Starting at the Bottom: What Bottom-dwelling Bugs Can Tell Us About Lake and River Condition

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Why Do We Need to Do Monitoring?

What is Biomonitoring?
& why do we do it?

“Since the effect of stream pollution is an alteration of the aquatic ecosystem, evaluation of that ecosystem is the logical way to detect pollution.”
–Hilsenhoff (1977)

“Biomonitoring is required … because the consequences of environmental stress can only be determined by an appraisal of the biota.”
–Wright (2000)

http://www.ontario.ca/laws/statute/90o40

What are Benthic Invertebrates?

Mayfly of the family Ephemerellidae

Caddisfly of the family Helicopsychidae

Why use Benthic Invertebrates as indicators of waterbody condition?

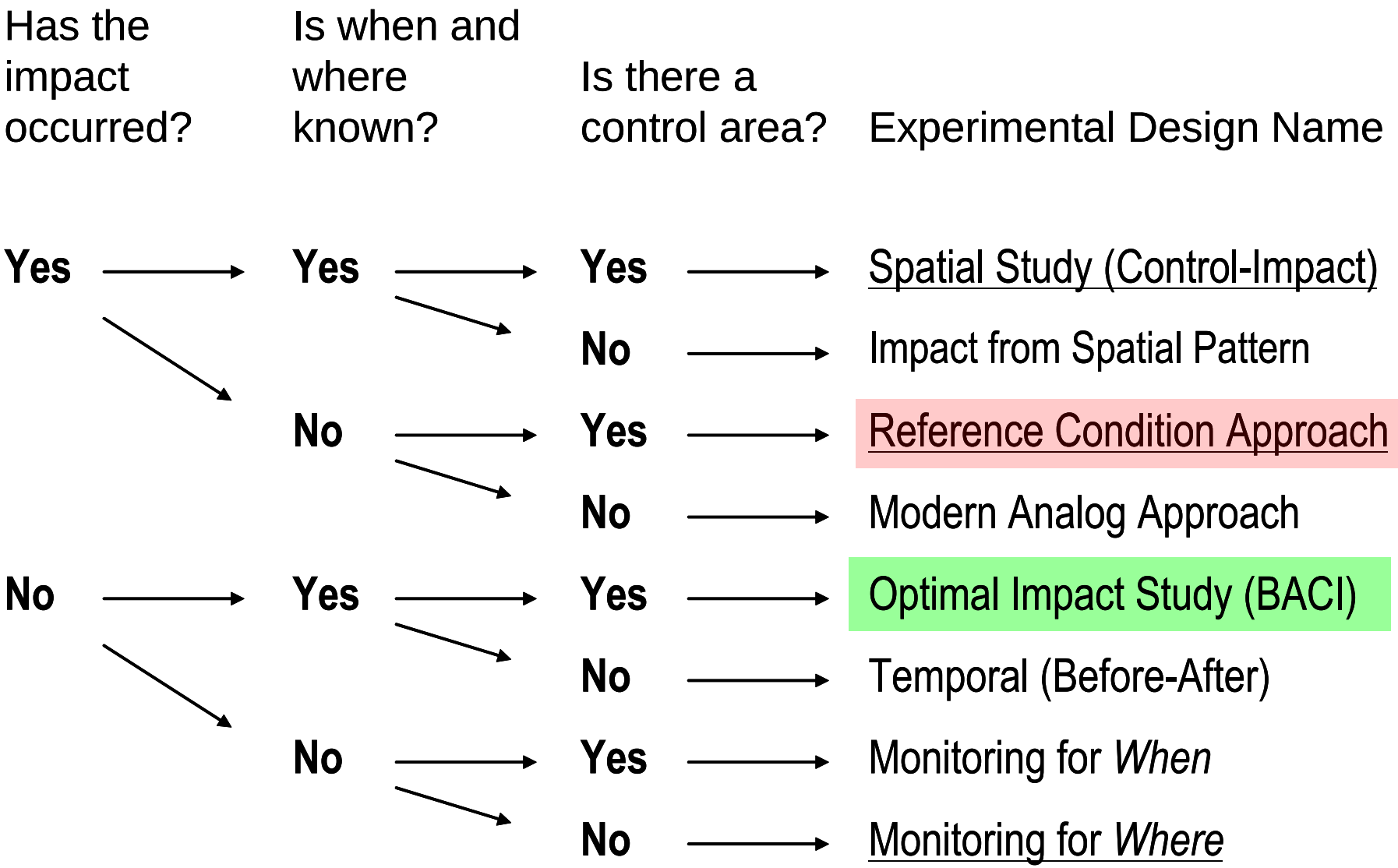
“Healthy is Variable”

– Dr. Robert Bailey, University of Western Ontario

Stream		
Sample		
Date		
Partner		
HYDRACARINA		
Trhypochthoniidae	2	1
EPHEMEROPTERA		
Baetidae	81	49
Ephemerellidae	1	2
PLECOPTERA		
Leuctridae	1	1
Capniidae	1	0
Perlodidae	6	5
Chloroperlidae	0	1
TRICHOPTERA		
Rhyacophilidae	2	1
Hydropsychidae	2	3
COLEOPTERA		
Elmidae	11	20
DIPTERA		
Chironomidae	20	29
Ceratopogonidae	3	2
Tipulidae	4	6
Simulidae	0	2
Empididae	1	0
Total:	135	122

Stream	Baxter	Baxter
Sample	Riffle 1	Riffle 2
Date	16-Aug-04	16-Aug-04
Partner	ORCA	ORCA
HYDRACARINA		
Trhypochthoniidae	2	1
EPHEMEROPTERA		
Baetidae	81	49
Ephemerellidae	1	2
PLECOPTERA		
Leuctridae	1	1
Capniidae	1	0
Perlodidae	6	5
Chloroperlidae	0	1
TRICHOPTERA		
Rhyacophilidae	2	1
Hydropsychidae	2	3
COLEOPTERA		
Elmidae	11	20
DIPTERA		
Chironomidae	20	29
Ceratopogonidae	3	2
Tipulidae	4	6
Simulidae	0	2
Empididae	1	0
Total:	135	122

Experimental Designs for Bioassessments

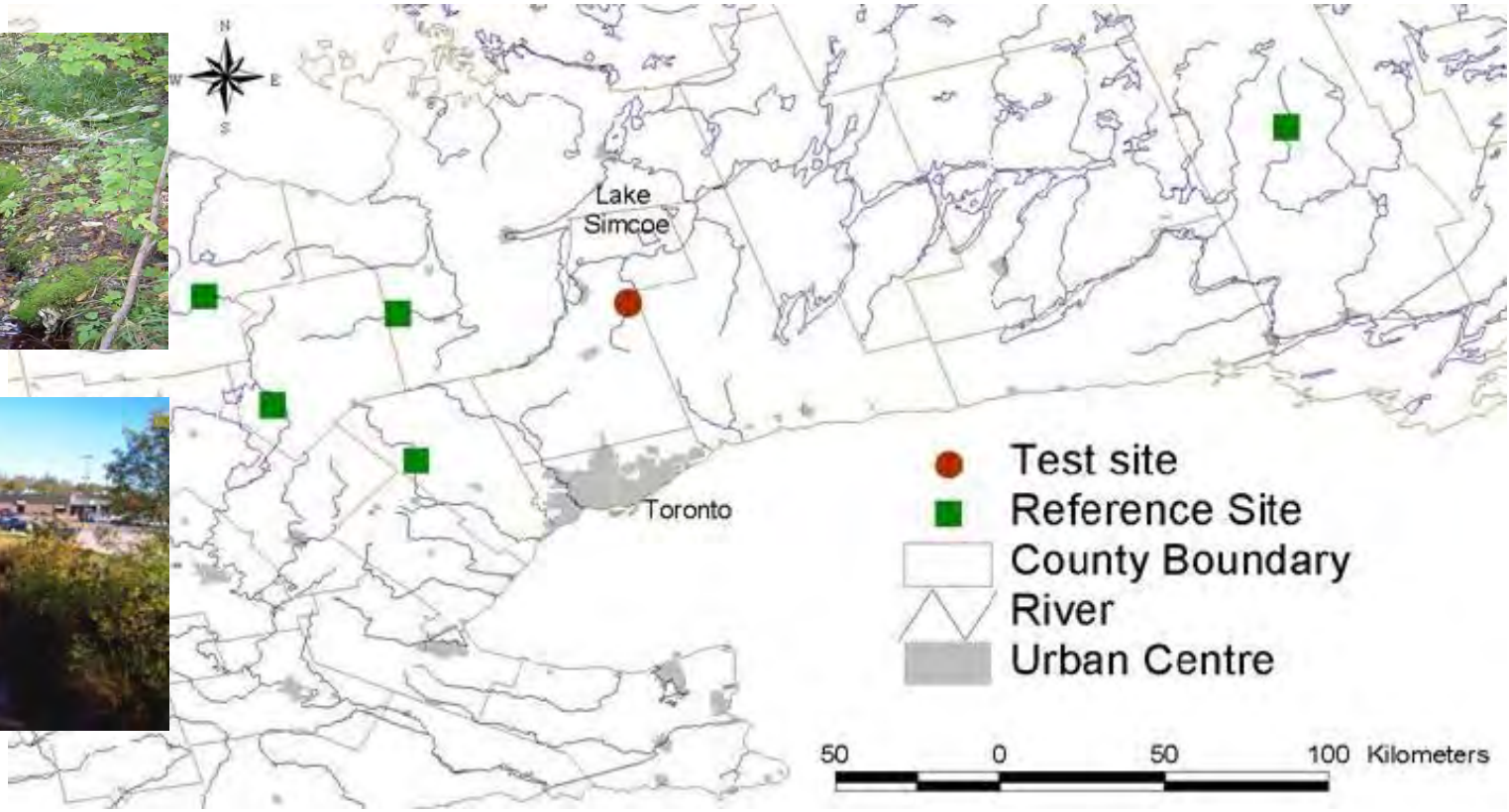


Reference Condition Approach

Multiple, minimally impacted control sites define the normal range of biological conditions to be expected at a test site

Reference site

Test site



"Long-term monitoring programs…provide the measures of normal (reference data) against which the abnormal is judged. It is impossible to convince a court that something is wrong if 'right' is not defined."

– Ministry of Environment Biomonitoring Review Committee (1994)

Why do we use indices in biomonitoring?

