Elevated Dissolved Solids, Biota, and Whole Effluent Toxicity

WaterTec 2015

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Barr Engineering Company

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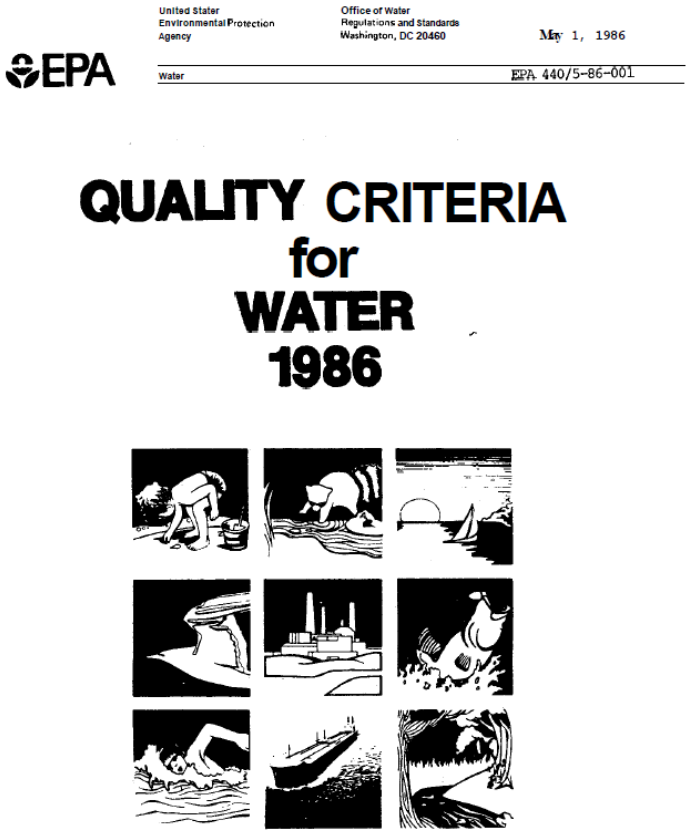
Brief History of Dissolved Solids Toxicity
My View

- The "Gold Book"-1986
- Solids (Dissolved) and Salinity
  - 250 mg/L for chlorides and sulfates in domestic water supplies
- Minnesota and Many States
  - Chronic chloride standard
    - MN 230 mg/L
  - Dissolved salts (solids) standard
    - 700 mg/L for irrigation water


EPA

United States Environmental Protection Agency | Office of Water Regulations and Standards Washington, DC 20460 | May 1, 1986

Water | EPA 440/5-86-001

QUALITY CRITERIA for WATER 1986

Brief History of Dissolved Solids Toxicity
Key Research

- Salinity-Toxicity Relationship (FW STR)
  - Gas Research Institute
  - 1993-1996. Mount, Gulley, Hockett, Tietge, Evans.
  - Multivariet logistic regression approach
  - C. dubia, LC50

http://en.wikipedia.org/wiki/Logistic_regression

- Mount et. al (1997). Env. Tox. and Chem.
  - Logistic function for C. dubia, D. magna, fathead minnows
  - $\text{Logit}(P) = B_o + B_1X_1 + B_2X_2 \ldots B_iX_i$

  - **% Survival** = 100*(1/(1+exp(-(-64.81 + 2.46*Unionized Ammonia +0.0068*Alkalinity - 0.0171*Chloride - 0.0262*Potassium -4.99*Aluminum -2.93*K/NA - 0.0053*SO_4))))

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Brief History of Dissolved Solids Toxicity
Key Research

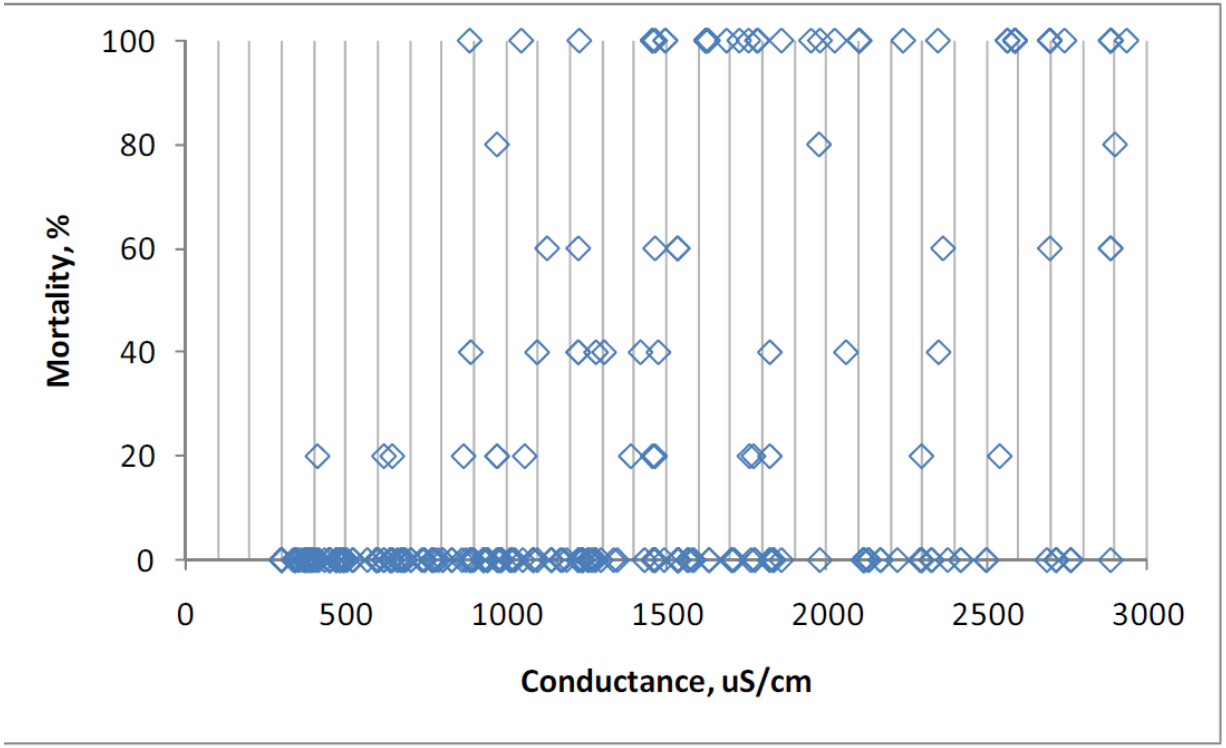

Figure A5 Conductance v. *D. magna* 48-hour Percent Mortality

Ion Pairs of: Cl, K, Na, Mg, Ca, SO4, HCO3

NCASI Technical Bulletin 965 (2009)

