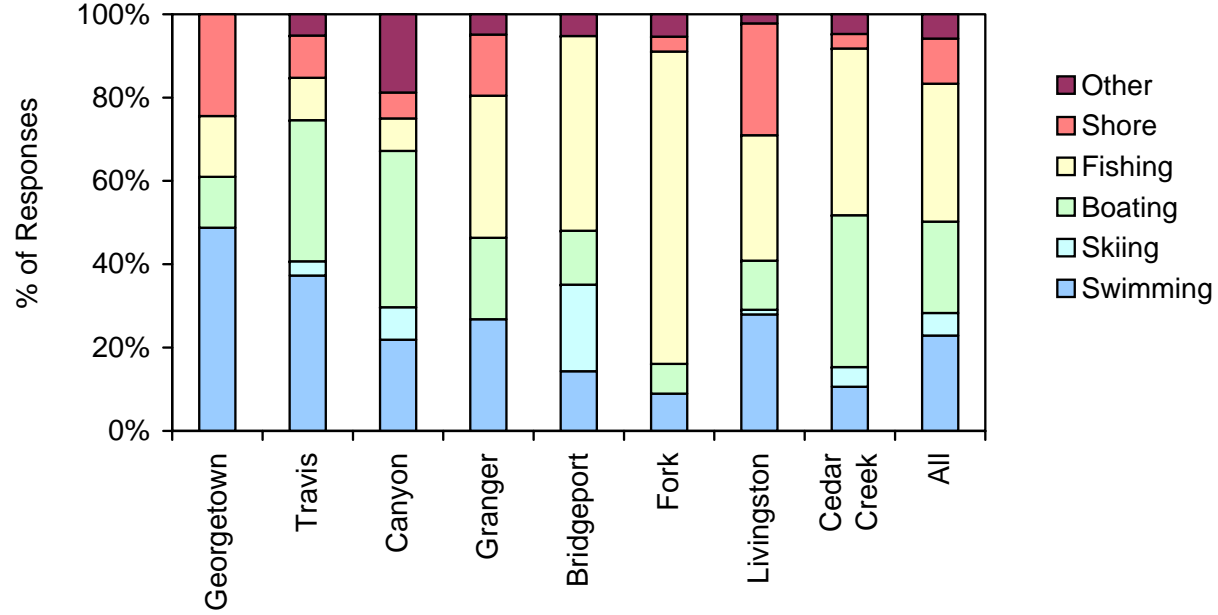
Question 2 - Use Impairment

		Beautiful	OK	Slight Imp	Impaired	Severe Imp	Total
ResLabel	Cove_Mai	a	b	c	d	e	
Bridgeport	Cove	13	29	9	3		54
	Main	33	20	3			56
Canyon	Cove	15	27	4			46
	Main	22	23		1		46
Cedar Creek	Cove	8	35	13	2		58
	Main	14	37	5			56
Fork	Cove	7	12	12	2	1	34
	Main	17	27	6			50
Georgetown	Cove	19	13	1			33
	Main	17	20	2			39
Granger	Cove		3	8	2		13
	Main	6	27	21	5		59
Livingston	Cove	2	43	12	3		60
	Main	11	36	15	1		63
Travis	Cove	16	23	2			41
	Main	24	24	1			49
Grand Total		224	399	114	19	1	757

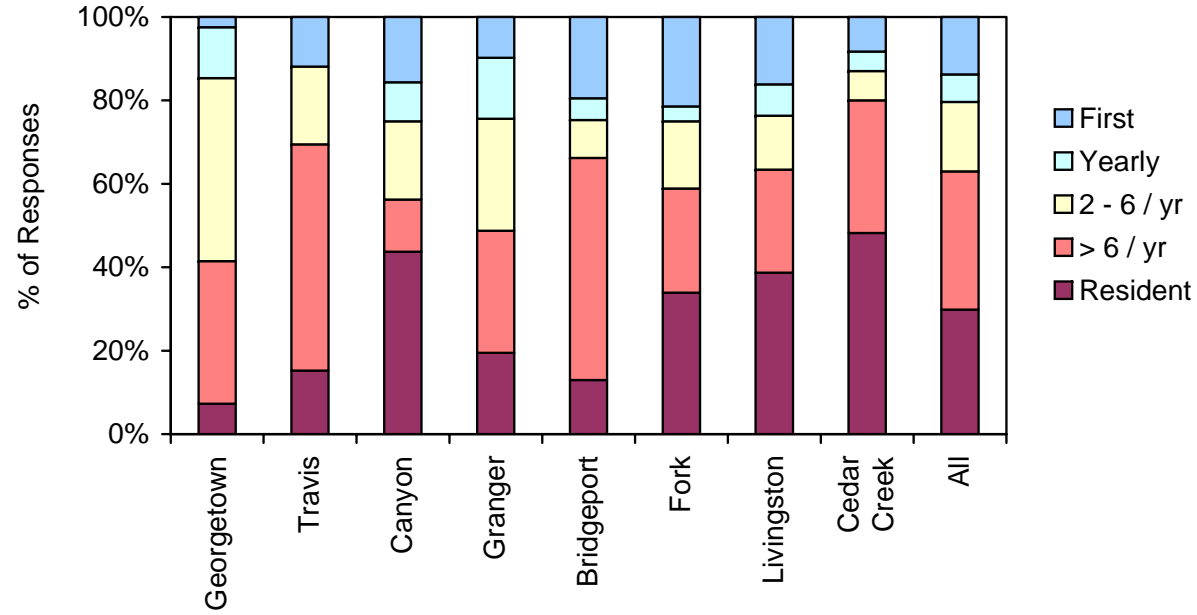
Question 5 - Water Use

ResLabel	Cove_Mai	Swimming	Fishing	Boating	Skiing	Shore	Other	Sampling Crew	Total
		a	b	c	d	e	f	f	
Bridgeport	Cove	9	7	5	14		3	16	54
	Main	4	33	8	3		6	17	71
Canyon	Cove	4	4	22	3	1	6	14	54
	Main	10	4	6	4	4	6	14	48
Cedar Creek	Cove	8	20	16	2	1	4	17	68
	Main	2	19	21	3	2	1	15	63
Fork	Cove	3	12	4		2	2	14	37
	Main	2	32	4	1		1	14	54
Georgetown	Cove	15	2			1		16	34
	Main	5	6	6	1	13		15	46
Granger	Cove		1					12	13
	Main	11	17	15	1	12	2	19	77
Livingston	Cove	16	14	10	4	12	1	15	72
	Main	10	24	10	4	18	1	16	83
Travis	Cove	8	3	16	3	2	2	17	51
	Main	14	5	13	4	7	1	14	58
Grand Total		121	203	156	47	75	36	245	883

Q5 - Use Type



Q4 - Visit Frequency



2003 Water Quality Summary by Site

Reservoir	Site	Number of Depth-Average Values	Chlorophyll	Chlorophyll-a + Pheo	Max Chl-a + Phaeo	Transparency	Turbidity, field	Turbidity, lab	Water Temp	DO	Conductivity	pH	TP	TKN	NO2/NO3	Nitrite, as Nitrogen	Nitrate, as Nitrogen	TSS	VSS
Bridgeport	Main	8	5	6	7	1.64	4.7		27.6	7.3	343	8.1	0.026	0.67	0.01			4.6	4.0
Bridgeport	Cove	8	12	14	37	0.88	19.6		28.7	7.3	314	8.2	0.057	0.78	0.02			13.2	4.7
Canyon	Main	7	3	4	6	2.65	2.61	1.8	28.5	8.2	382	8.1	0.036	1.00	0.09			1.8	1.2
Canyon	Cove	7	5	7	8	1.71	1.84	3.2	28.0	8.3	375	8.1	0.031	1.24	0.10			2.8	1.3
Cedar Creek	Main	8	38	46	66	0.69	6.8		28.6	7.1	193	8.3	0.085	1.15	0.03			7.5	4.5
Cedar Creek	Cove	8	48	57	74	0.43	13.3		29.5	8.1	192	8.8	0.120	1.34	0.01			14.3	6.4
Fork	Main	7	16	18	28	1.84		1.8	26.6	7.2	158	7.5	1.677	0.82	0.04	0.02	0.02	3.1	
Fork	Cove	7	15	17	28	1.40		3.6	27.2	7.7	159	8.0	1.050	0.22	0.04	0.02	0.02	4.1	
Georgetown	Main	8	7	7	17	2.10		1.6	28.5	7.3	351	8.2	0.295	0.45		0.02	0.02	5.0	1.3
Georgetown	Cove	8	6	6	17	1.23		4.1	28.9	7.2	348	8.2	0.315	0.47		0.02	0.02	7.3	1.7
Granger	Main	8	7	7	17	0.50		13.9	28.1	7.2	343	8.2	0.370	0.48		3.34	0.45	13.0	2.9
Granger	Cove	8	6	7	17	0.30		32.4	28.6	6.9	347	8.1	0.437	0.62		0.02	0.37	44.0	6.9
Livingston	Main	8	32	39	63	0.88		5.1	29.0	10.6	352	8.8	0.218		0.05			7.9	4.6
Livingston	Cove	8	58	65	131	0.42		15.0	29.7	9.3	420	8.9	0.388		0.24			19.8	8.4
Travis	Main	8	4	4	5	2.82		1.3	28.6	7.6	442	8.3	0.020	0.41	0.02			1.9	1.8
Travis	Cove	8	4	5	7	2.31		1.6	29.2	7.7	455	8.2	0.020	0.34	0.02			2.0	1.8