Site	Habitat	Sample	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20	T21	T22	T23	T24	T25	T26	T27	T28	T29	T30	T31	T32	T33	T34	T35	T36	T37	T38	T39	T40	T41	T42	T43	T44	T45	T46	T47	T48	T49	T50
2GA0212	Riffle	1	0	0	0	4	0	0	1	3	0	1	17	2	11	2	1	17	0	6	4	29	3	0	0	5	7	4	7	2	2	2	2	1	7	2	0	0	5	7	4	7	0	7	0	2	1	2	6	1	17	0	7
2GA0212	Pool	2	0	0	0	8	0	0	1	4	3	1	8	1	17	3	0	7	0	8	3	38	3	0	4	12	1	8	1	1	1	3	0	1	1	0	0	0	12	1	8	1	0	1	0	3	0	1	8	0	7	0	1
2GA0212	Riffle	3	0	0	0	3	0	0	1	3	0	2	12	1	12	2	4	7	0	0	4	42	3	0	2	1	1	3	1	1	1	2	4	1	1	0	0	1	1	3	1	0	1	0	2	4	1	0	4	7	0	1	
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2HD0643	Riffle	2	0	2	0	7	0	0	2	0	0	0	11	1	0	5	0	14	0	3	6	37	3	0	0	0	6	0	6	0	1	1	5	0	0	1	2	2	0	0	6	0	2	0	2	5	0	1	3	0	14	0	0
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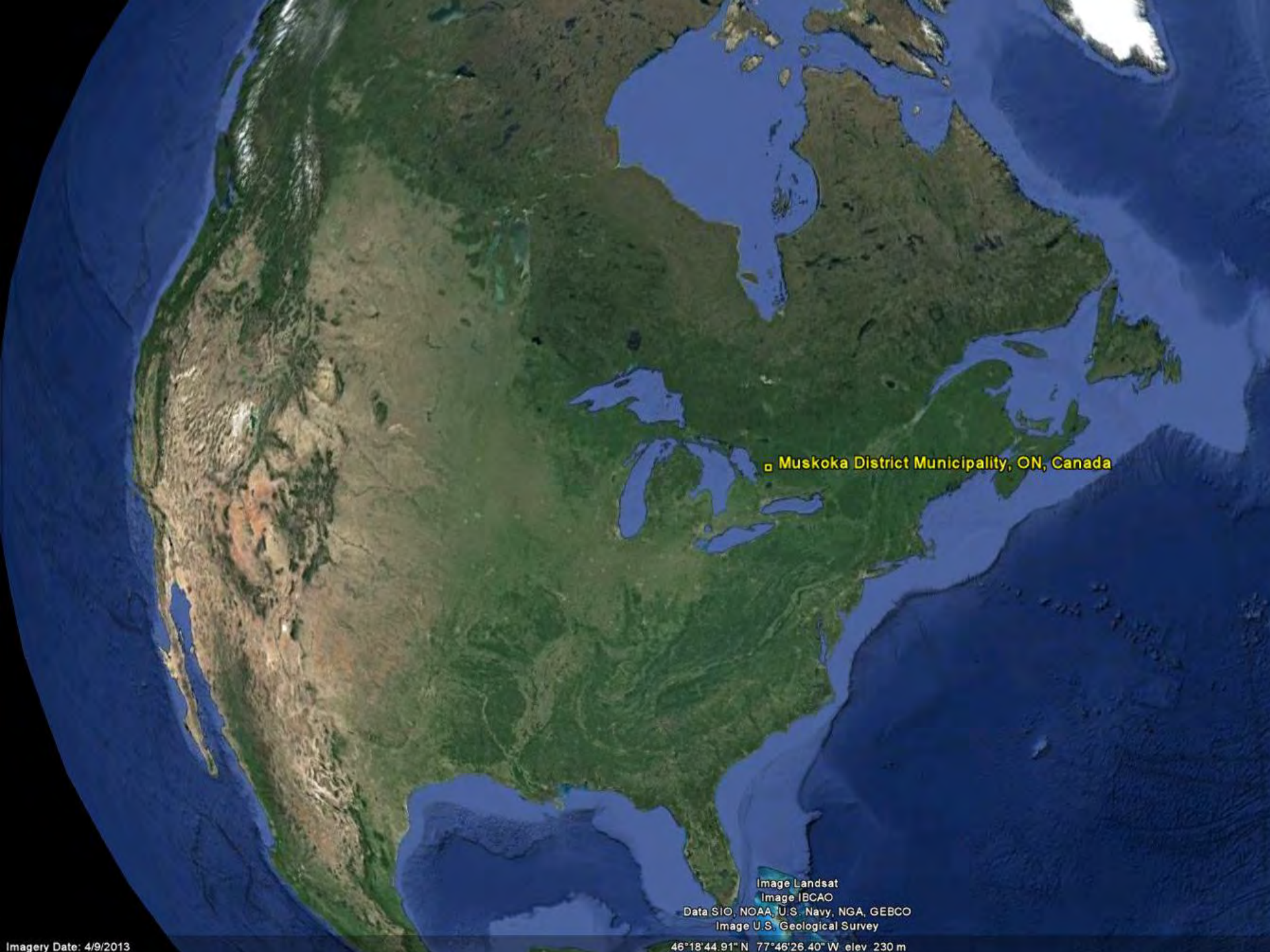
2GA1142	Riffle	3	0	1	0	6	0	0	1	1	0	0	6	1	0	0	1	28	0	7	0	36	0	0	3	4	10	0	10	1	1	0	1	10	1	1	1	4	10	0	10	1	10	1	0	1	1	7	1	28	0	10	
Test Site 2HA0747	Riffle	1	0	0	2	25	1	14	0	0	0	1	0	0	0	0	0	1	0	14	3	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	1	0	0	
Test Site 2HA0747	Pool	2	0	0	3	34	4	10	0	0	0	0	1	0	0	0	0	0	0	8	15	38	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	
Test Site 2HA0747	Riffle	3	0	0	6	22	3	13	0	0	0	0	0	0	0	0	0	2	0	16	5	42	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	2	0	0	

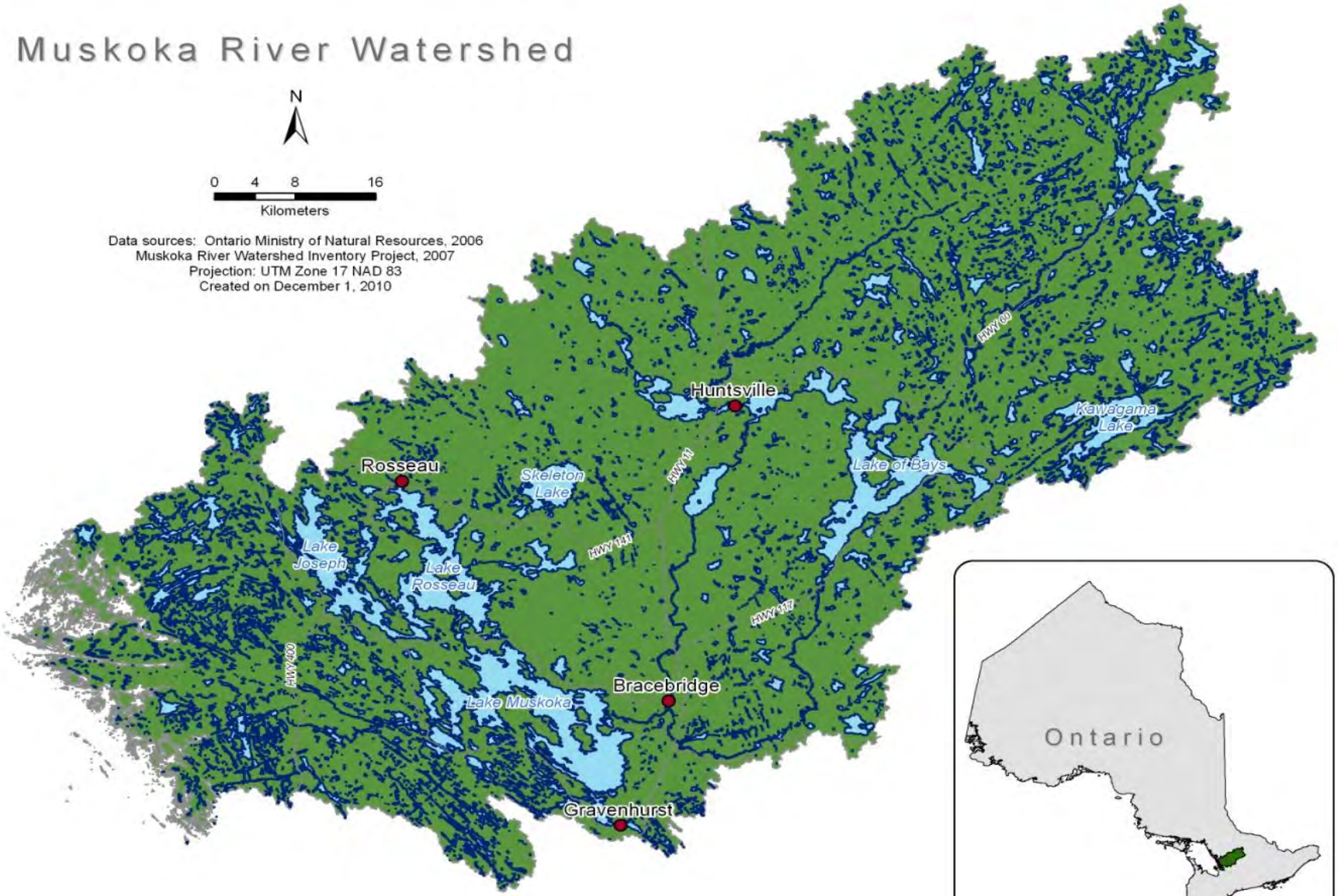
Canadian Water Network

THE DISTRICT MUNICIPALITY OF MUSKOKA

Managing Our Legacy Together


Muskoka District Municipality, ON, Canada
Image Landsat
Image IBCAO
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image U.S. Geological Survey
Imagery Date: 4/9/2013
46°18'44.91" N 77°46'26.40" W elev 230 m