The Potential Influence of Effluent-Related Dissolved Solids On Chronic Whole Effluent Toxicity Test Results With *Ceriodaphnia Dubia* and *Selenastrum Capricornutum*

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Brief History of Dissolved Solids Toxicity
Key Research

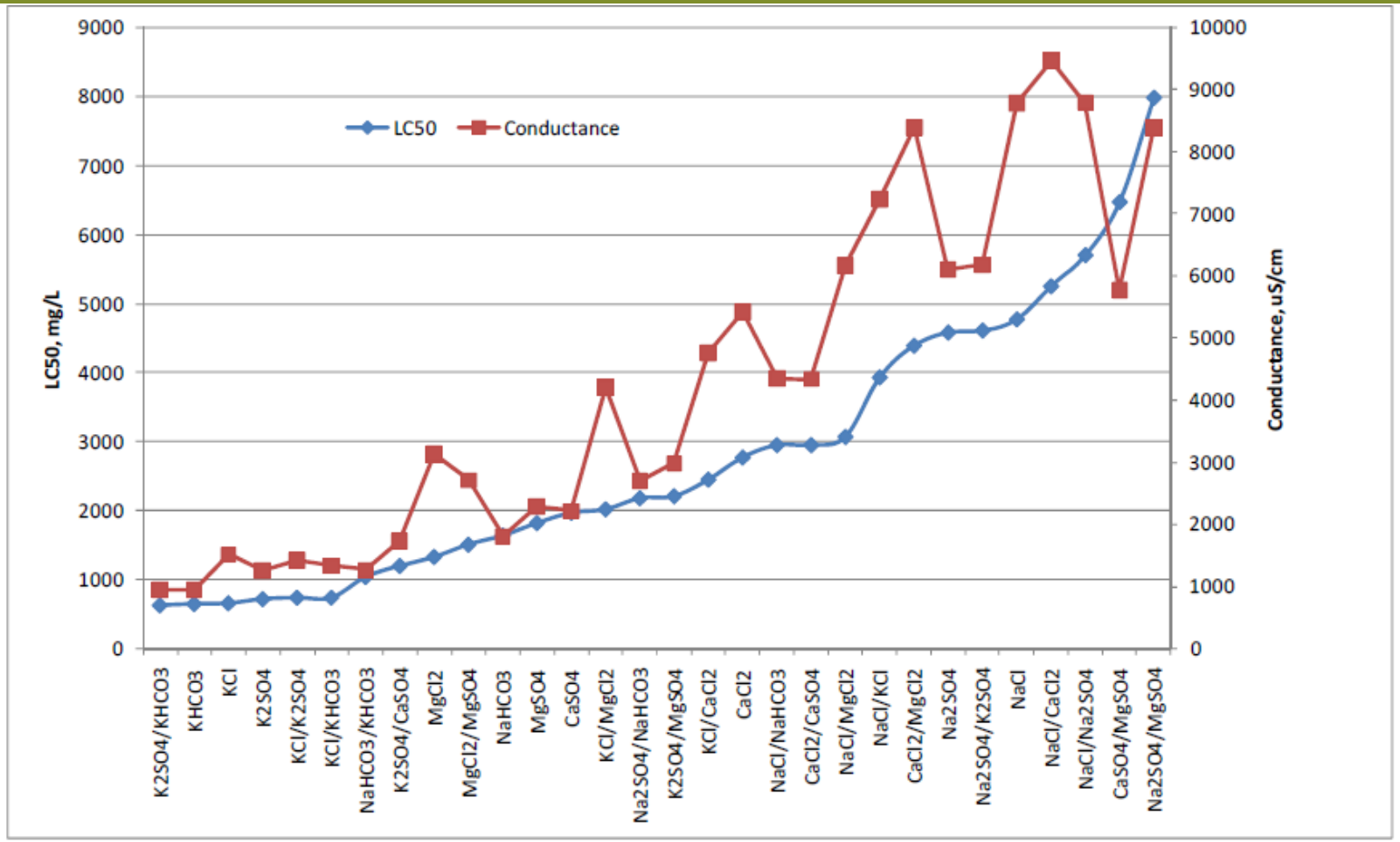

Figure A7 *Daphnia magna* LC_{50} Concentrations for Ion Pairs (sorted by LC_{50}, lowest to highest)

Brief History of Dissolved Solids Toxicity
Sulfate and Chloride Criteria

Soucek and Kennedy, 2005. Effects of hardness, chloride, and acclimation on the acute toxicity of sulfate to freshwater invertebrates.
Soucek et al. 2011. Influence of water hardness and sulfate on the acute toxicity of chloride to sensitive freshwater invertebrates.