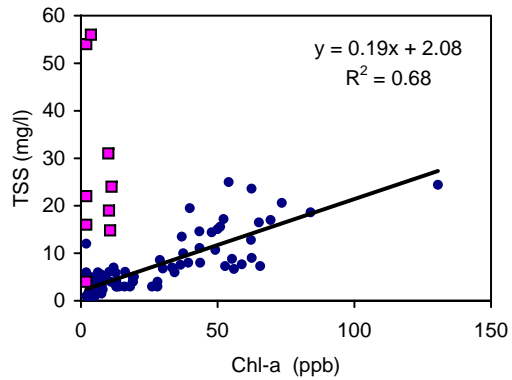
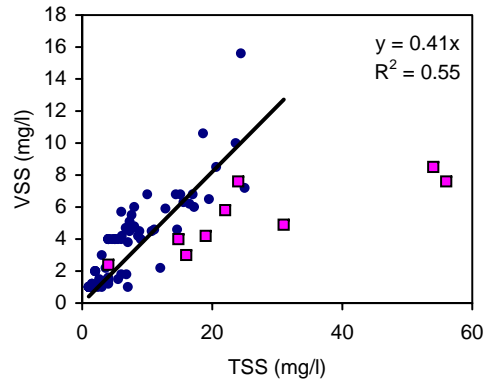
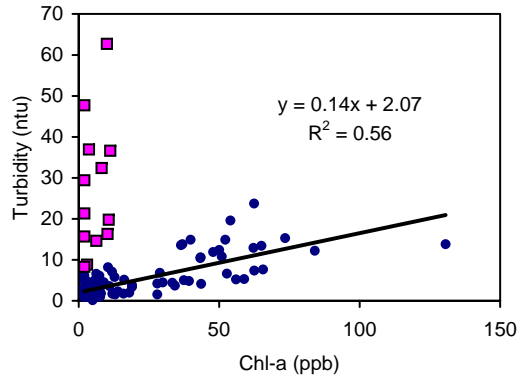
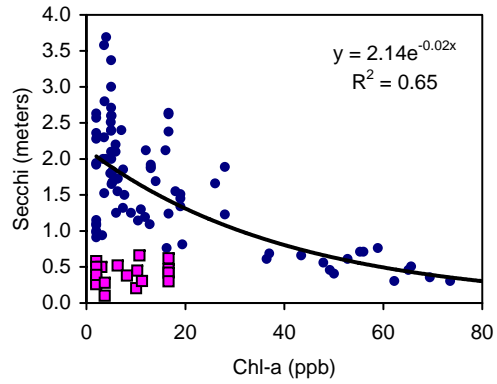
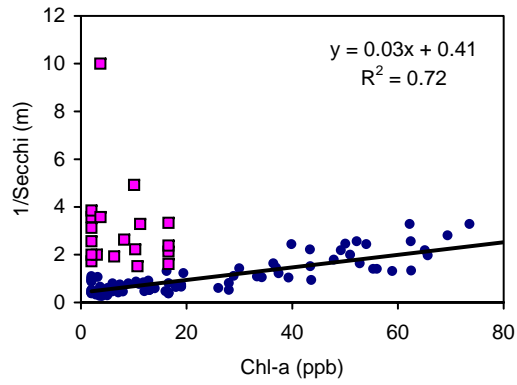
Yearly Statistics Computed from Depth-Averaged Values on Each Date

Factors Potentially Affecting Correlations Between Survey Responses & Chlorophyll-a

Initial Results

- yes Non-Algal Turbidity (Inorganic SS, Color)
- yes Observer Category (Lay Public vs. Sampling Crew)
- yes Water Use (Swimming, Skiing, Boating, Fishing, Hiking, etc)
- yes Level of Enrichment (Low P vs. High P)
- no Observer Visit Frequency
- no Season (June-July vs.. Aug-Sept)
- no Include or Exclude Phaeophytin
- yes Site Type (Cove vs. Open Lake)
- yes Reservoir
 - Region
 - Time of Day
 - Weather

Data Screening Based upon Non-Algal Turbidity

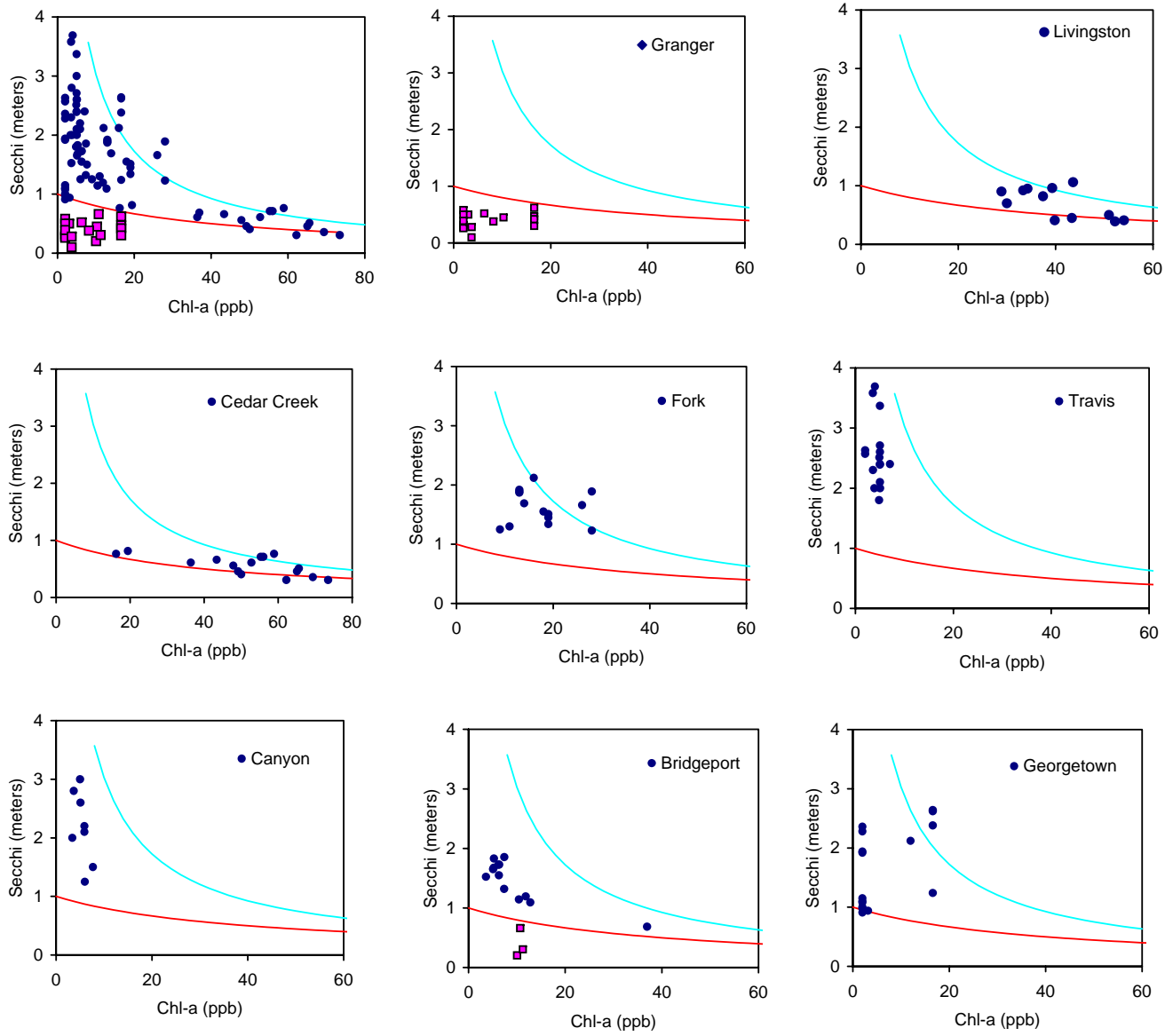


● Regression
 ■ Excluded

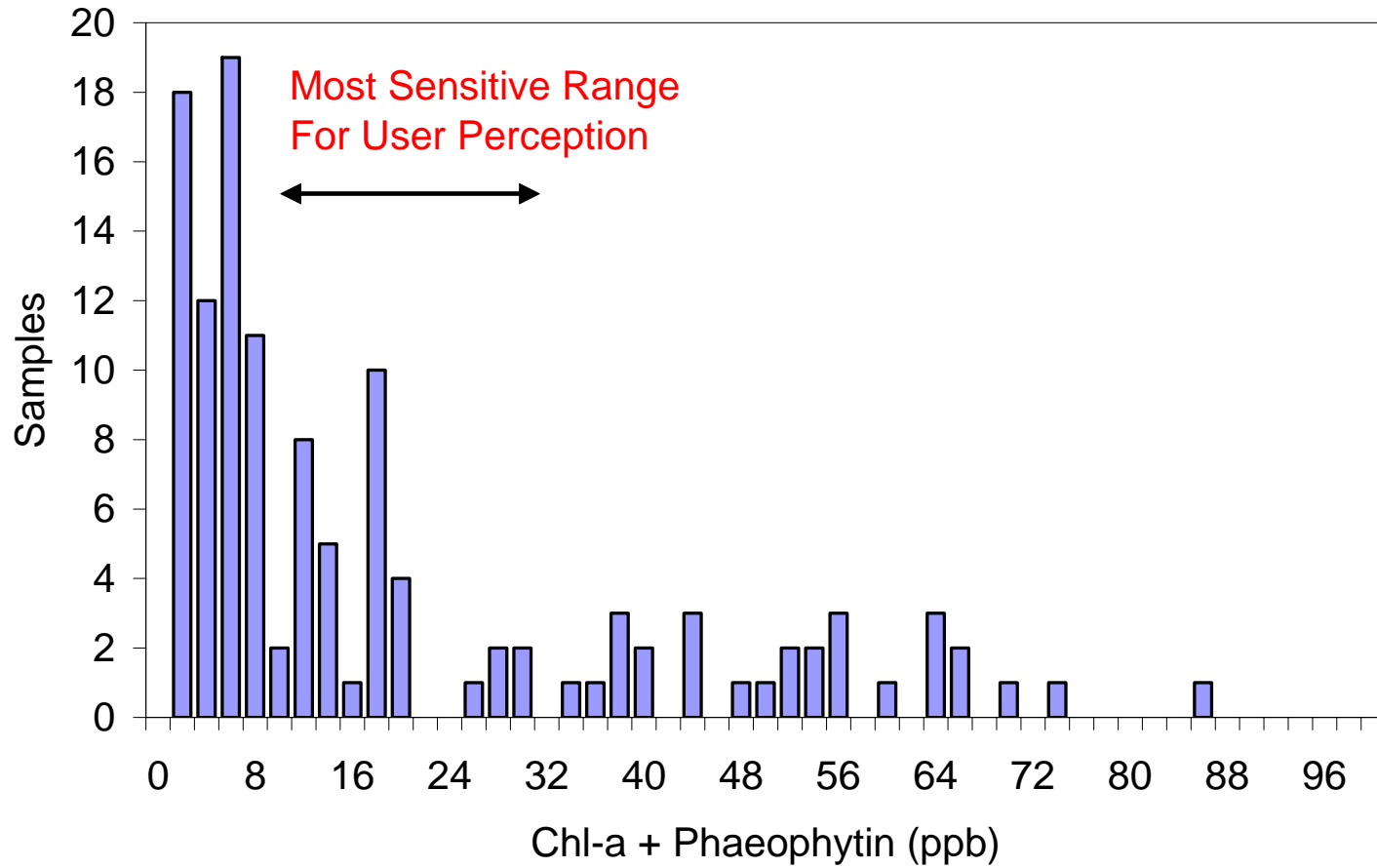
Excluded Data (high non-algal turbidity)
 - Granger, All sites & dates
 - Bridgeport, Cove Site, 3 dates