Muskoka River Watershed

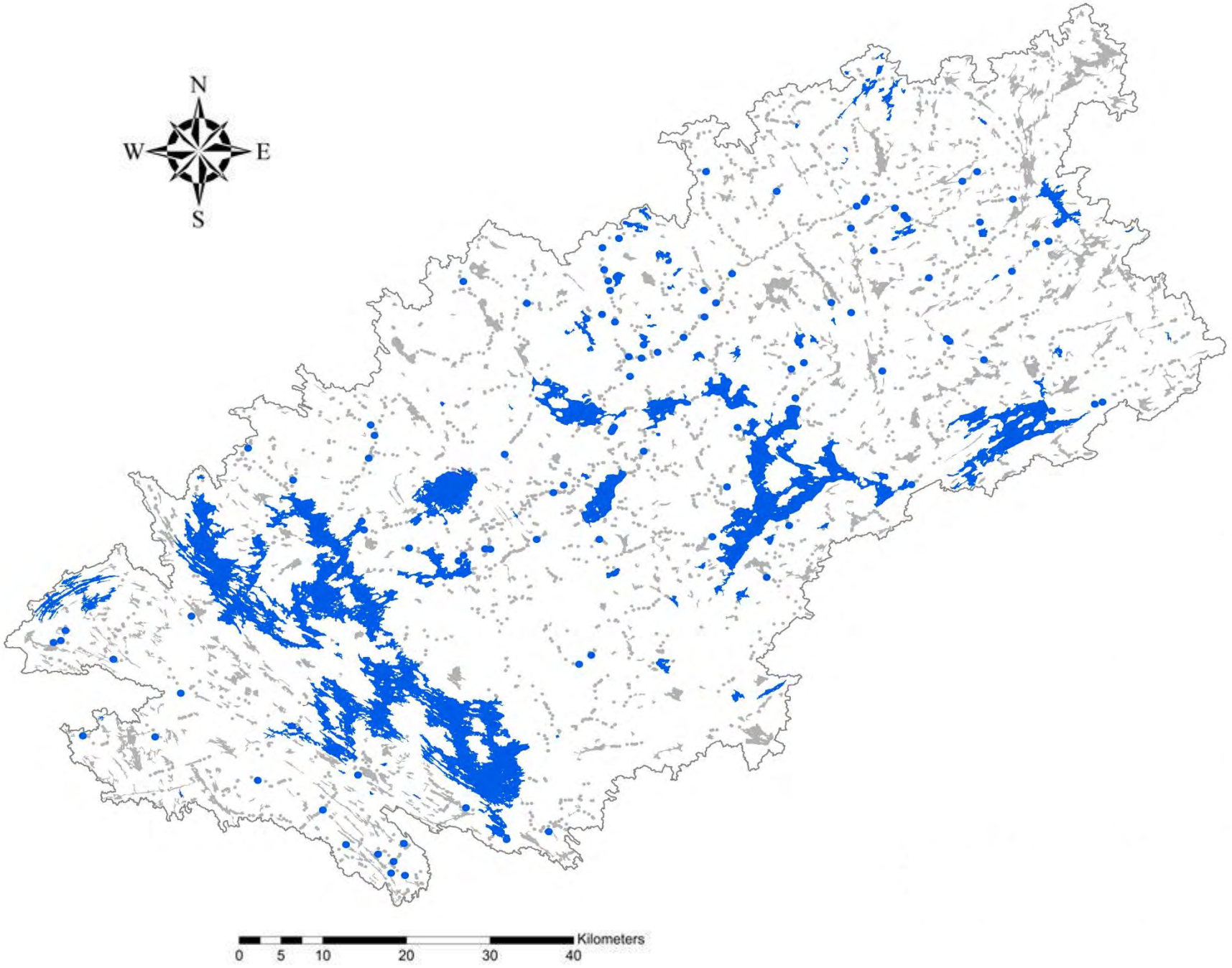


Questions

1. What is the biological condition of lakes and rivers in the Muskoka River Watershed? Indices ‘ normal ranges?

2. Which biological indices best distinguish minimally impacted (reference) from impacted lakes and streams?

3. What proportion of the biological variation is explained by land-use, and how large is this proportion relative to natural habitat related variation?


N
W
E
S
0
5
10
20
30
40
Kilometers


33 GRAM CO

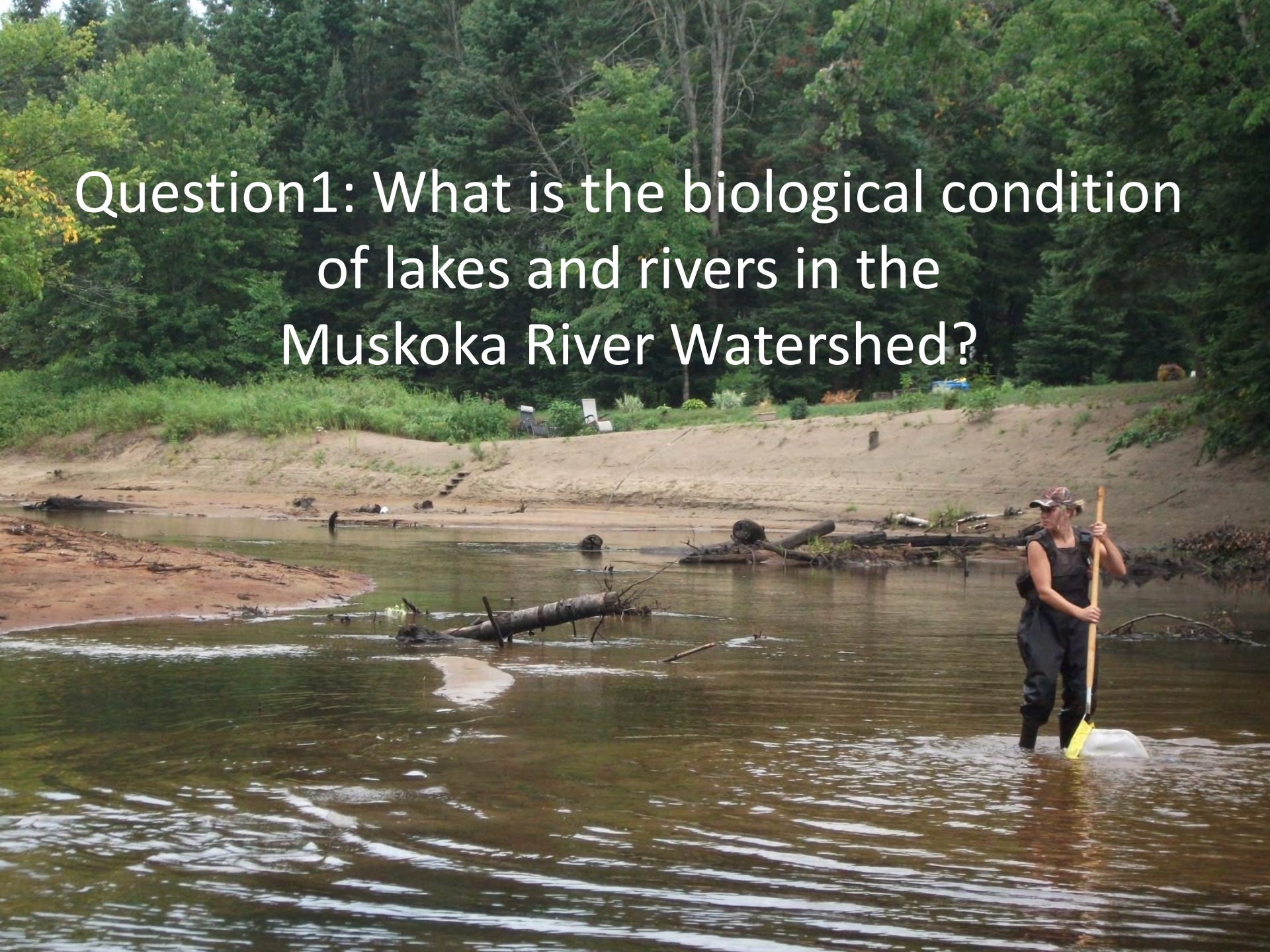

2012/08/2


C
CREW C: Chris, Deanna, Bogdan
Site Substitution Rules
If a lake is unsampleable, substitute with:
A lake of a similar size (based on map)
A lake that is in the same impact class
— Replace reference with reference and impacted with impacted
A lake as close as possible to the original
A lake not being sampled by another crew
If a stream is unsampleable, substitute with:
A randomly selected stream
— Replace reference with reference and impacted with impacted
Tributaries (T_ sites) must be sampled downstream of the confluence
Stream Sampling
Lakes
Crew C Reference
Crew C Impacted
Crew A Lake
Roads
Freeway
Ramp
Expressway / Highway
Orders by Strahler Order
Chain Subwatersheds
0 5 10 20 30
Kilometers
Lorna Murison, B.A., UTM NAD 83 Zone 17N
July 4th, 2012
2012/08/29