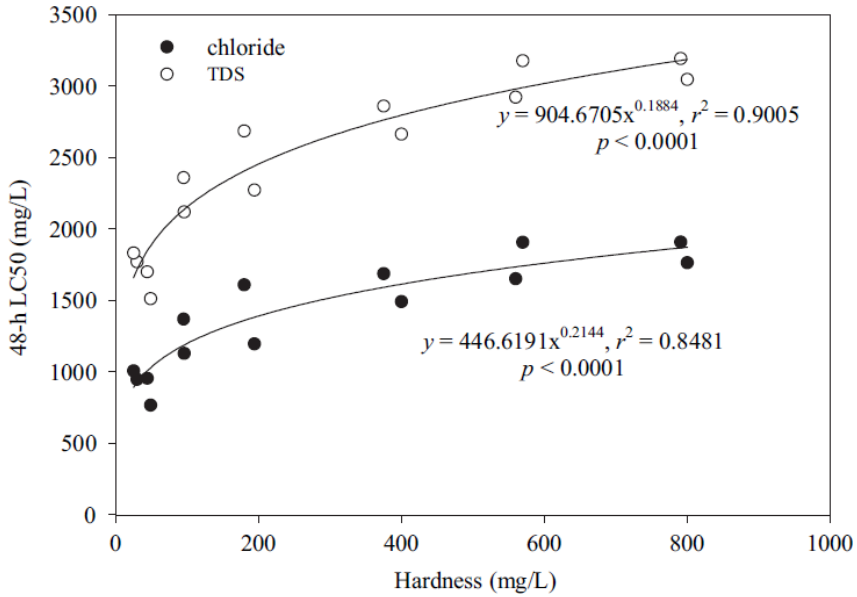

Fig. 1. Relationship between water hardness (mg/L as $CaCO_3$) in diluent and 48-h median lethal concentration (LC50s) values for *Ceriodaphnia dubia* in terms of chloride (mg Cl^-/L) and total dissolved solids (mg TDS/L).

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Brief History of Dissolved Solids Toxicity

Sulfate and Chloride Criteria

Hardness (mg/L)

Chloride (mg/L)	<100	100	150	200	250	300	350	400	450	500	>500
0-5	*500*	*500*	*500*	*500*	*500*	*500*	*500*	*500*	*500*	*500*	*500*
5	*500*	515	703	891	1080	1268	1456	1644	1832	2020	*2000*
10	*500*	691	879	1067	1256	1444	1632	1820	2008	2196	*2000*
15	*500*	867	1055	1243	1432	1620	1808	1996	2184	2372	*2000*
20	*500*	1043	1231	1419	1608	1796	1984	2172	2360	2549	*2000*
25	*500*	1164	1343	1522	1701	1880	2059	2238	2417	2596	*2000*
50	*500*	1141	1320	1499	1678	1857	2036	2215	2394	2573	*2000*
100	*500*	1093	1272	1451	1630	1809	1988	2167	2346	2525	*2000*
150	*500*	1046	1225	1404	1583	1762	1941	2120	2299	2478	*2000*
200	*500*	998	1177	1356	1535	1715	1894	2073	2252	2431	*2000*
250	*500*	951	1130	1309	1488	1667	1846	2025	2204	2383	*2000*
300	*500*	904	1083	1262	1441	1620	1799	1978	2157	2336	*2000*
350	*500*	856	1035	1214	1393	1572	1751	1930	2109	2288	*2000*
400	*500*	809	988	1167	1346	1525	1704	1883	2062	2241	*2000*
450	*500*	762	941	1120	1299	1478	1657	1836	2015	2194	*2000*
500	*500*	714	893	1072	1251	1430	1609	1788	1967	2146	*2000*

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Quick Summary
Published Data

- Anions and cations were looking at:
  - Ca, Mg, Na, K, HCO_3, SO_4, Cl……(nitrate, pH, OH)
- General ranking of toxicity:
  - K^{+} > HCO^{-2} > Mg^{+2} > Cl^{-} > $SO4^{-2}$
- Salt mixtures can have significantly different toxicity
- Additive and antagonistic effects
- Organism specific

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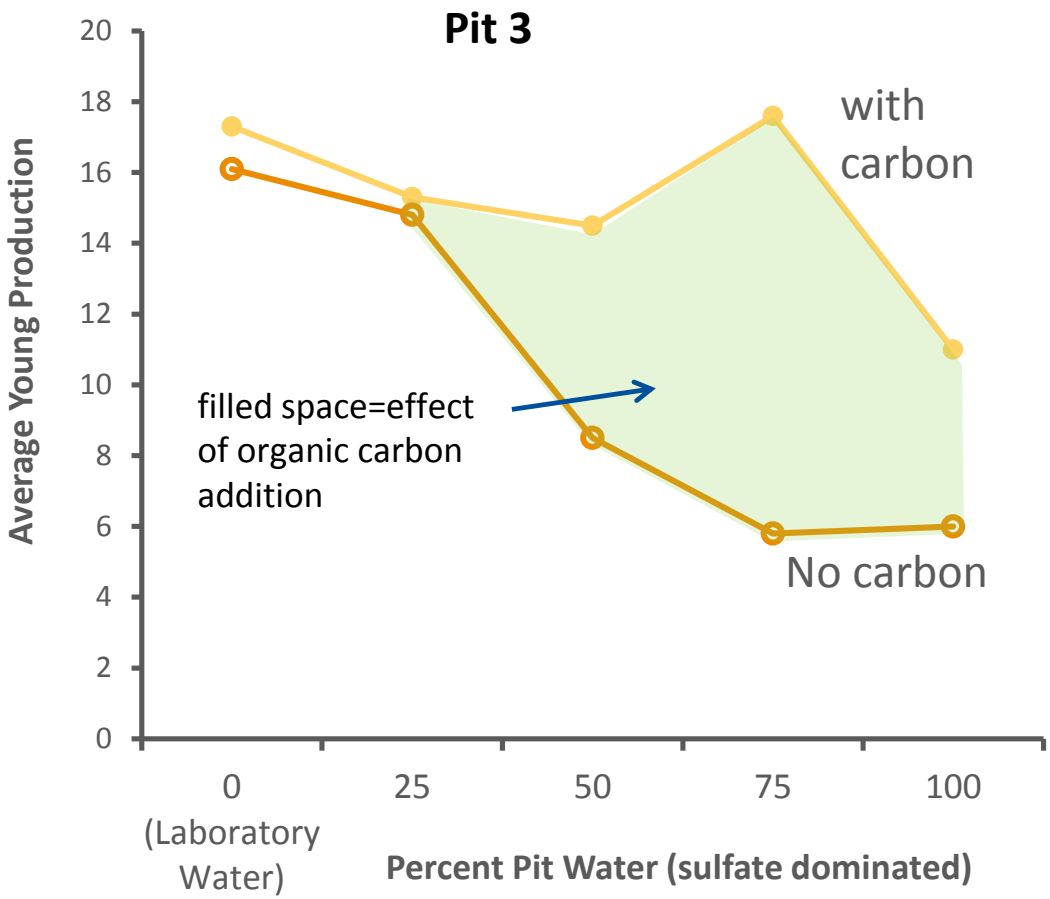
Other Relationships