X-Axis = Chlorophyll-a + Phaeophytin

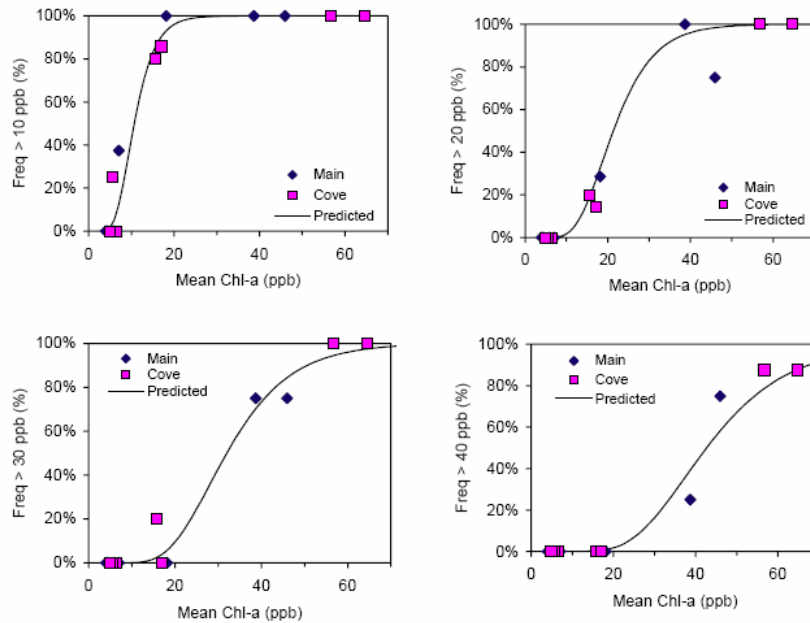
Transparency vs. Chlorophyll-a



Chl-a Frequency Distribution



Bloom Frequencies vs. Mean Chlorophyll-a



Log-Normal Freq. Distribution

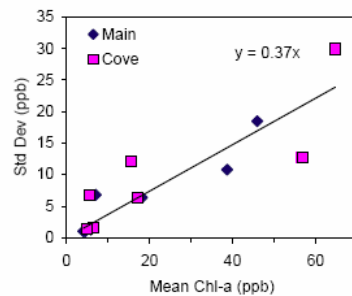
Temporal Coef. of Variation

This Study ~ 0.37

Historical Data (Same Res.) ~0.67

Other Lakes & Reserv. 0.4 – 0.7

Calibration:



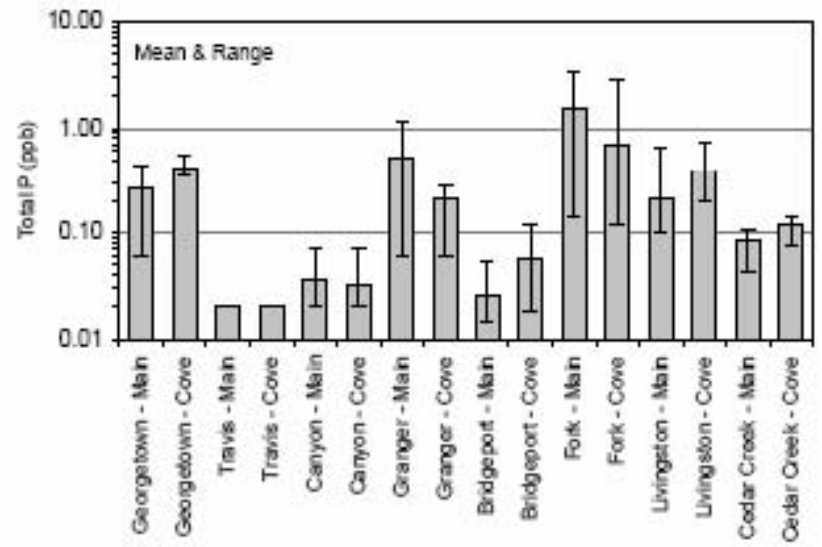
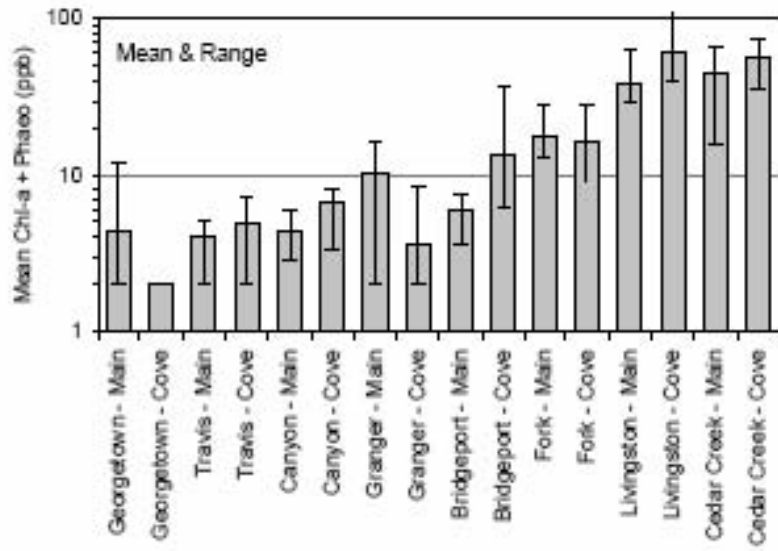
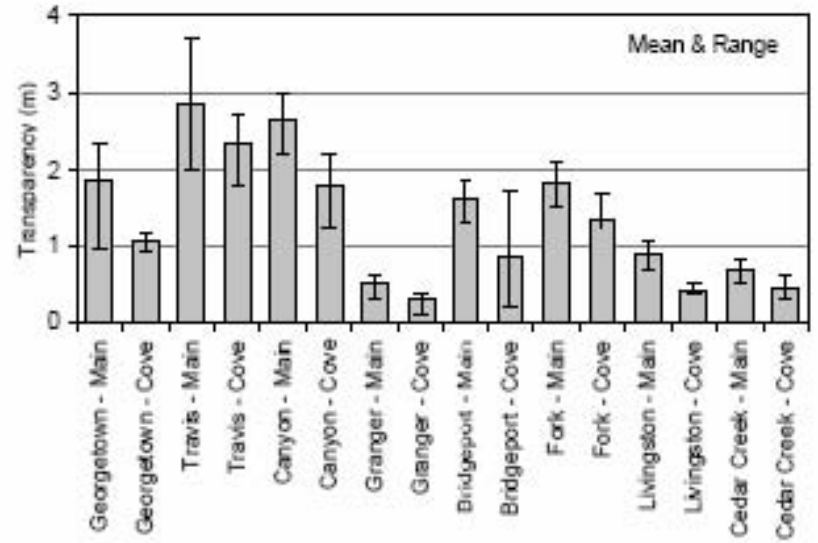
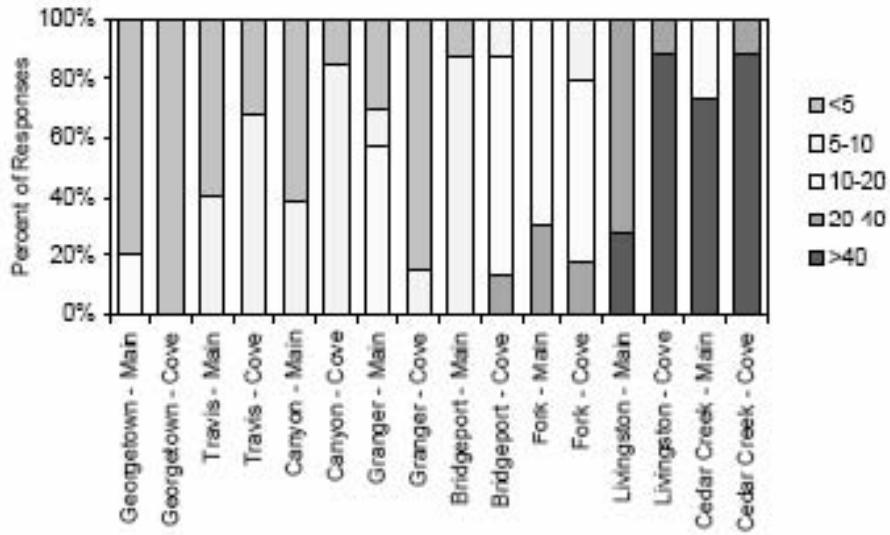
Symbol = Station Means

Predicted = Lognormal Distribution Model

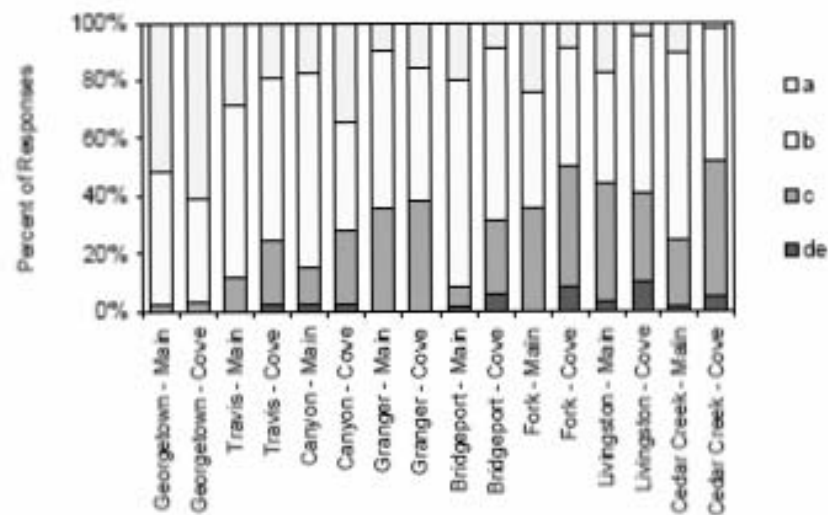
CV = 0.37

Figure 11. Chlorophyll-a Exceedance Frequencies Predicted from Mean Concentration.