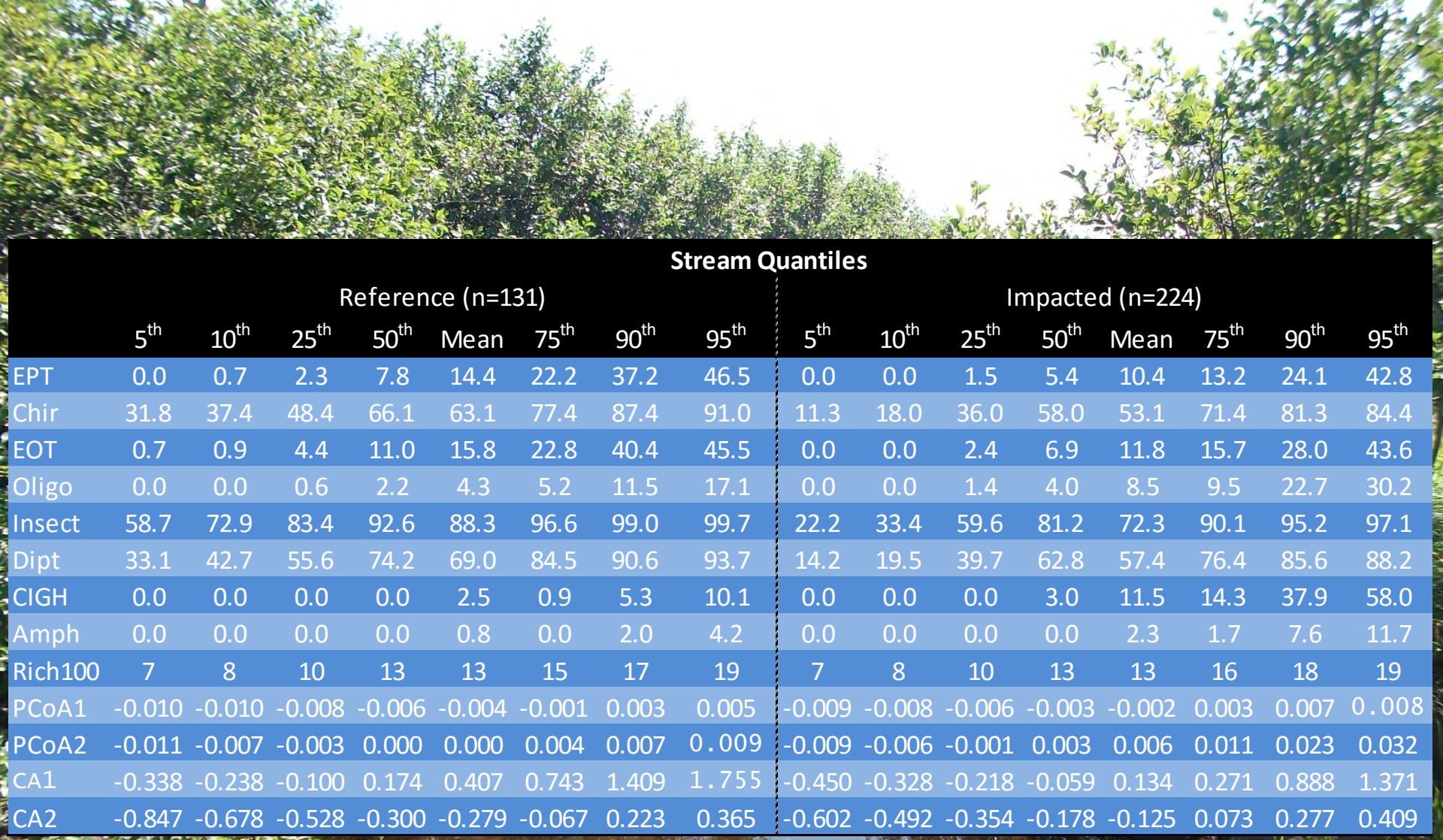

2012/08/22


MIRRO Craft

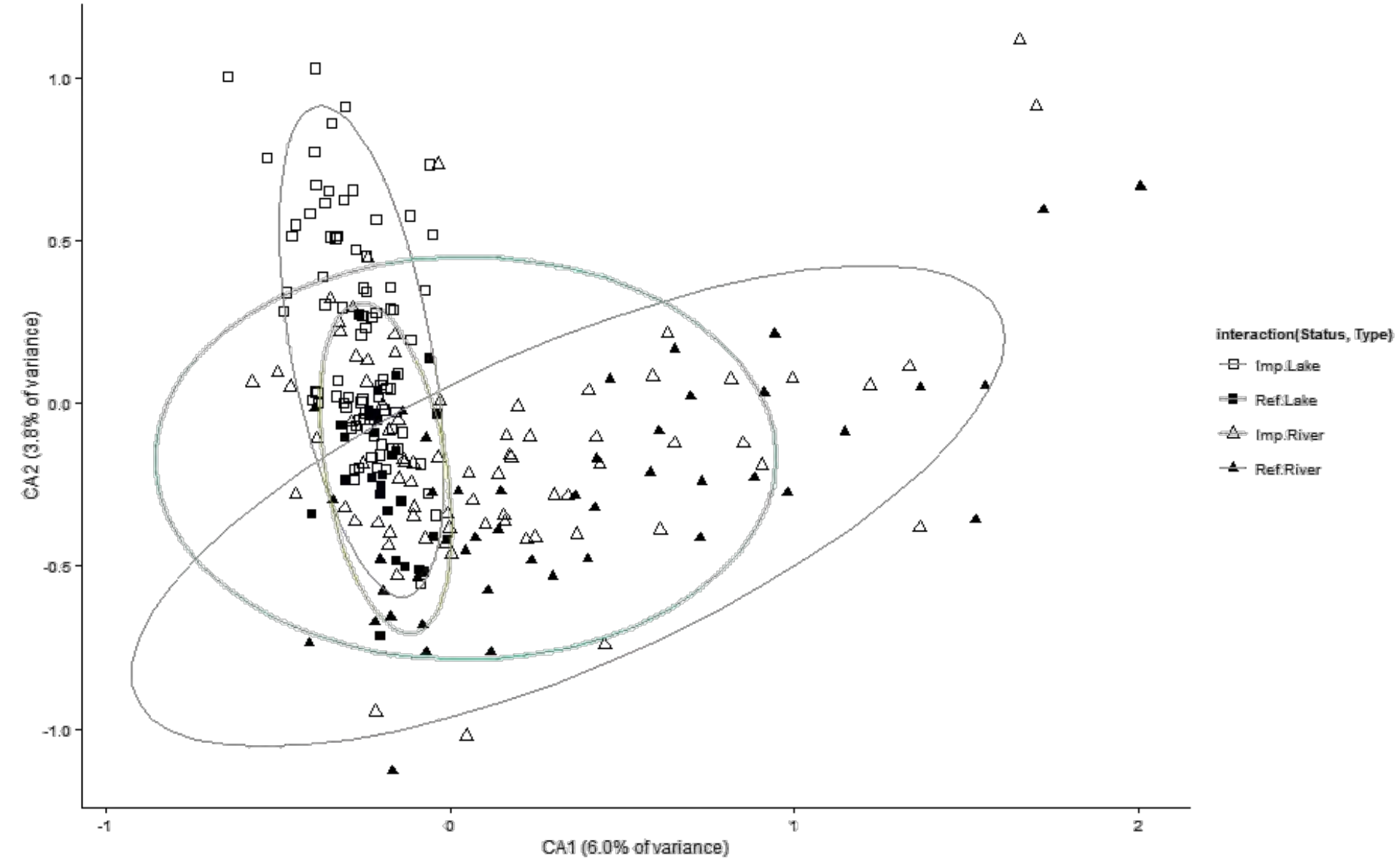
Index	Definition
EPT	% Ephemeroptera, Plecoptera & Trichoptera
EOT	% Ephemeroptera, Odonata & Trichoptera
Insect	% Insecta
Dipt	% Diptera
Chir	% Chironomidae
Oligo	% Oligochaetous Clitellata
CIGH	% Corixidae. Isopoda, Gastropoda & Hirudinea
Amph	% Amphipoda
Rich100	Taxonomic richness
PCoA1	PCoA axis 1
PCoA2	PcoA axis 2
CA1	CA axis 1
CA2	CA axis 2

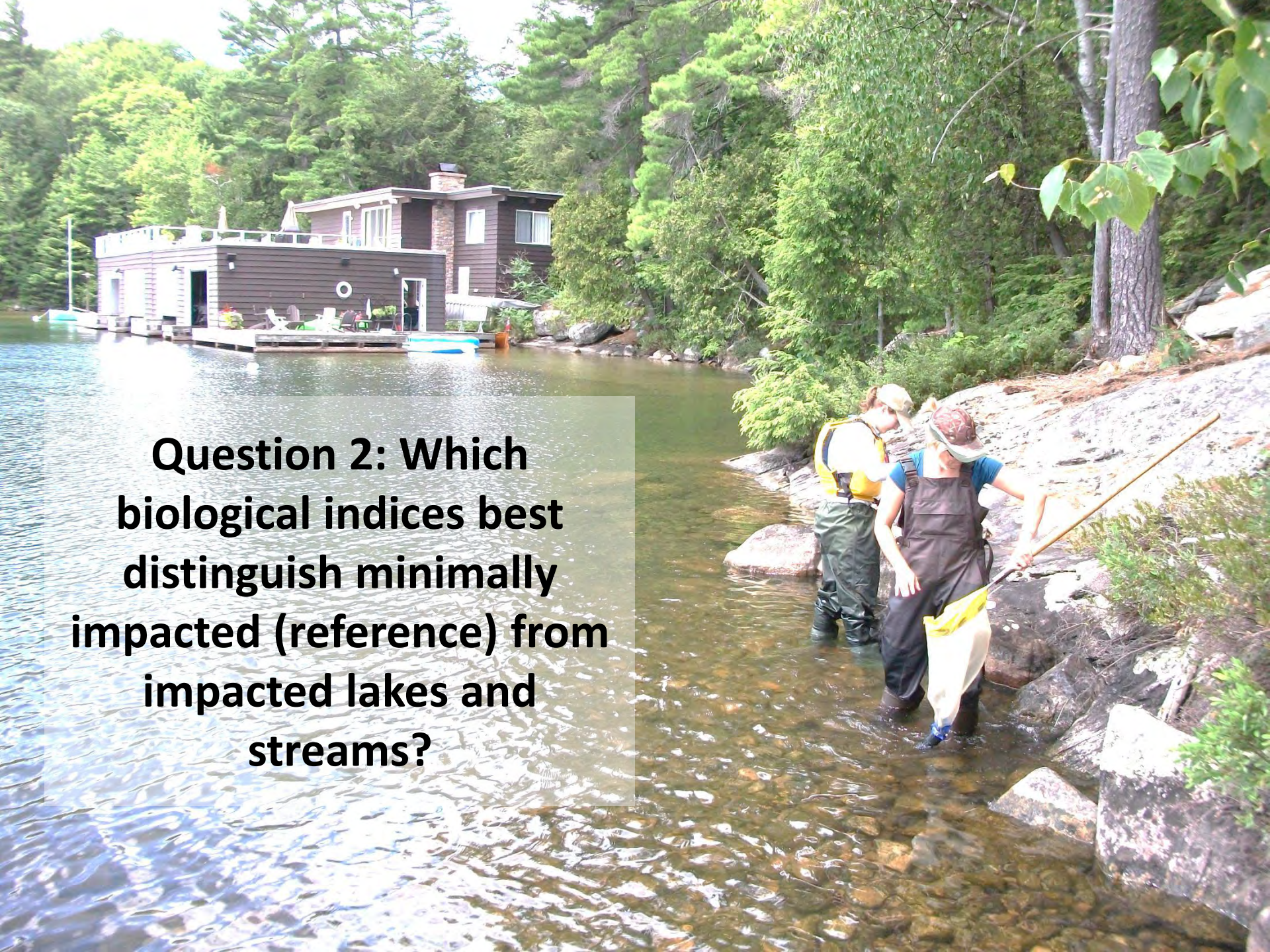

Question1: What is the biological condition of lakes and rivers in the Muskoka River Watershed?