My data: Mine pit water



Chronic sulfate toxicity to C. dubia reduced with humic acid

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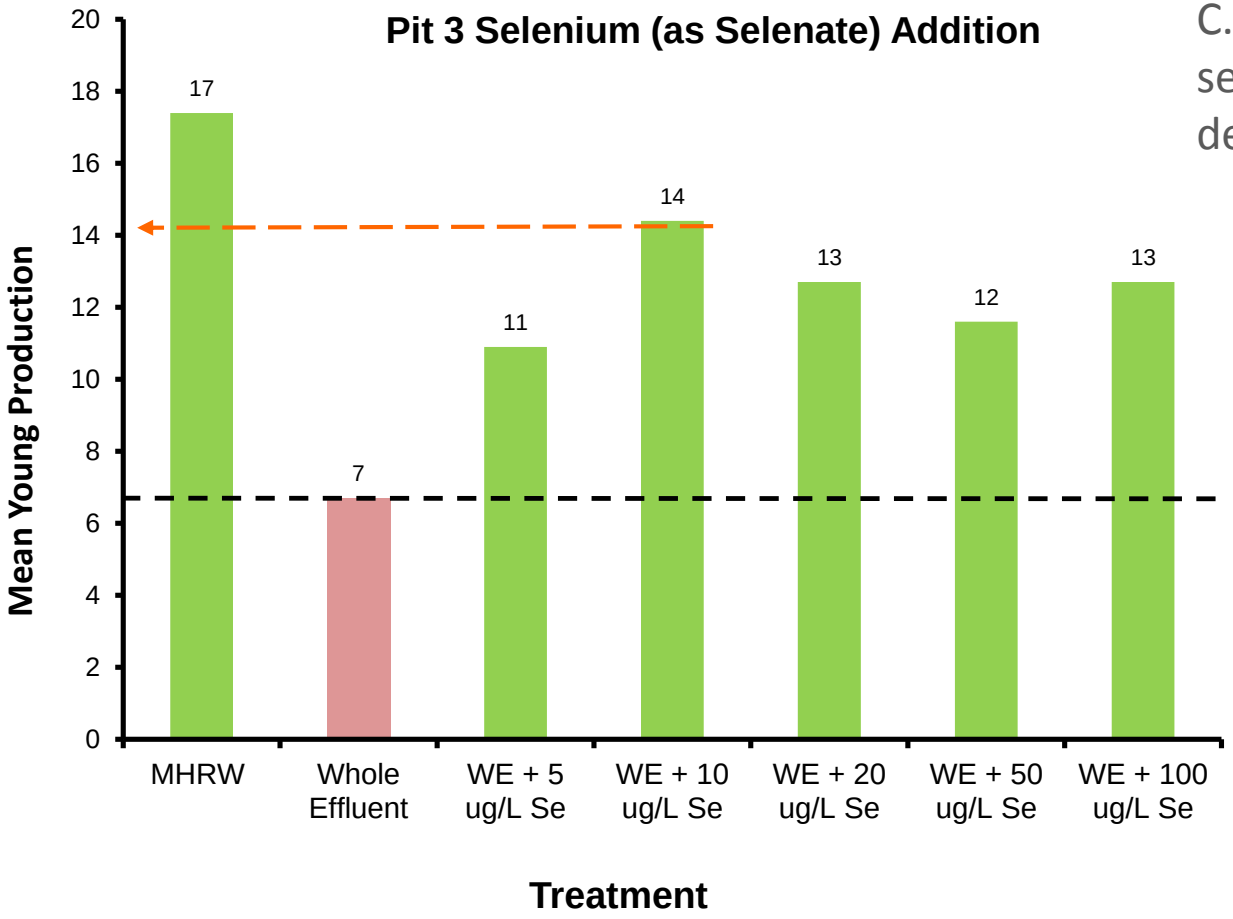
Other Relationships

My data: Mine pit water



Chronic sulfate toxicity to C. dubia mediated by selenium and zinc deficiency

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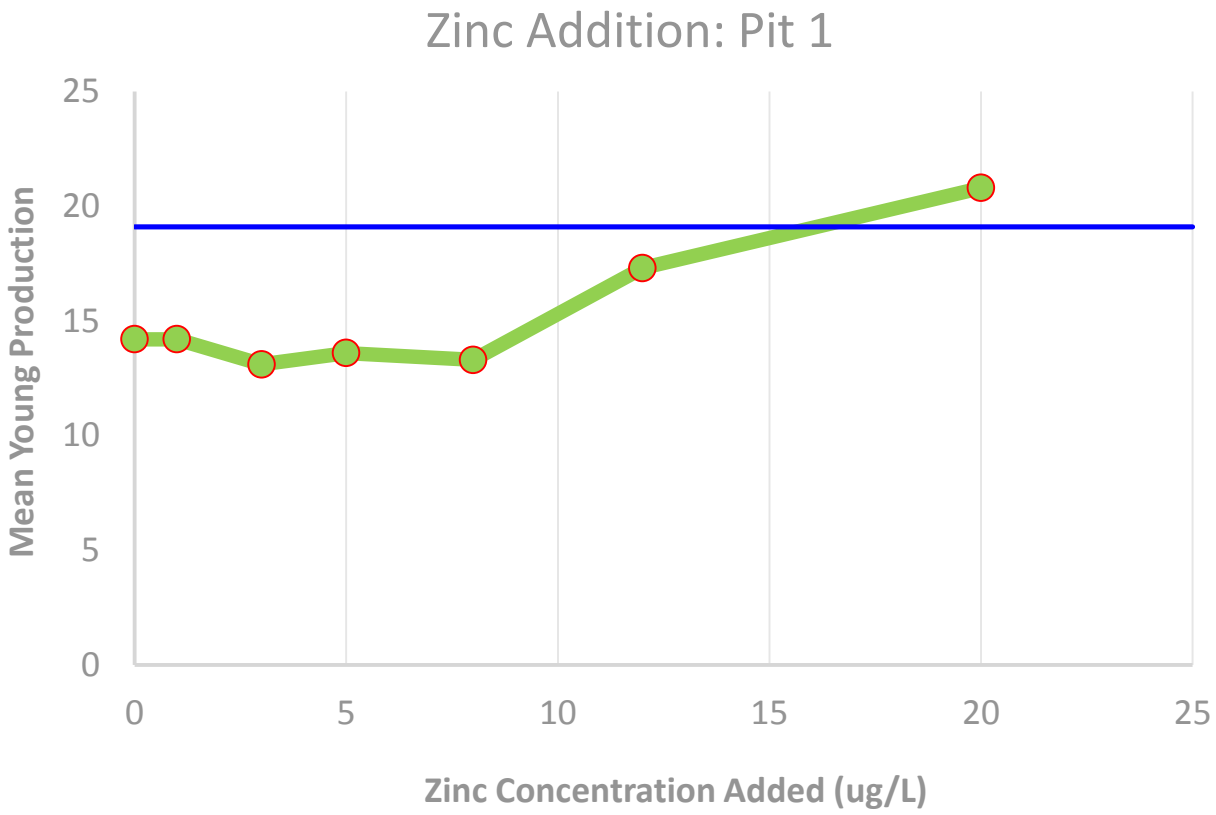
My data: Mine pit water