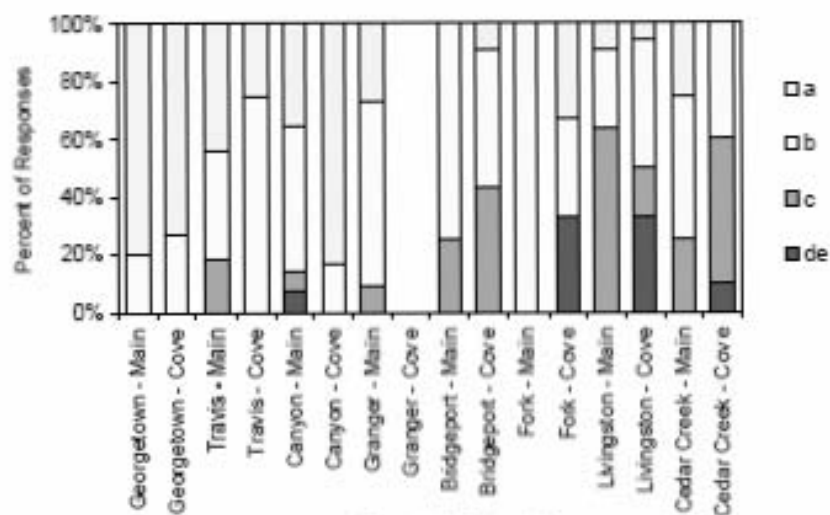
Interval Frequencies - Chlorophyll-a + Phaeophytin



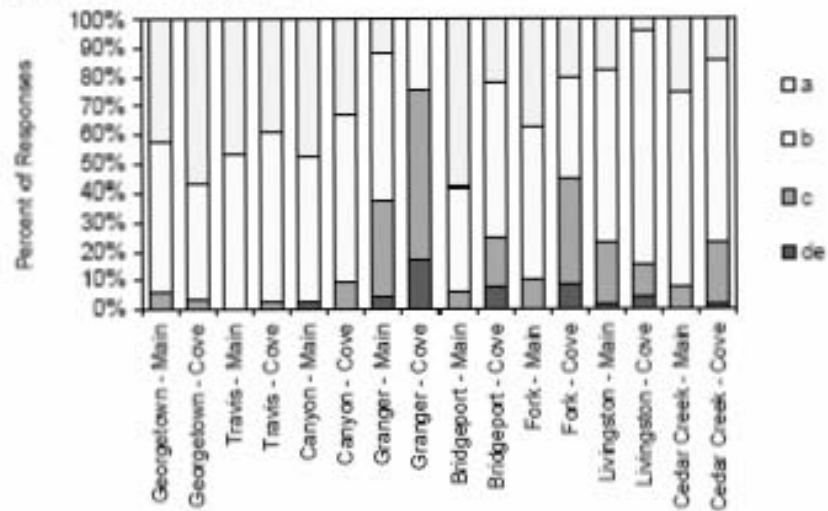
Question 1 - Physical Appearance



Question 1 - Physical Appearance - Contact Water Users



Question 2 - Use Impairment



Question 2 - Use Impairment - Contact Water Users

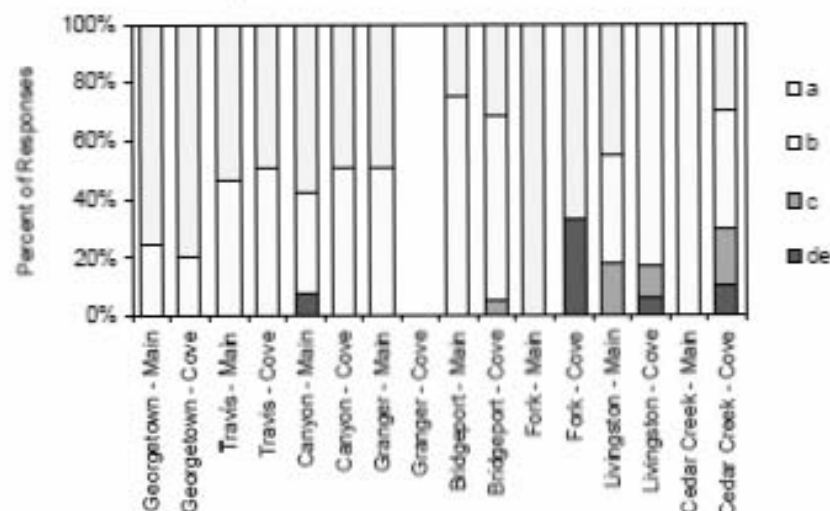
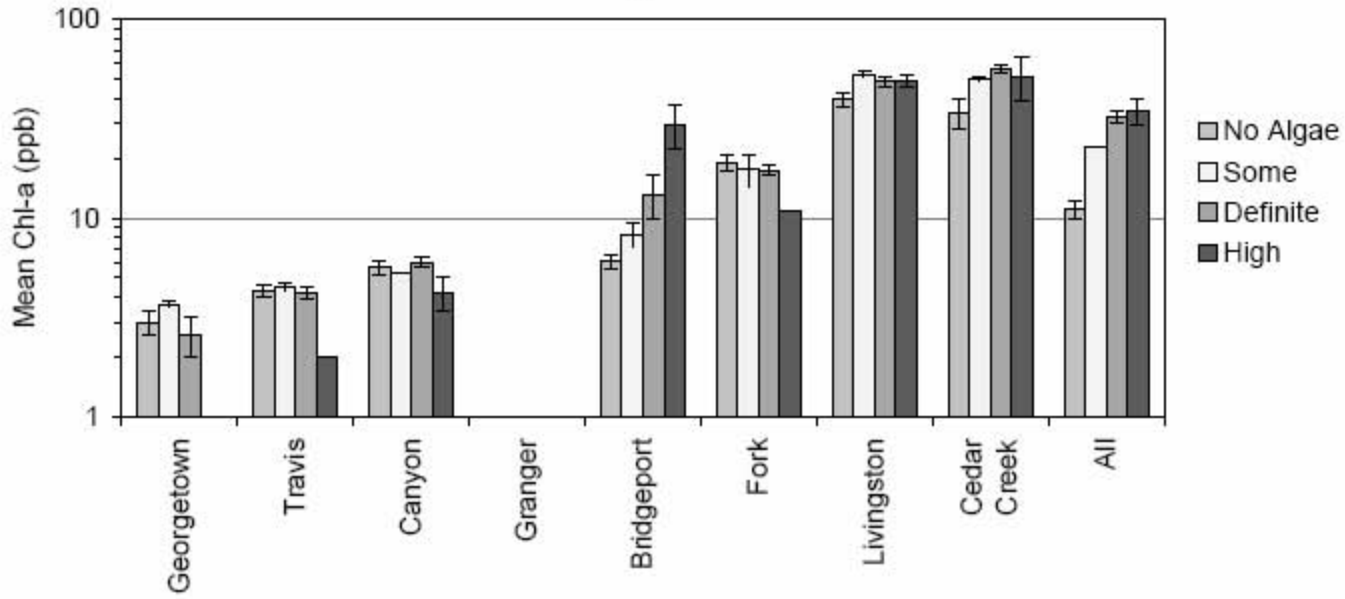


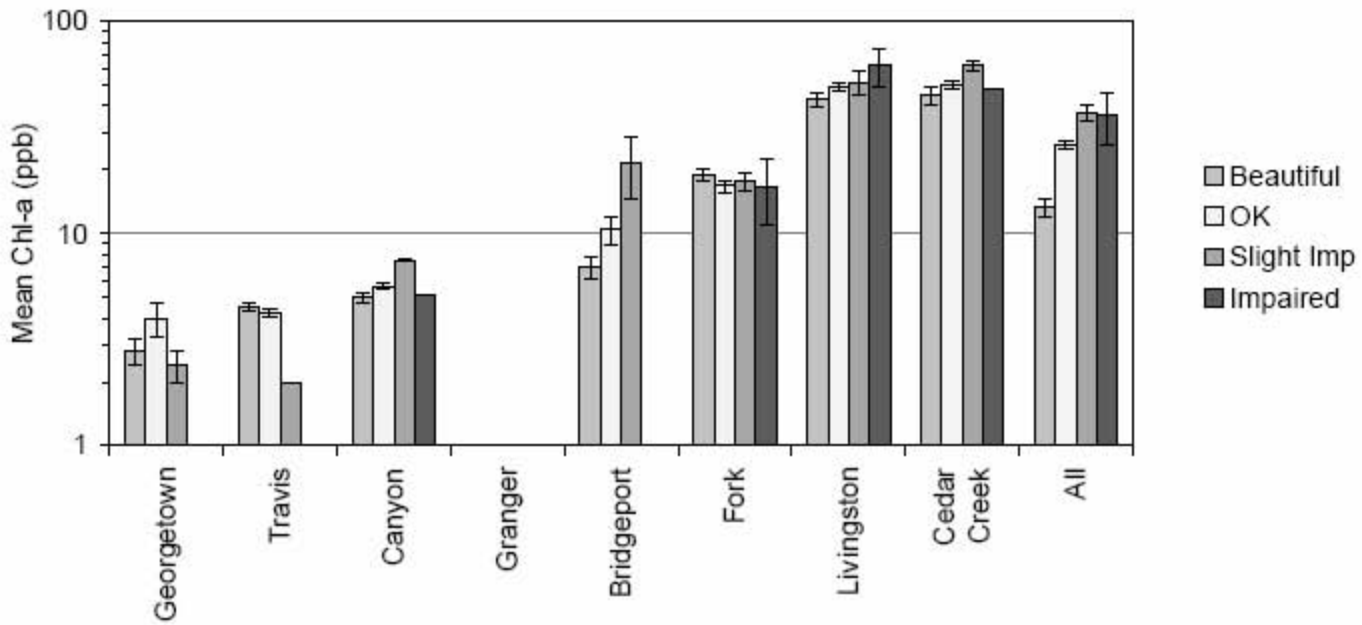
Figure 4. Summary of Water Quality & Survey Responses by Station.