Lake Quantiles																
	Reference (n=87)								Impacted (n=247)							
	5th	10th	25th	50th	Mean	75th	90th	95th	5th	10th	25th	50th	Mean	75th	90th	95th
EPT	0.0	0.8	1.9	4.8	6.4	9.8	13.8	17.4	0.3	1.4	3.1	7.2	10.5	14.2	24.4	32.3
Chir	33.2	36.7	46.8	67.2	63.0	77.4	87.9	91.1	7.5	11.2	20.5	33.0	37.2	51.8	67.6	73.3
EOT	0.8	1.2	3.4	6.6	8.4	11.8	19.1	23.3	1.0	1.9	4.4	8.8	11.9	16.1	26.1	33.9
Oligo	0.0	0.0	1.0	2.6	4.3	5.9	10.3	13.0	0.9	1.8	5.0	10.8	14.0	18.9	27.2	41.4
Insect	47.5	57.4	66.5	82.7	77.8	89.8	95.5	98.2	19.8	28.4	40.9	54.8	54.7	70.3	81.8	86.3
Dipt	37.0	40.5	49.8	70.1	66.0	81.3	89.6	92.0	8.1	12.4	21.7	37.2	39.6	55.8	70.5	74.9
CIGH	0.0	0.0	0.0	0.8	2.8	2.8	9.3	12.8	0.0	0.8	1.8	5.0	8.6	11.2	23.2	30.4
Amph	0.0	0.0	0.8	4.6	10.3	14.3	26.6	40.7	0.0	0.9	4.7	12.1	15.0	22.5	31.6	38.5
Rich100	7	8	10	12	12	15	16	17	10	11	13	15	15	18	20	21
PCoA1	-0.009	-0.008	-0.007	-0.004	-0.003	0.001	0.004	0.005	-0.005	-0.003	0.001	0.006	0.005	0.009	0.011	0.012
PCoA2	-0.014	-0.013	-0.009	-0.006	-0.005	-0.002	0.002	0.004	-0.015	-0.013	-0.010	-0.006	-0.004	0.000	0.009	0.017
CA1	-0.352	-0.317	-0.252	-0.191	-0.184	-0.123	-0.040	-0.008	-0.495	-0.443	-0.342	-0.259	-0.263	-0.172	-0.099	-0.049
CA2	-0.561	-0.520	-0.389	-0.206	-0.206	-0.049	0.105	0.225	-0.283	-0.180	-0.085	0.138	0.199	0.472	0.700	0.902



Stream Quantiles																
	Reference (n=131)								Impacted (n=224)							
	5th	10th	25th	50th	Mean	75th	90th	95th	5th	10th	25th	50th	Mean	75th	90th	95th
EPT	0.0	0.7	2.3	7.8	14.4	22.2	37.2	46.5	0.0	0.0	1.5	5.4	10.4	13.2	24.1	42.8
Chir	31.8	37.4	48.4	66.1	63.1	77.4	87.4	91.0	11.3	18.0	36.0	58.0	53.1	71.4	81.3	84.4
EOT	0.7	0.9	4.4	11.0	15.8	22.8	40.4	45.5	0.0	0.0	2.4	6.9	11.8	15.7	28.0	43.6
Oligo	0.0	0.0	0.6	2.2	4.3	5.2	11.5	17.1	0.0	0.0	1.4	4.0	8.5	9.5	22.7	30.2
Insect	58.7	72.9	83.4	92.6	88.3	96.6	99.0	99.7	22.2	33.4	59.6	81.2	72.3	90.1	95.2	97.1
Dipt	33.1	42.7	55.6	74.2	69.0	84.5	90.6	93.7	14.2	19.5	39.7	62.8	57.4	76.4	85.6	88.2
CIGH	0.0	0.0	0.0	0.0	2.5	0.9	5.3	10.1	0.0	0.0	0.0	3.0	11.5	14.3	37.9	58.0
Amph	0.0	0.0	0.0	0.0	0.8	0.0	2.0	4.2	0.0	0.0	0.0	0.0	2.3	1.7	7.6	11.7
Rich100	7	8	10	13	13	15	17	19	7	8	10	13	13	16	18	19
PCoA1	-0.010	-0.010	-0.008	-0.006	-0.004	-0.001	0.003	0.005	-0.009	-0.008	-0.006	-0.003	-0.002	0.003	0.007	0.008
PCoA2	-0.011	-0.007	-0.003	0.000	0.000	0.004	0.007	0.009	-0.009	-0.006	-0.001	0.003	0.006	0.011	0.023	0.032
CA1	-0.338	-0.238	-0.100	0.174	0.407	0.743	1.409	1.755	-0.450	-0.328	-0.218	-0.059	0.134	0.271	0.888	1.371
CA2	-0.847	-0.678	-0.528	-0.300	-0.279	-0.067	0.223	0.365	-0.602	-0.492	-0.354	-0.178	-0.125	0.073	0.277	0.409


1.0
0.5
0.0
-0.5
-1.0
CA2 (3.8% of variance)
-1
0
1
2
CA1 (6.0% of variance)
interaction(Status, Type)
Imp.Lake
Ref.Lake
Imp.River
Ref.River



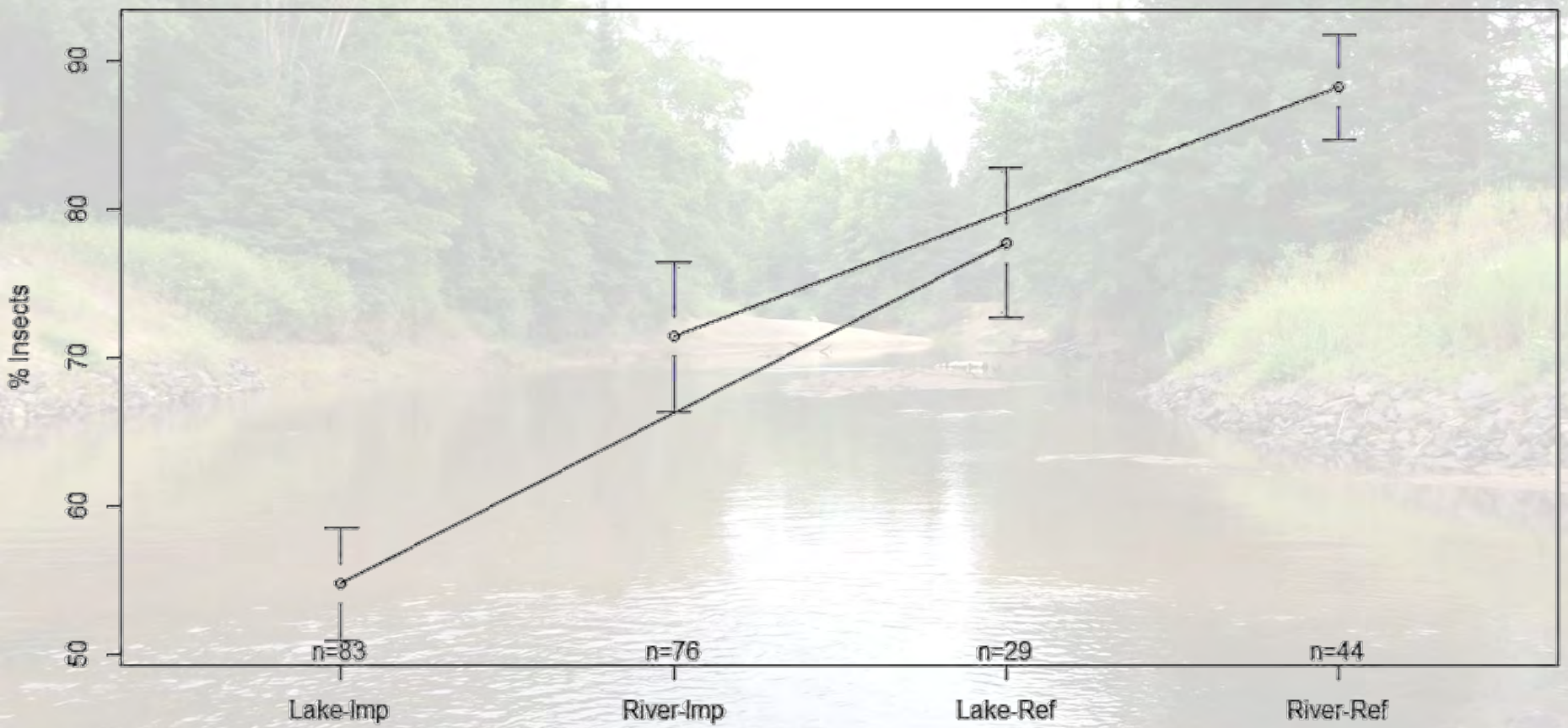
Question 2: Which biological indices best distinguish minimally impacted (reference) from impacted lakes and streams?