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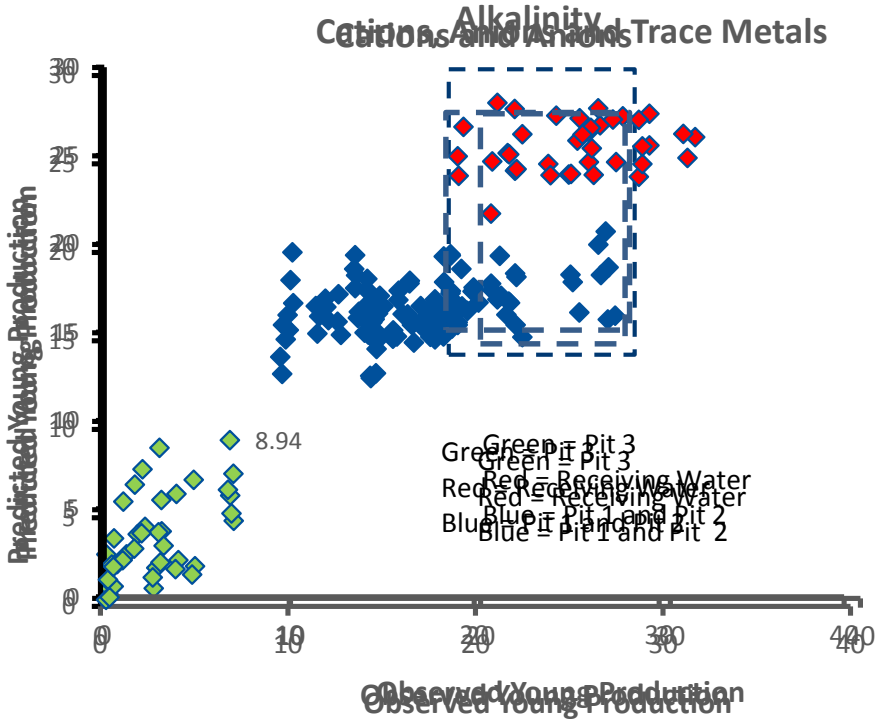
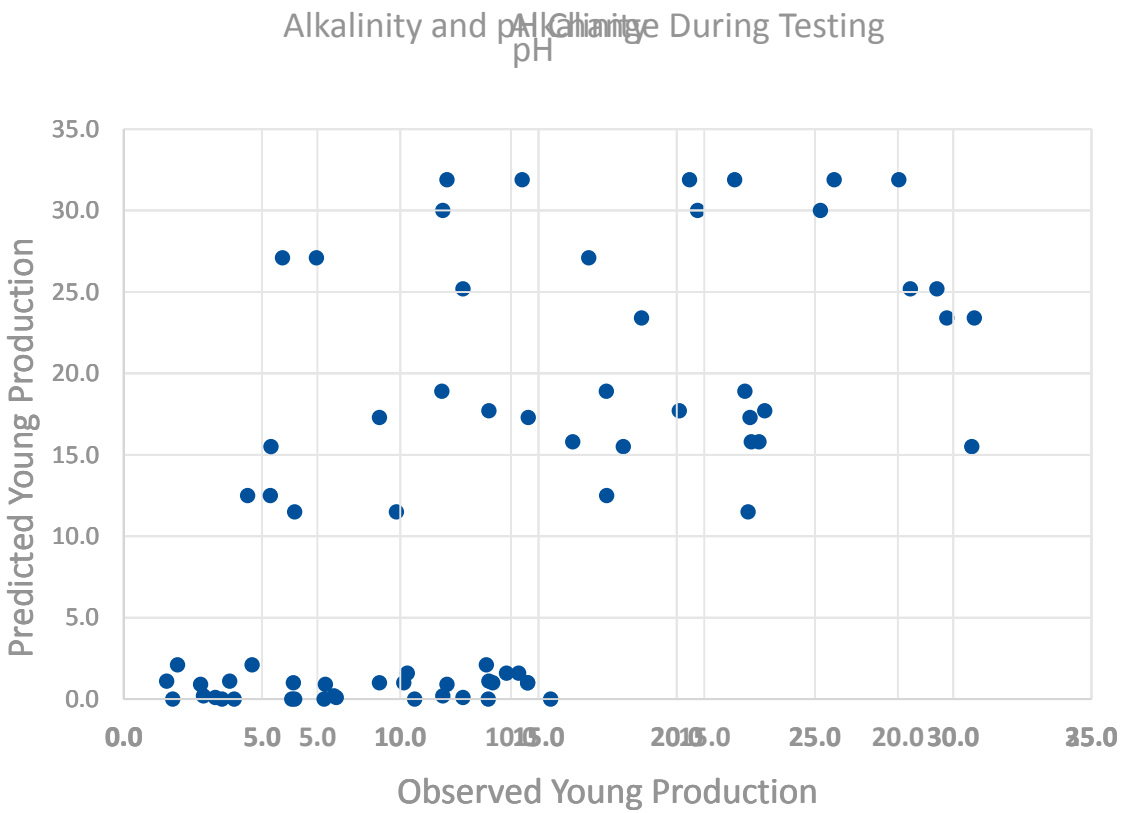


The effect of everything

Other Relationships

My data: Industrial discharge



Effect of pH rise on bicarbonate toxicity
Chronic C. dubia WET test

Fluctuating pH environment!