Sorted in order of increasing mean chlorophyll-a, contact users = swimmers, skiers, windsurfers

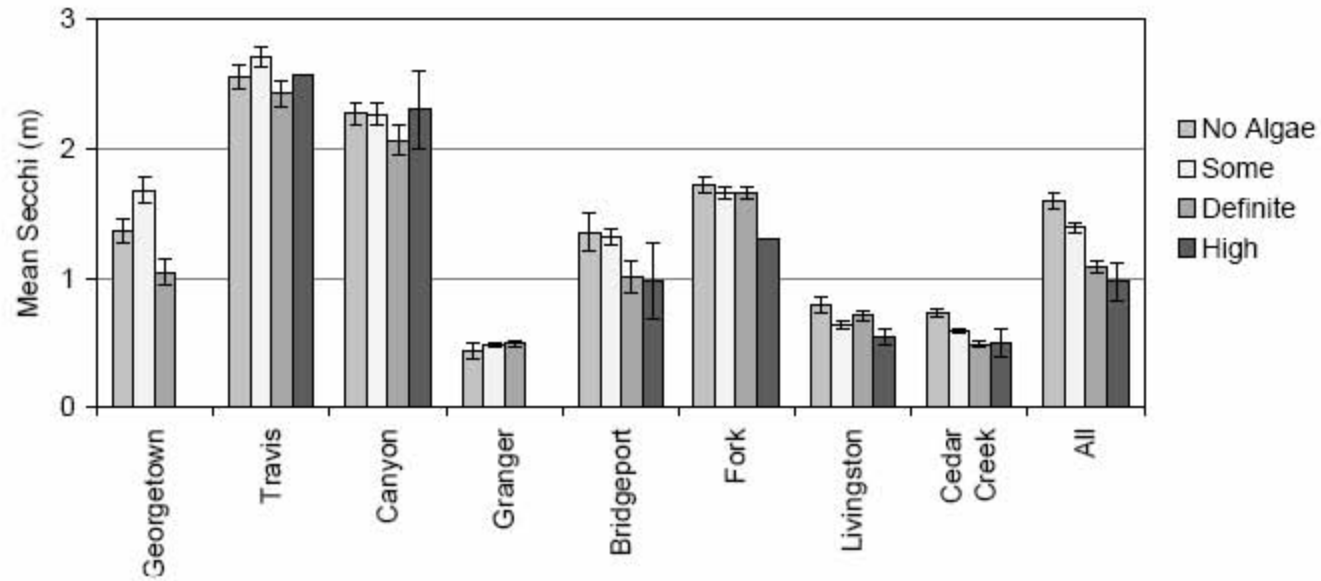
Question 1 - Appearance



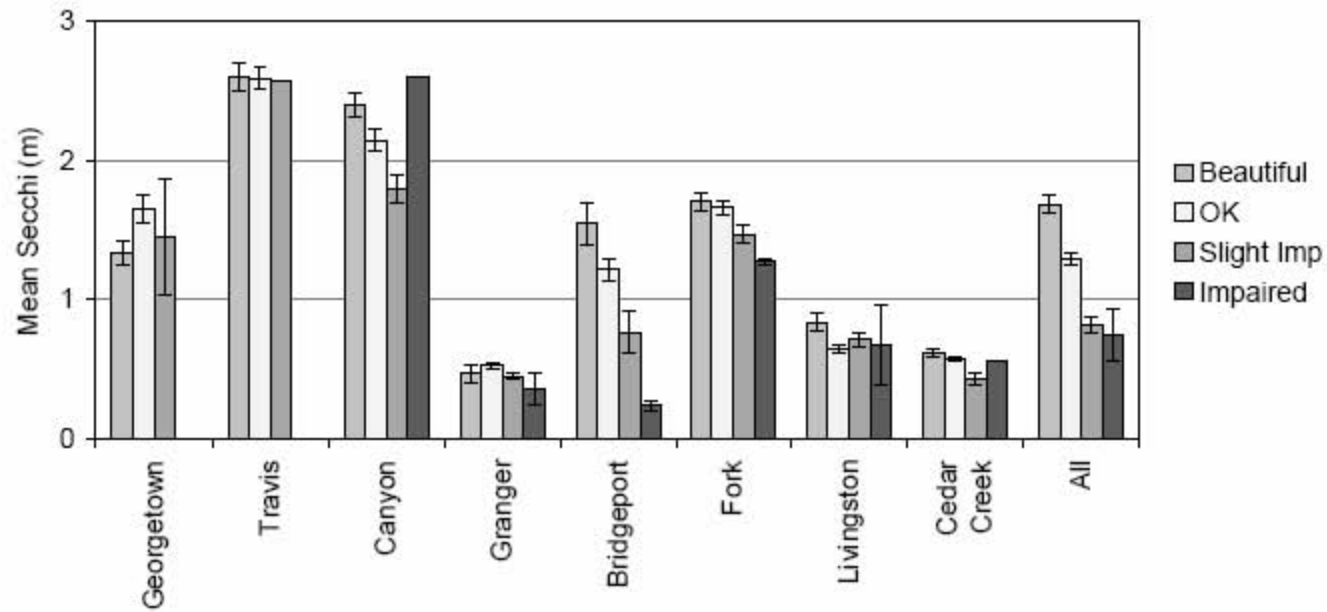
Question 2 - Use Impairment



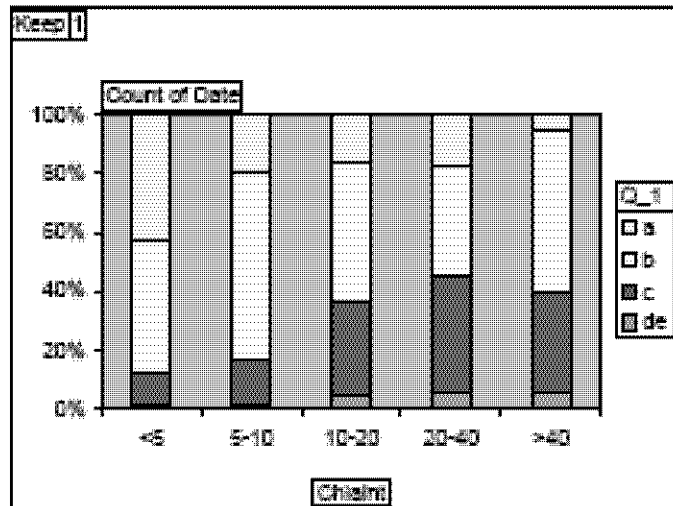
Question 1 - Appearance



Question 2 - Use Impairment



All Categories



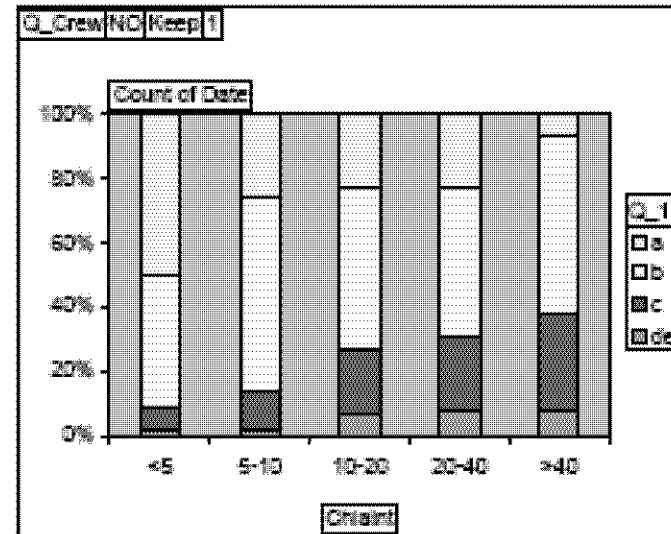
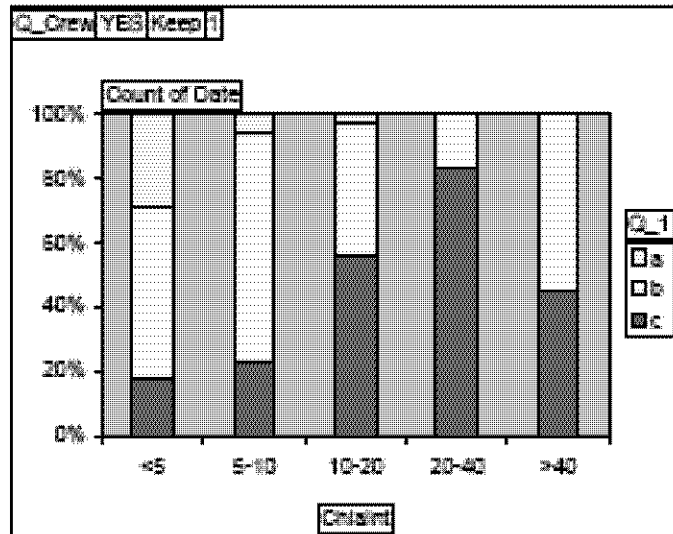
1) Please circle the one response that best describes the physical condition of the lake water today:

- a) No algae, or crystal clear water
- b) A little algae visible
- c) Definite algal greenness
- d) High algae levels and/or mild odor apparent
- e) Severely high algae levels with one or more of the following: massive floating scums on lake or washed up on shore, strong foul odor, or fish kill