Index Performance

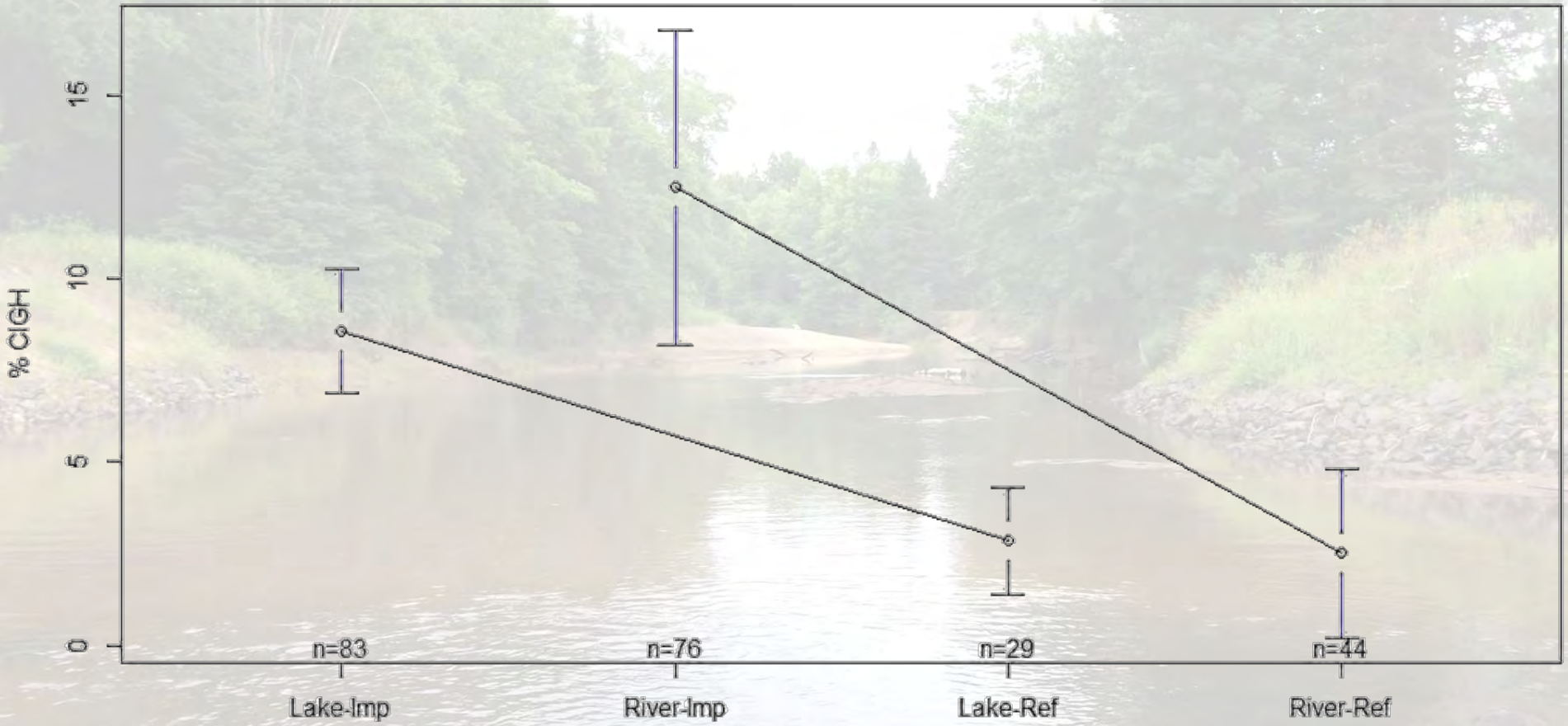
	P-value		P-value
EPT		**Amph**	
Type	6.870E-02	Type	**2.000E-16**
Status	7.584E-01	Status	**7.510E-03**
Type*Status	**8.000E-03**	Type*Status	1.473E-01
Chir		**Rich100**	
Type	**2.070E-07**	Type	**2.610E-04**
Status	**9.530E-10**	Status	**1.880E-04**
Type*Status	**3.690E-03**	Type*Status	**1.223E-03**
EOT		**PCoA1**	
Type	8.270E-02	Type	**2.000E-16**
Status	6.341E-01	Status	**3.180E-12**
Type*Status	**1.400E-02**	Type*Status	**1.200E-04**
Oligo		**PCoA2**	
Type	**1.250E-04**	Type	**3.140E-12**
Status	**2.450E-07**	Status	**1.650E-03**
Type*Status	**2.914E-02**	Type*Status	1.061E-01
Insect		**CA1**	
Type	**4.420E-13**	Type	**2.000E-16**
Status	**1.050E-12**	Status	**8.640E-04**
Type*Status	1.340E-01	Type*Status	8.336E-02
Dipt		**CA2**	
Type	**3.250E-09**	Type	**8.600E-10**
Status	**2.370E-10**	Status	**5.330E-08**
Type*Status	**8.700E-03**	Type*Status	**1.130E-02**
CIGH			
Type	5.950E-01		
Status	**8.480E-06**		
Type*Status	3.980E-01		

Degrees of Freedom: Type, Status, & Type*Status=1
Residuals=225

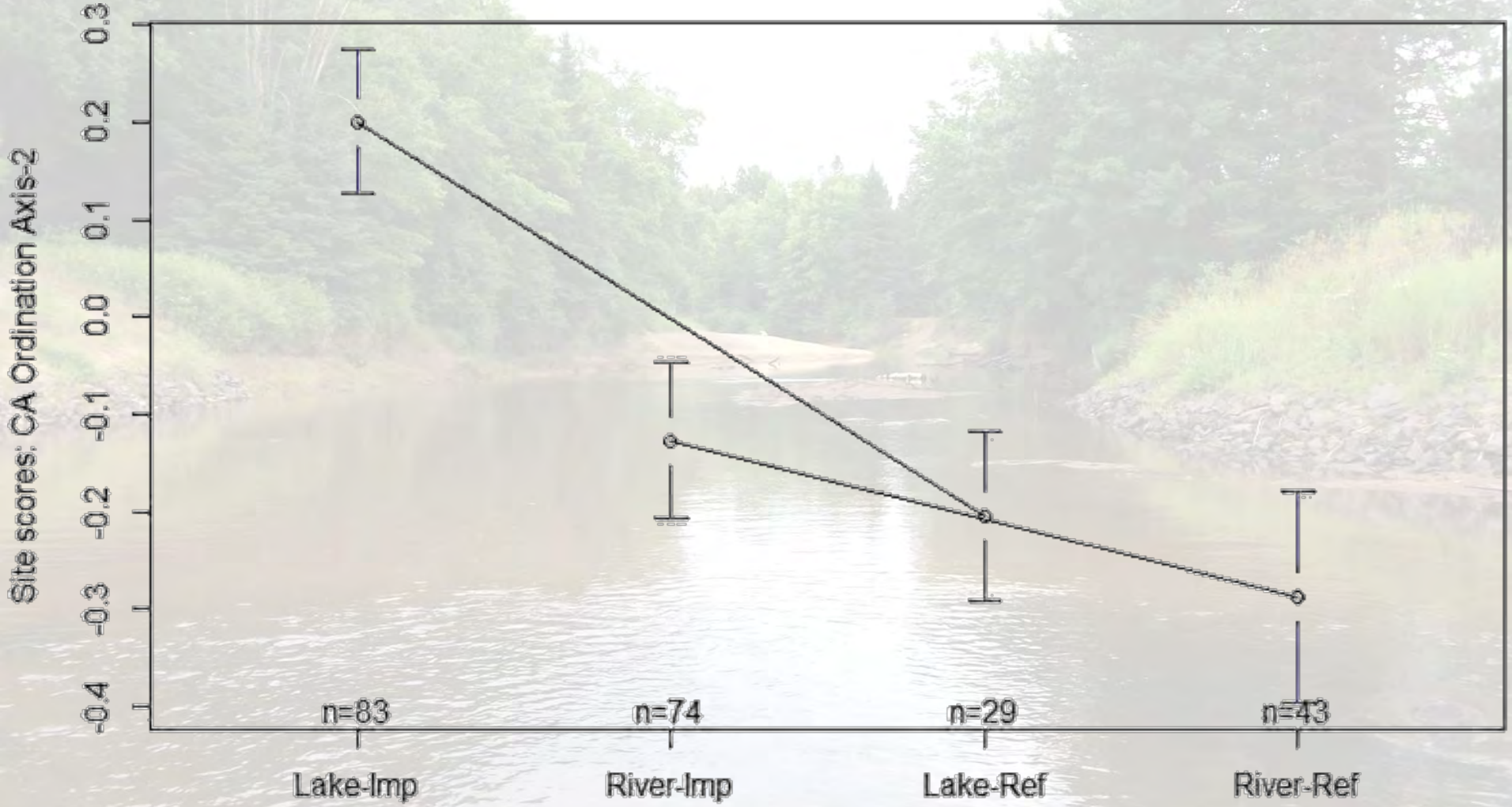
% Insects


% Insects
90
80
70
60
50
n=83
n=76
n=29
n=44
Lake-Imp
River-Imp
Lake-Ref
River-Ref