Another Summary

- Ion composition
- Organic carbon
- Micronutrients
- Physical-chemical variables…pH and temperature

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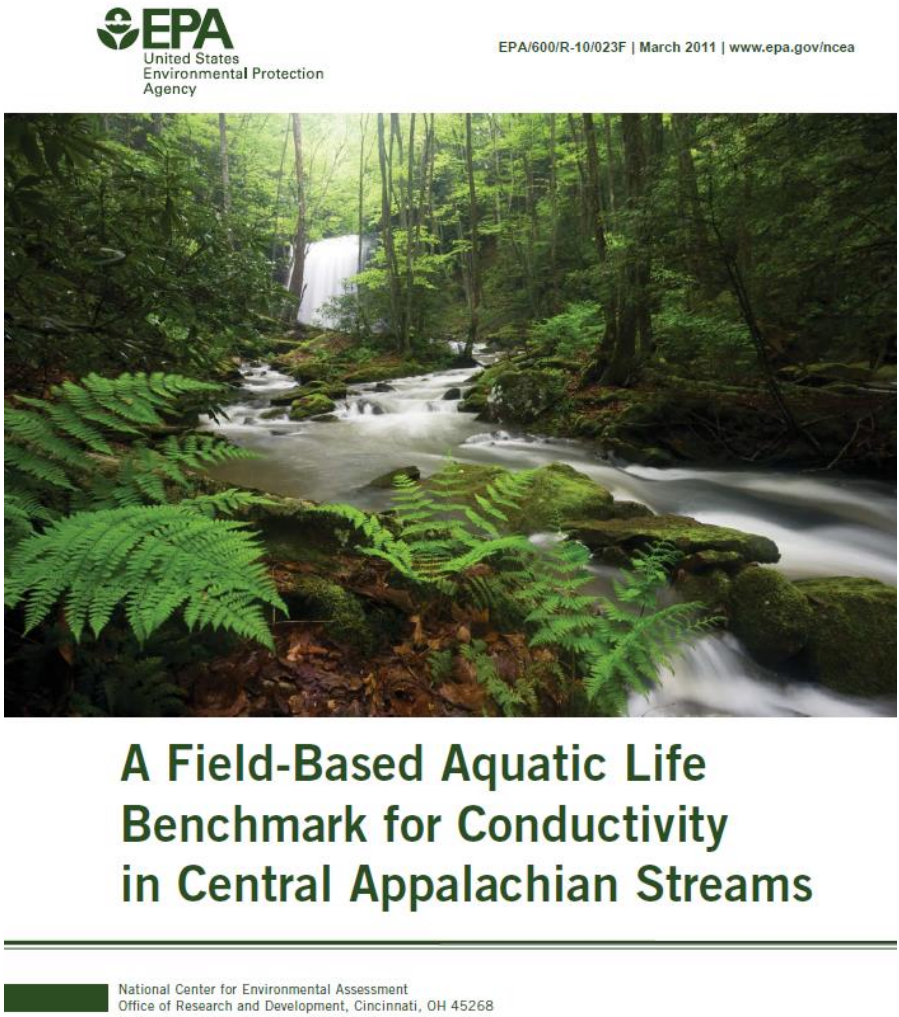
In-Stream Biological Monitoring
Dissolved solids effects

- Appalachian region
- Ca^{+2}, Mg^{+2}, SO_4^{-2}, and HCO_3^-
- 139 biological monitoring sites
- Goal: developed a conductivity-based benchmark
- Benchmark: 300 us/cm


EPA
United States Environmental Protection Agency

EPA/600/R-10/023F | March 2011 | www.epa.gov/ncea

A Field-Based Aquatic Life Benchmark for Conductivity in Central Appalachian Streams

National Center for Environmental Assessment
Office of Research and Development, Cincinnati, OH 45268

In-Stream Biological Monitoring
Dissolved solids effects

Benchmark from extirpation concentration (XC)