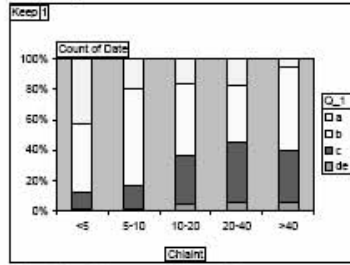
Q_1	a	b	c	d	Total
<5	63	67	18	2	148
10-20	18	48	22	4	98
5-10	23	107	28	2	168
20-40	15	33	25	5	88
>40	8	31	55	9	103
Total	135	344	164	22	665

- Excludes Granger & 3 Bridgeport Samples (high non-algal turbidity)

Sampling Crew vs. Other Observer



All Categories



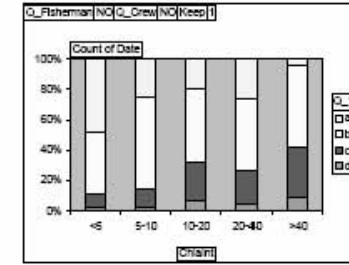
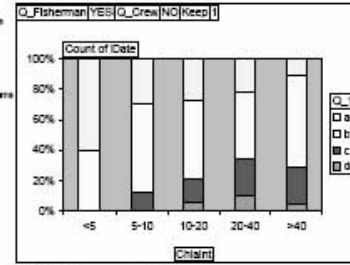
1) Please circle the row response that best describes the physical condition of the lake water today:

- a) No algae, or crystal clear water
- b) A little algae visible
- c) Distinct algae greenness
- d) High algae levels and/or mild odor apparent
- e) Severely high algae levels with one or more of the following: massive floating scums on lake or washed up on shore, strong foul odor, or fish kill

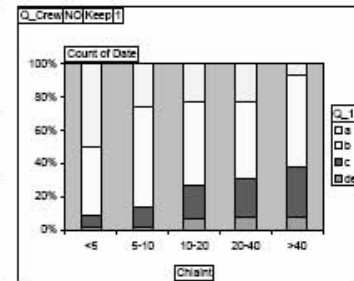
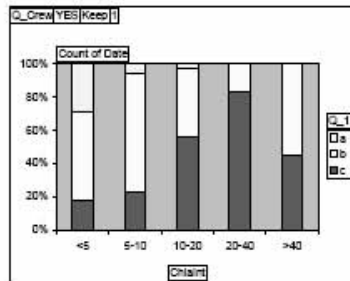
Chl-a	a	b	c	d	e	Total
<=5	63	67	16	2	148	
5-10	18	48	32	4	98	
10-20	33	107	26	2	168	
20-40	15	33	35	5	88	
>40	8	91	55	0	154	
Total	135	344	164	22	665	

- Excludes Granger & 3 Bridgeport Samples (high non-algal turbidity)

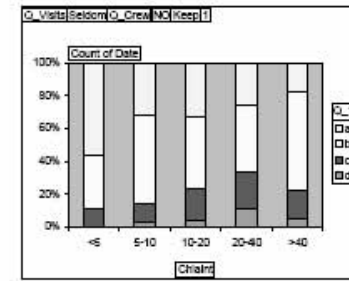
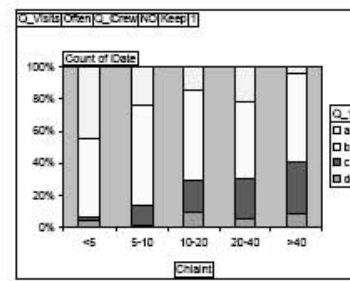
Fishermen vs. Other Observers



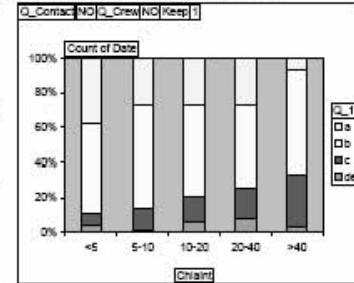
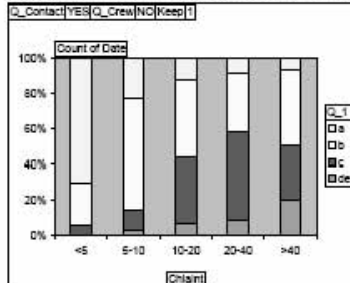
Sampling Crew vs. Other Observer



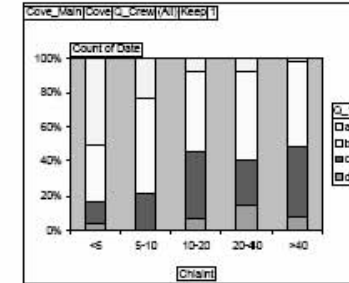
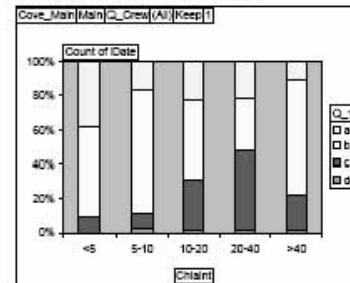
Visit Often vs. Seldom



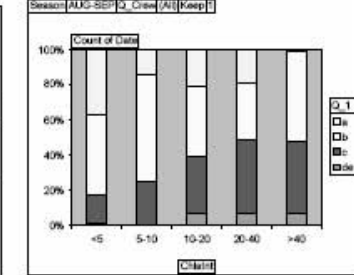
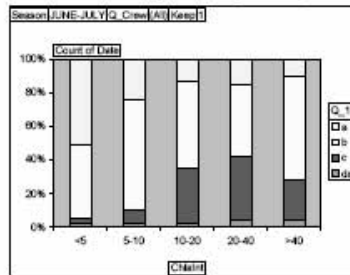
Contact vs. NonContact Recreation Question 5: Contact = a,d Non-Contact = other



Main Reservoir vs. Cove Sites



Season: June-July vs. August-September



Low P (Travis, Canyon, Bridgeport) vs. High P (Fork, Cedar, Living., Georgetown)

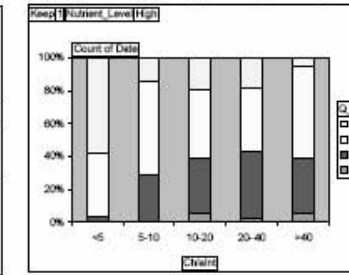
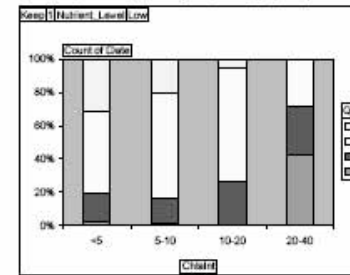
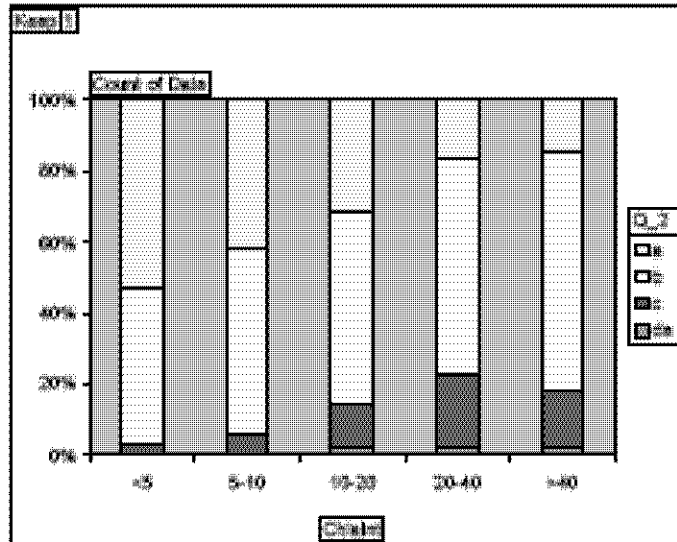


Figure 9. Question 1 Responses vs. Chlorophyll-a Interval & Other Factors. Excludes turbid samples (see Figure 1)

All Categories



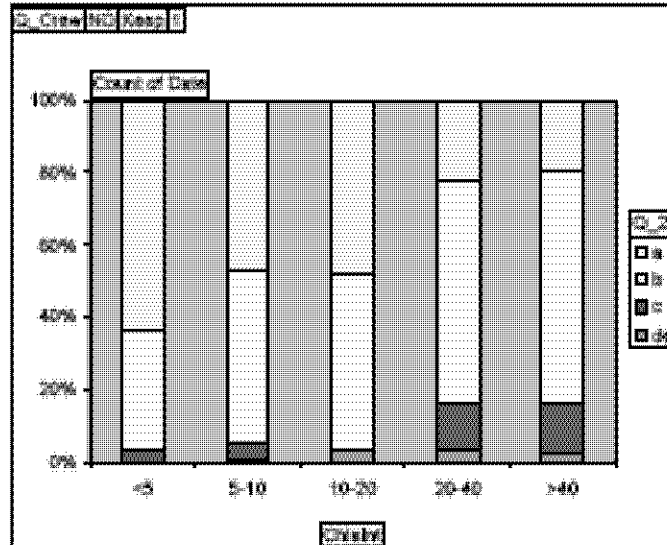
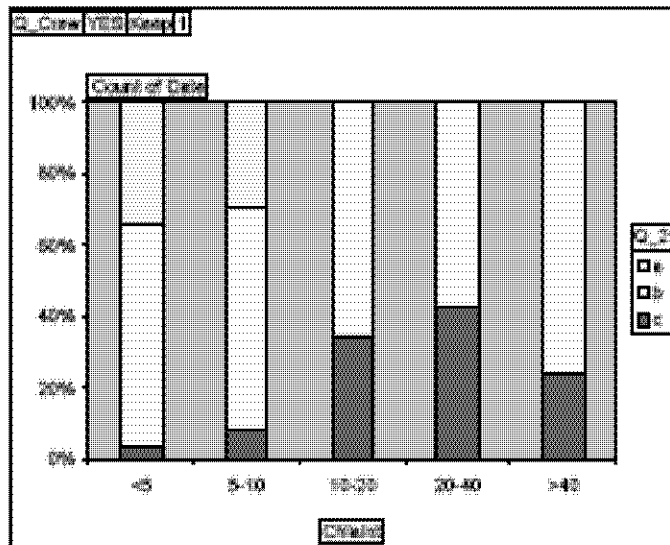
2) Please circle the one response that best describes your perception of how suitable the lake water is for recreation and aesthetic enjoyment today:

- 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

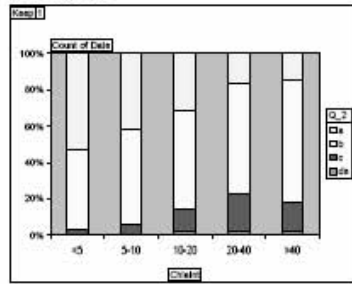
Q1-a	a	b	c	d	Total
<5	75	63	5	0	143
10-20	26	46	10	2	83
5-10	65	80	9	1	155
20-40	14	51	17	2	84
>40	22	102	24	3	151
Total	202	341	65	8	616

- Excludes Orange & 3 Bridgeport Samples (high non-algal turbidity)
- Excludes responses related to factors other than algae (Question 3)

Sampling Crew vs. Other Observer



All Categories



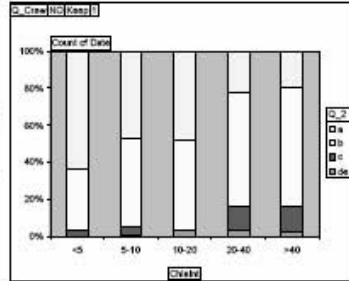
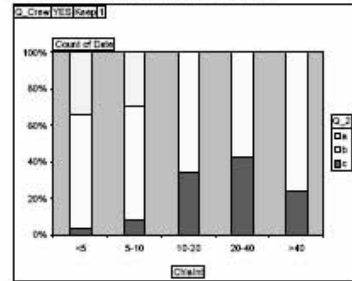
2) Please circle the one response that best describes your perception of how suitable the lake water is for recreation and aesthetic enjoyment today.

- a) Beautiful, could not be any finer
- 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

Chlor	a	b	c	d	e	Total
<5	75	63	5	0	143	
5-10	26	45	10	2	83	
10-20	65	80	9	1	155	
20-40	14	51	17	2	84	
>40	22	102	24	3	151	
Total	202	341	55	8	616	

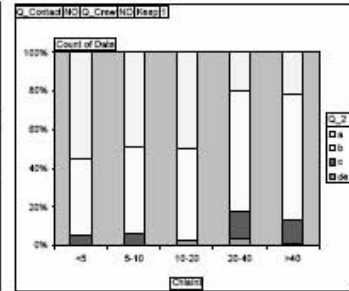
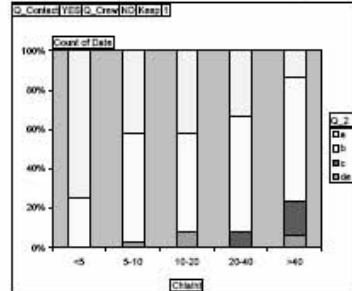
- Excludes Granger & 3 Bridgeport Samples (high non-algal turbidity)
 - Excludes responses related to factors other than algae (Question 3)

Sampling Crew vs. Other Observer

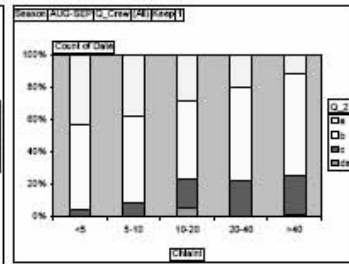
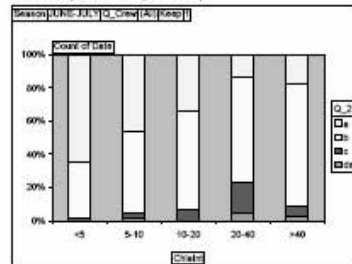


Contact vs. Non-Contact Use

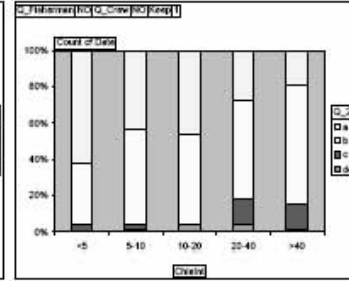
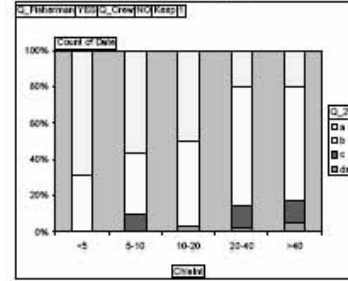
Question 5: Contact = a,d Non-Contact = other



June-July vs. August-September

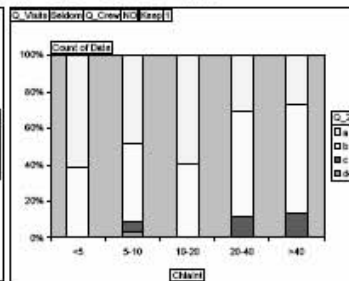
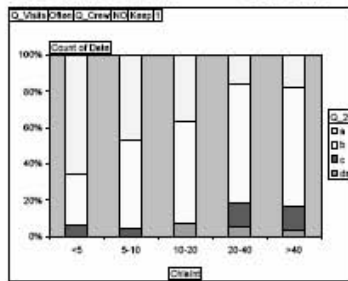


Fisherman vs. Other Observers

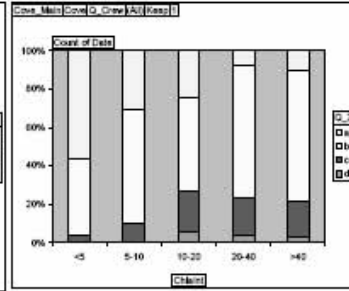
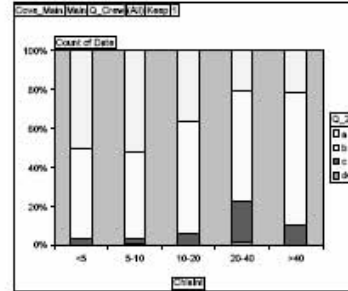


Visit Often vs. Seldom

Question 4: Often = a,b Seldom = c,d,e



Main Reservoir vs. Cove Sites



Low P (Travis, Canyon, Bridgeport) vs. High P (Fork, Cedar Ck, Living., Georgetown)

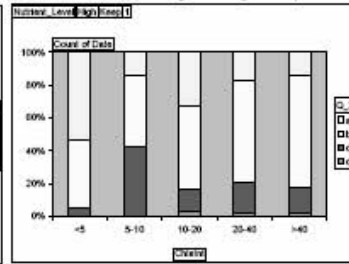
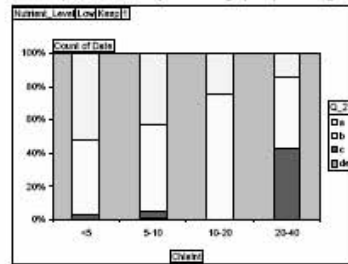
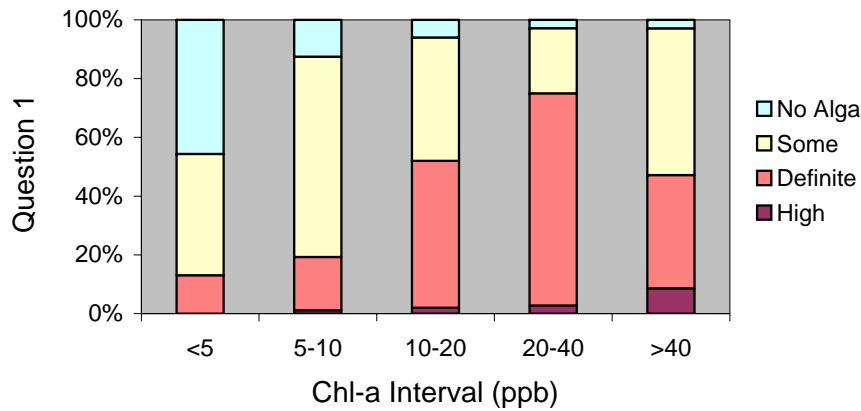
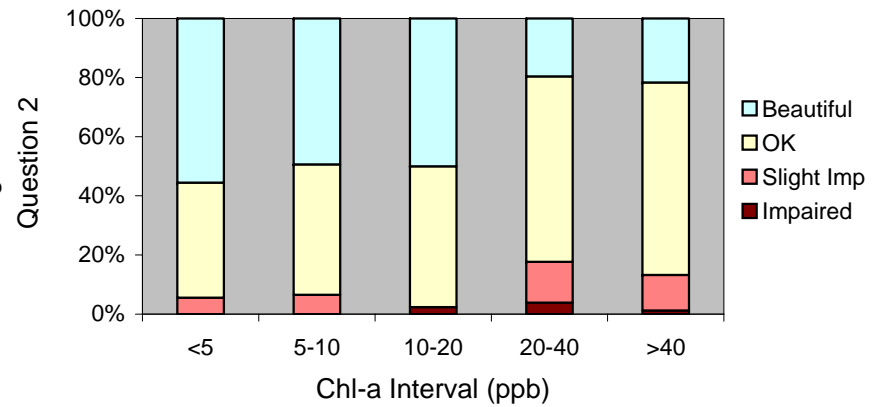
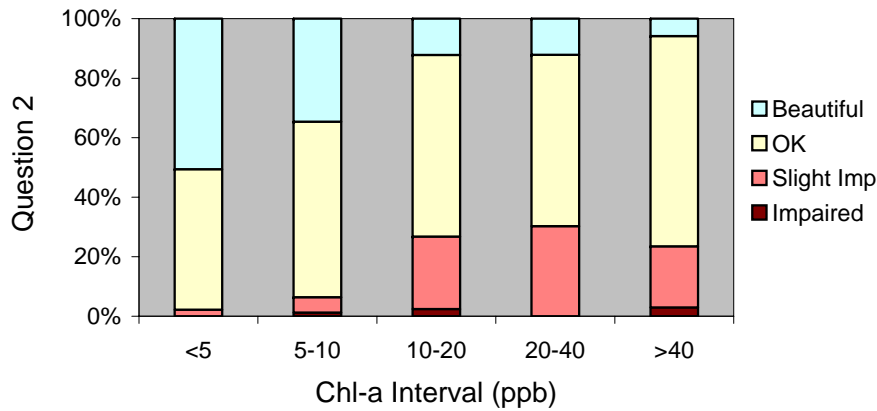
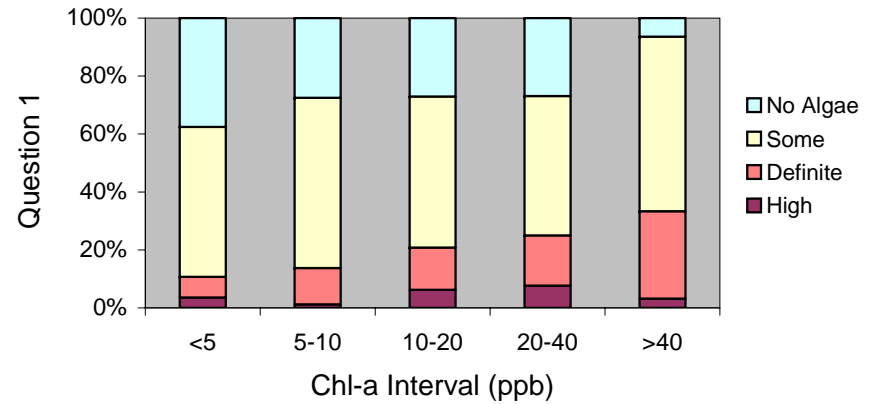