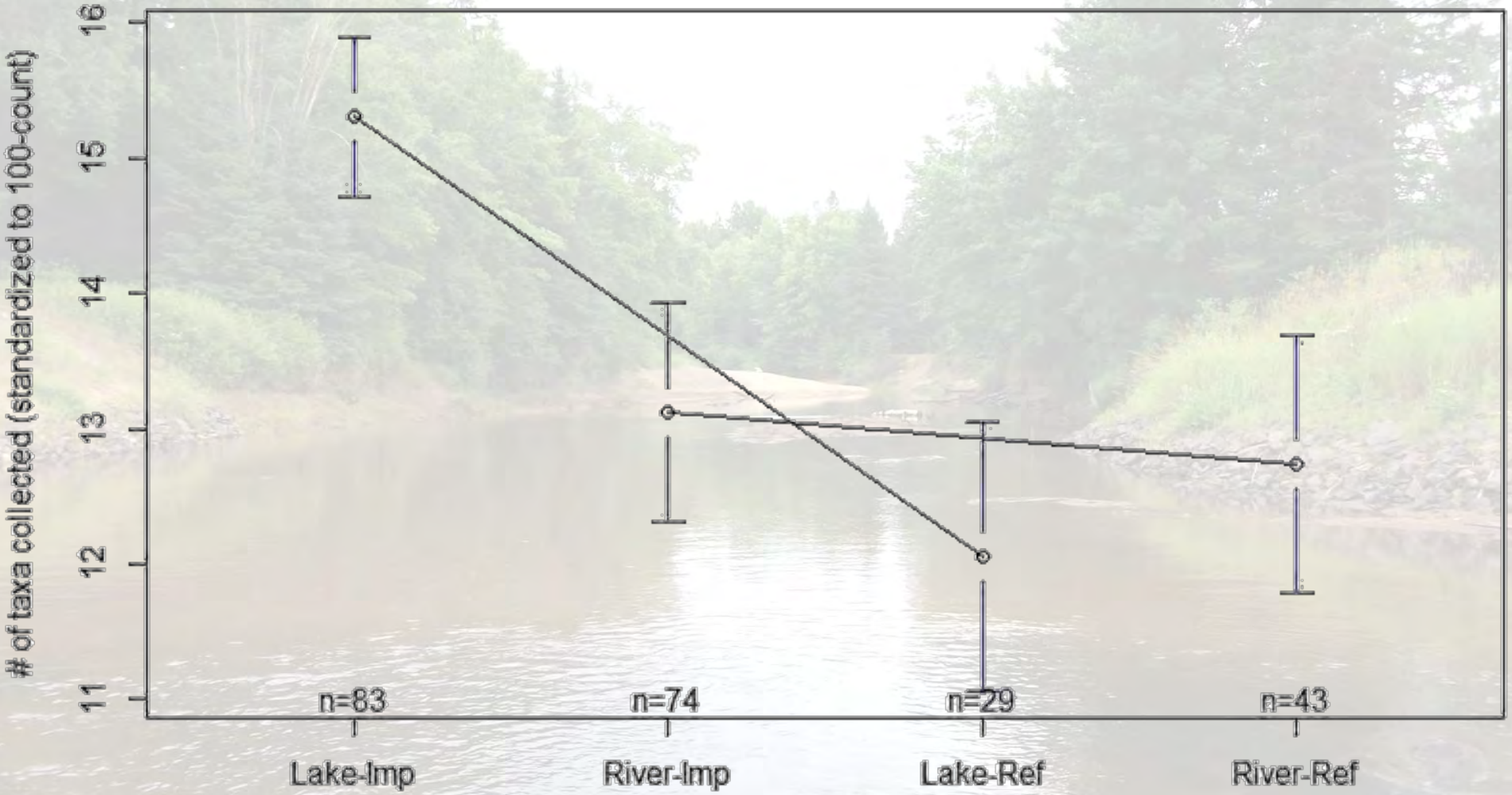
% CIGH


% CIGH
0
5
10
15
n=83
n=76
n=29
n=44
Lake-Imp
River-Imp
Lake-Ref
River-Ref

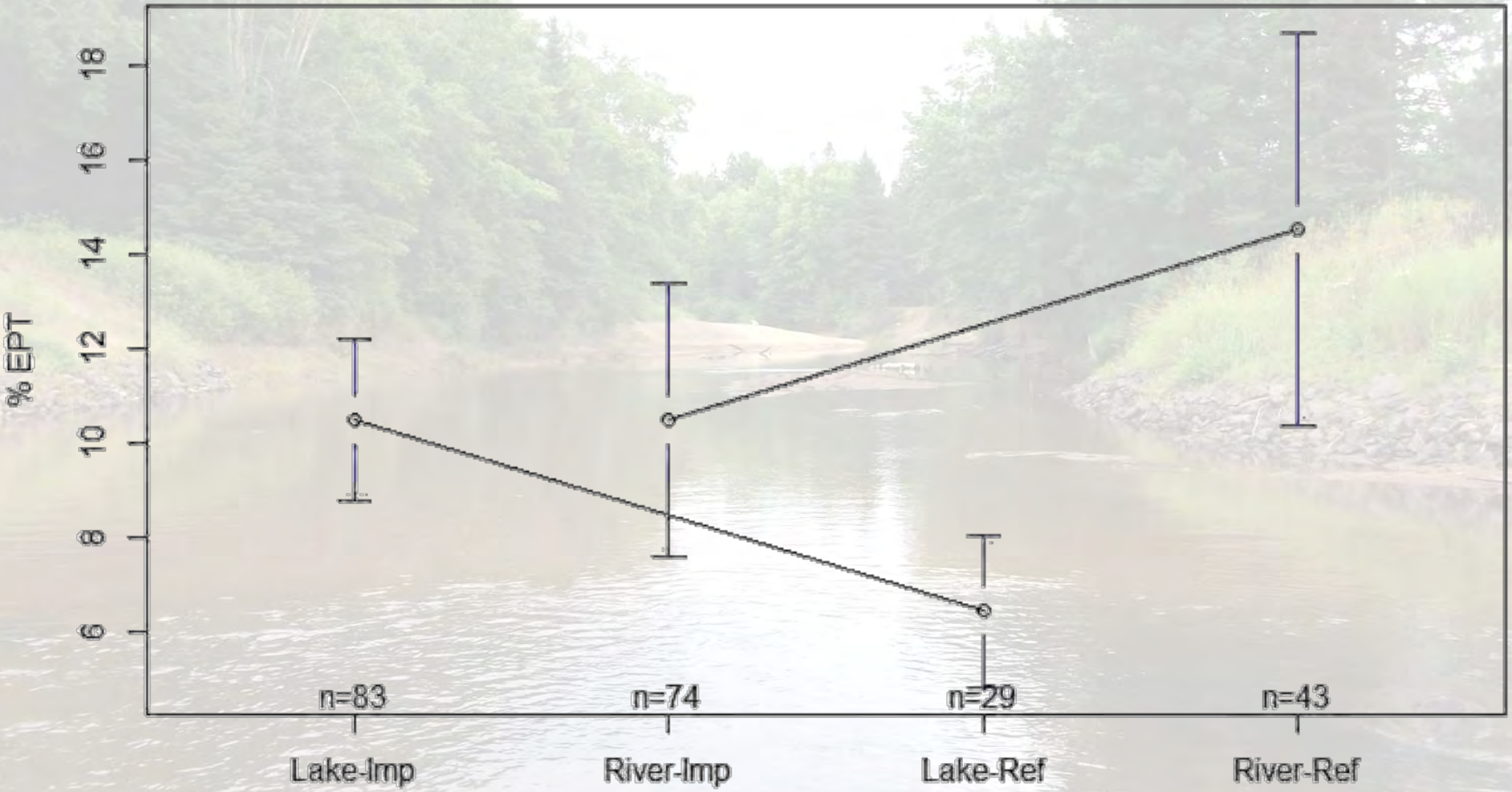
CA2

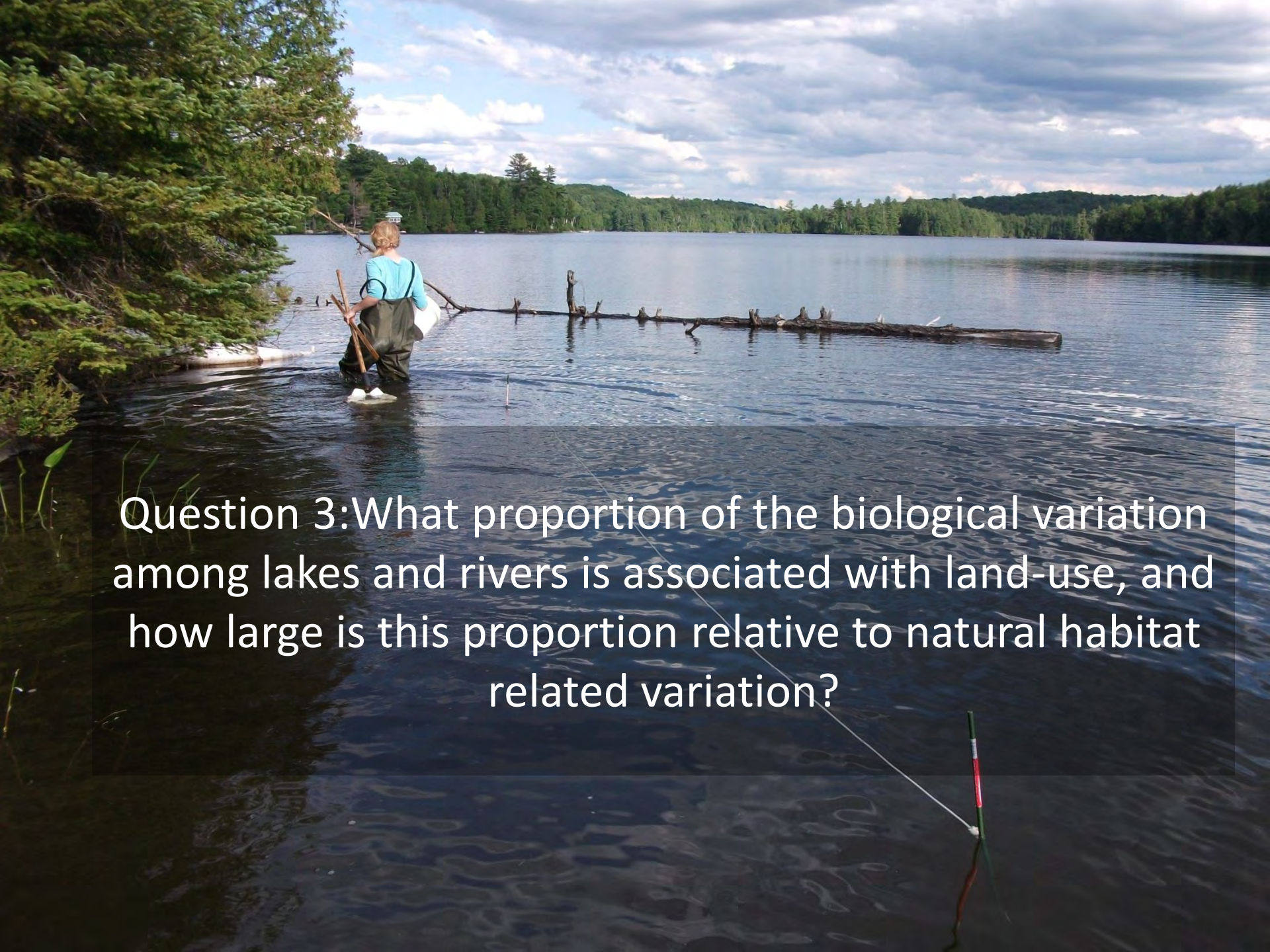

Site scores: CA Ordination Axis-2
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
n=83
n=74
n=29
n=43
Lake-Imp
River-Imp
Lake-Ref
River-Ref