XC = concentration at which genus becomes absent

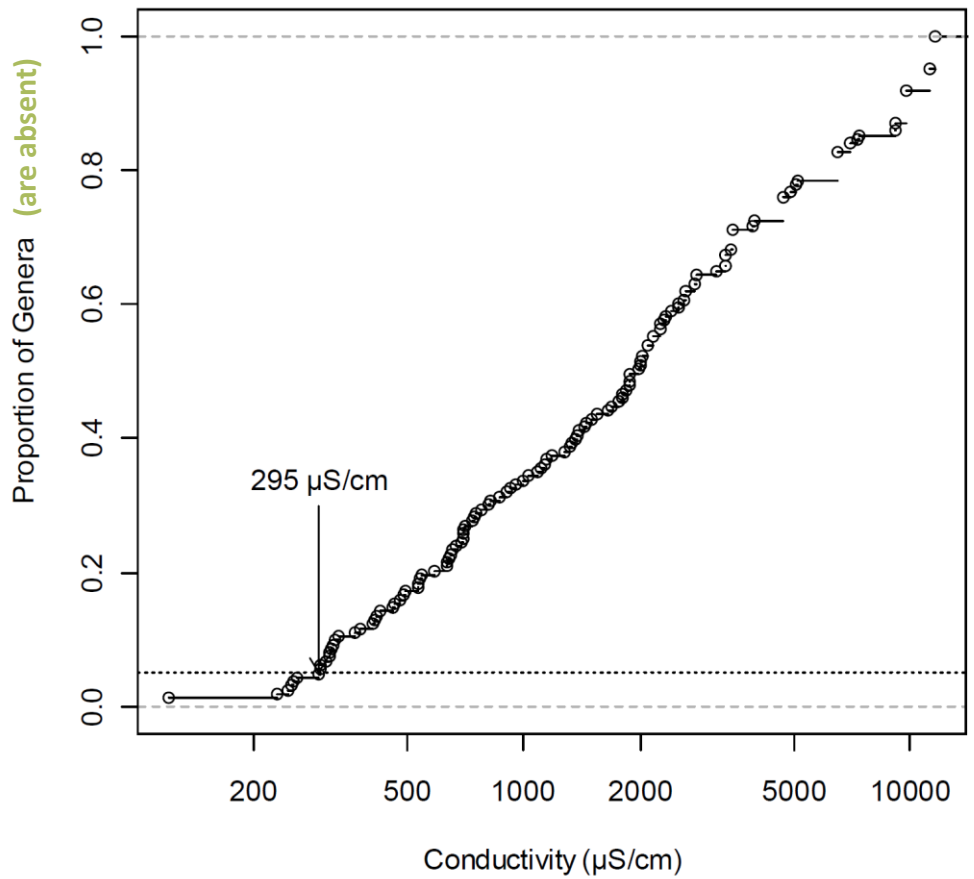


Figure 8. The species sensitivity distribution. Each point is an XC_{95} value for a genus. There are 163 genera. The HC_{05} (295 µs/cm) is the conductivity at the intercept of the SSD with the horizontal line at the 5th centile.

In-Stream Biological Monitoring
Dissolved solids effects

Mayflies were lost first

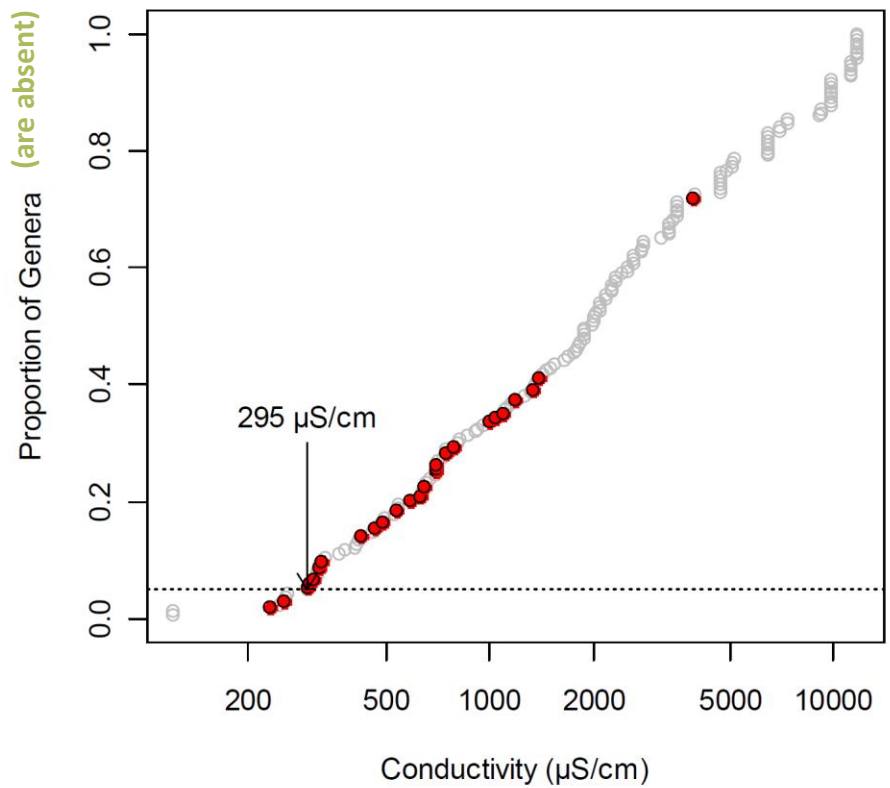


Figure A-1. The genera in the Order Ephemeroptera, as a group, are extirpated at lower conductivity levels than many other taxonomic groups. The plot is a species sensitivity distribution (SSD). Open circles represent the 95th centile extirpation concentration (XC_{95}) for a genus. The closed circles are genera of the Order Ephemeroptera. The genus at 230 µS/cm is *Cinygmula* and at 3,923 µS/cm is *Caenis*.

Biological Monitoring and Whole Effluent Toxicity: Industrial Discharge

Instream biological monitoring as permit condition for a specific conductance variance