Figure 10. Question 2 Responses vs. Chlorophyll-a Interval & Other Factors
 Excludes turbid samples (Figure 1) & responses with impairment related to factors other than algae (Question 3).

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

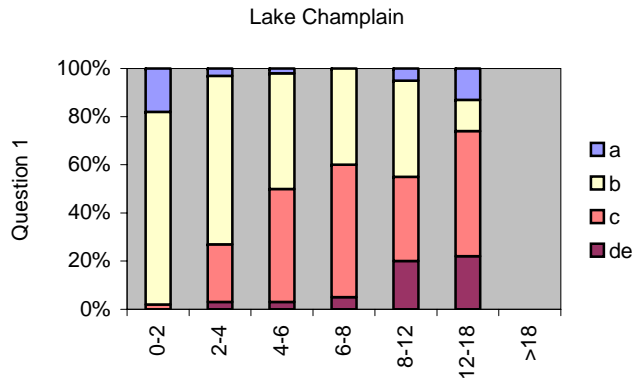


Survey Responses vs Chl-a Interval
Non-Contact Water Users

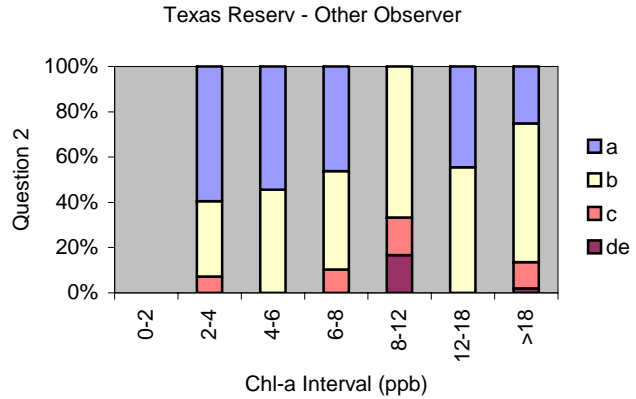
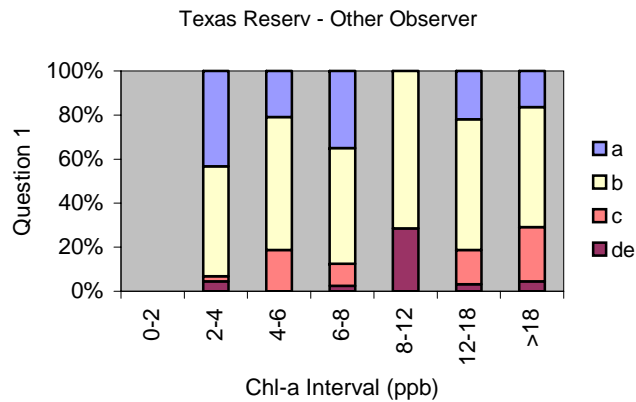
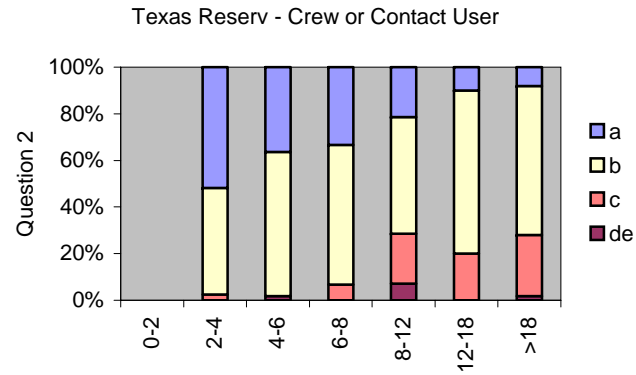
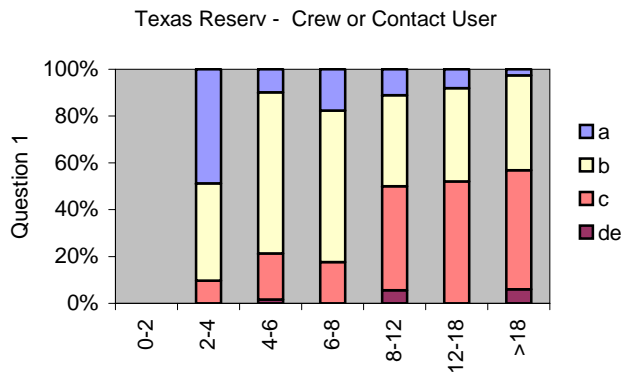
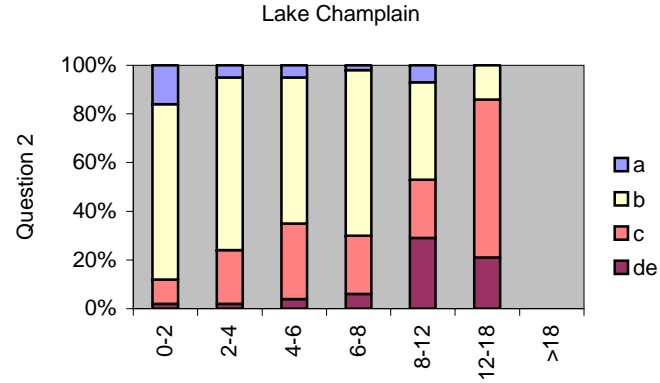


Survey Responses - Lake Champlain vs. Texas Reservoirs

Question 1 - Appearance

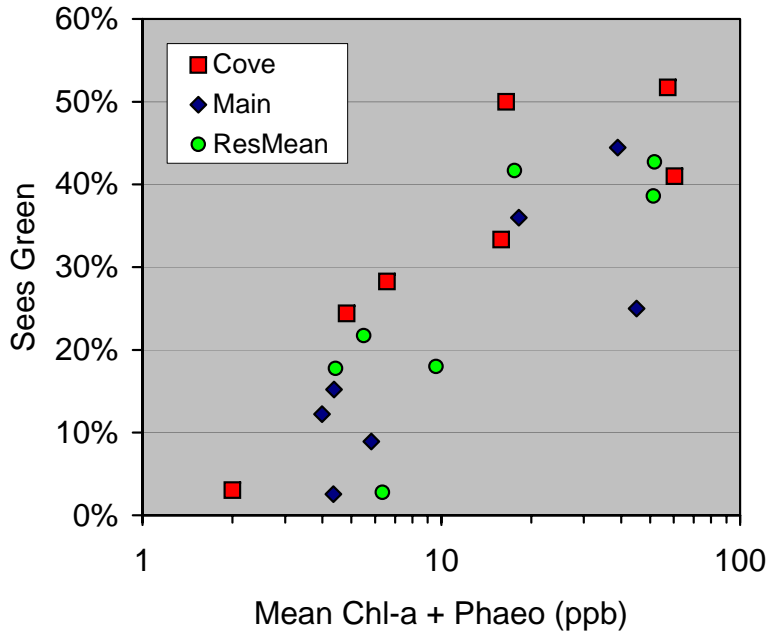


Question 2 - Use Impact



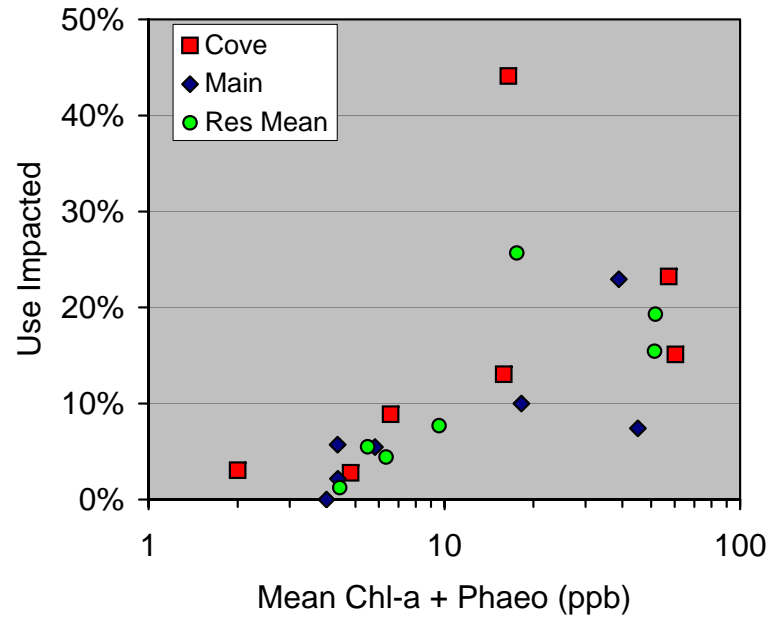
Survey Responses vs. Site-Mean Chl-a

Question 1 - Appearance



Sees Green = % Question 1 c, d, or e

Question 2 - Use Impact



Use Impacted = % Question 2 c, d, or e