Taxa Richness



% EPT

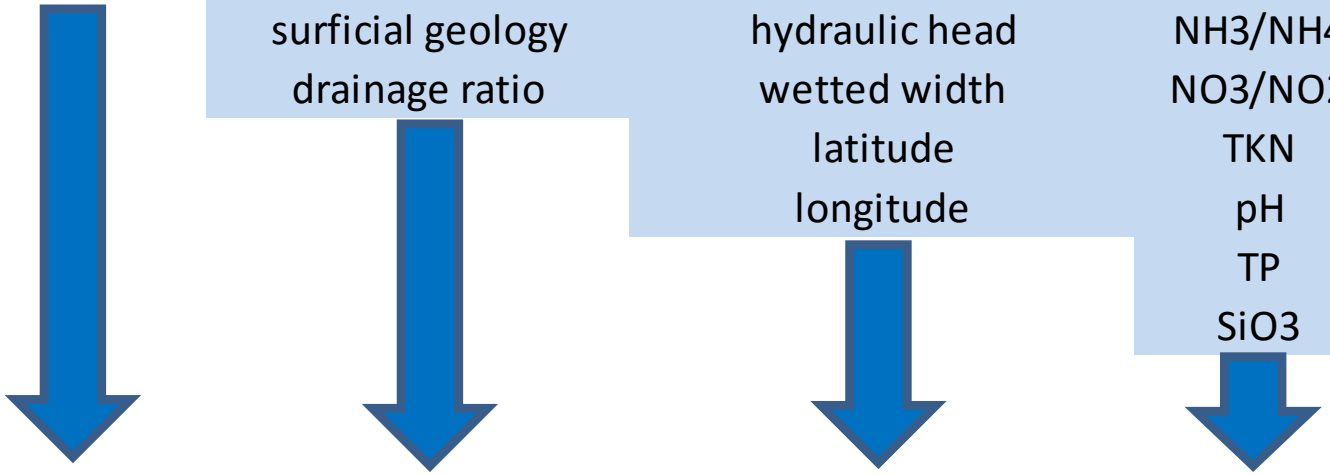

% EPT
6
8
10
12
14
16
18
n=83
n=74
n=29
n=43
Lake-Imp
River-Imp
Lake-Ref
River-Ref



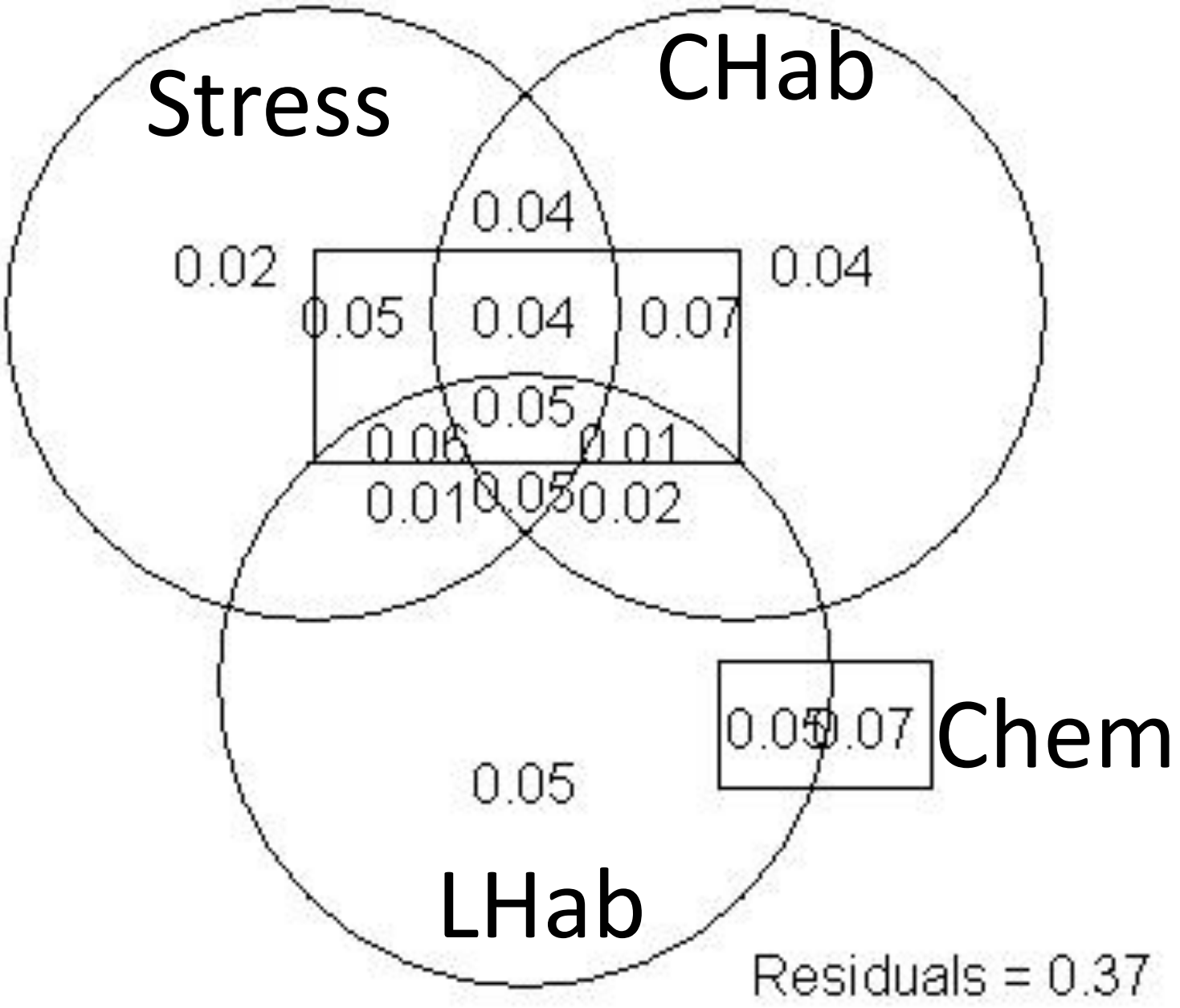
Question 3:What proportion of the biological variation among lakes and rivers is associated with land-use, and how large is this proportion relative to natural habitat related variation?

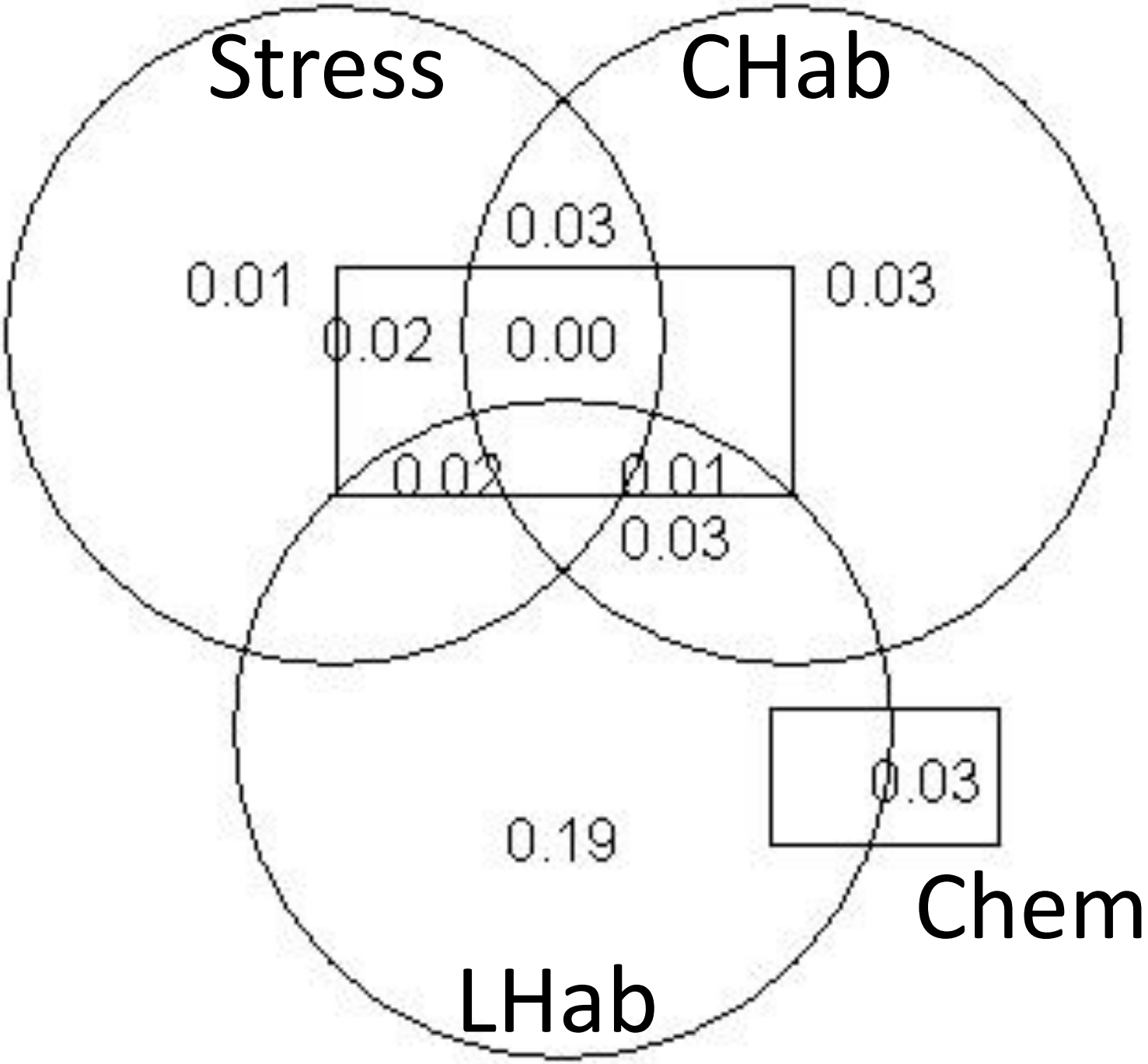
X			Y
RDA	**Lake**	**Stream**	**Lake+Stream**	CA1
Factors	Stress		Type/Status	CA2
	Cachment Habitat		Stress	
	Local Habitat		Habitat	
	Chemistry		Chemistry	

Stress	Catchment Habitat	Local Habitat	Chemistry
% agriculture	overburden thickness	elevation	alkalinity
% golf course	mean slope	substrate	Ca
% urban	drainage density	algae	Cl
road density	wetness index	macrophytes	Color
# waste sites	water retention time	organic matter	conductivity
# dams	catchment area	max depth at sample loc'n	DOC
	surficial geology	hydraulic head	NH3/NH4
	drainage ratio	wetted width	NO3/NO2
		latitude	TKN
		longitude	pH
			TP
			SiO3



X					Y
	PCA1 Stress	PCA1CHab	PCA1LHab	PCA1Chem	CA1
	PCA2Stress	PCA2 Chab	PCA2LHab	PCA2Chem	CA2


Stress
CHab
0.04
0.02
0.04
0.05
0.04
0.07
0.05
0.06
0.01
0.01
0.05
0.02
0.05
0.07
Chem
0.05
LHab
Residuals = 0.37


Stress
CHab
0.03
0.01
0.03
0.02
0.00
0.02
0.01
0.03
0.03
0.19
Chem
LHab