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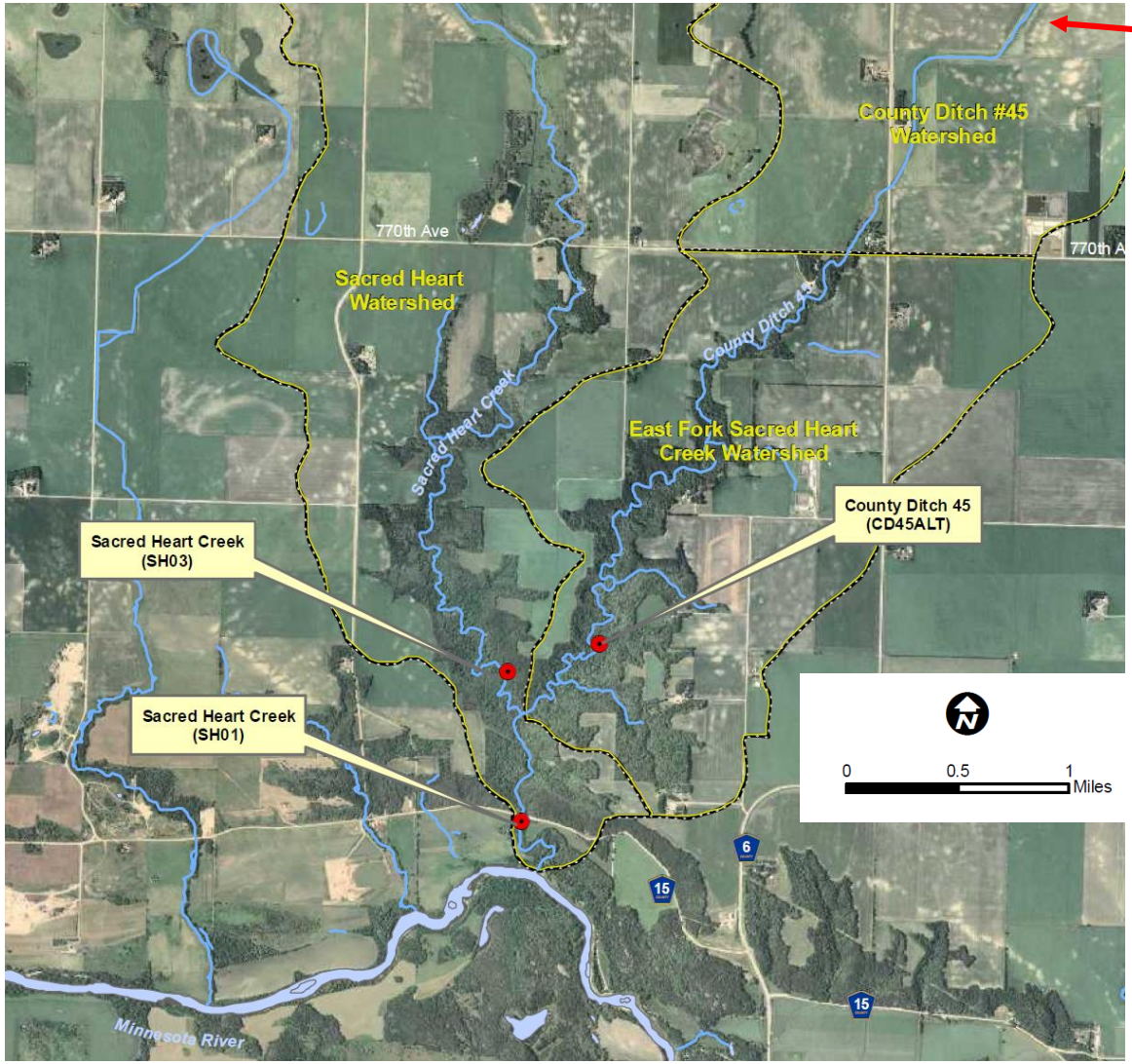
Biological Monitoring and Whole Effluent Toxicity: Industrial Discharge



Industrial Discharge

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Biological Monitoring and Whole Effluent Toxicity: Industrial Discharge

CD45

SH03
(control)

SH01
(downstream)

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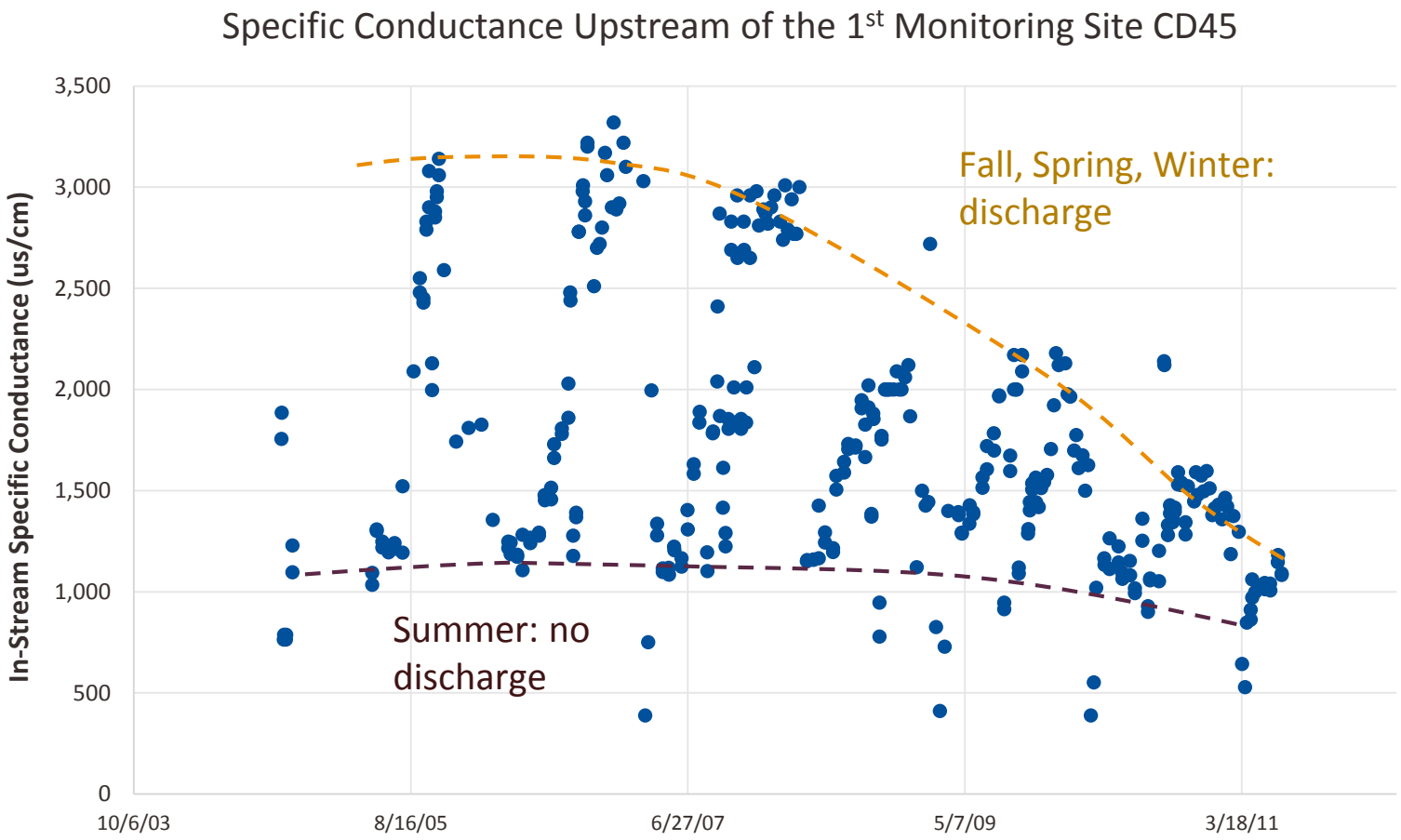
Chemistry In the Receiving Stream



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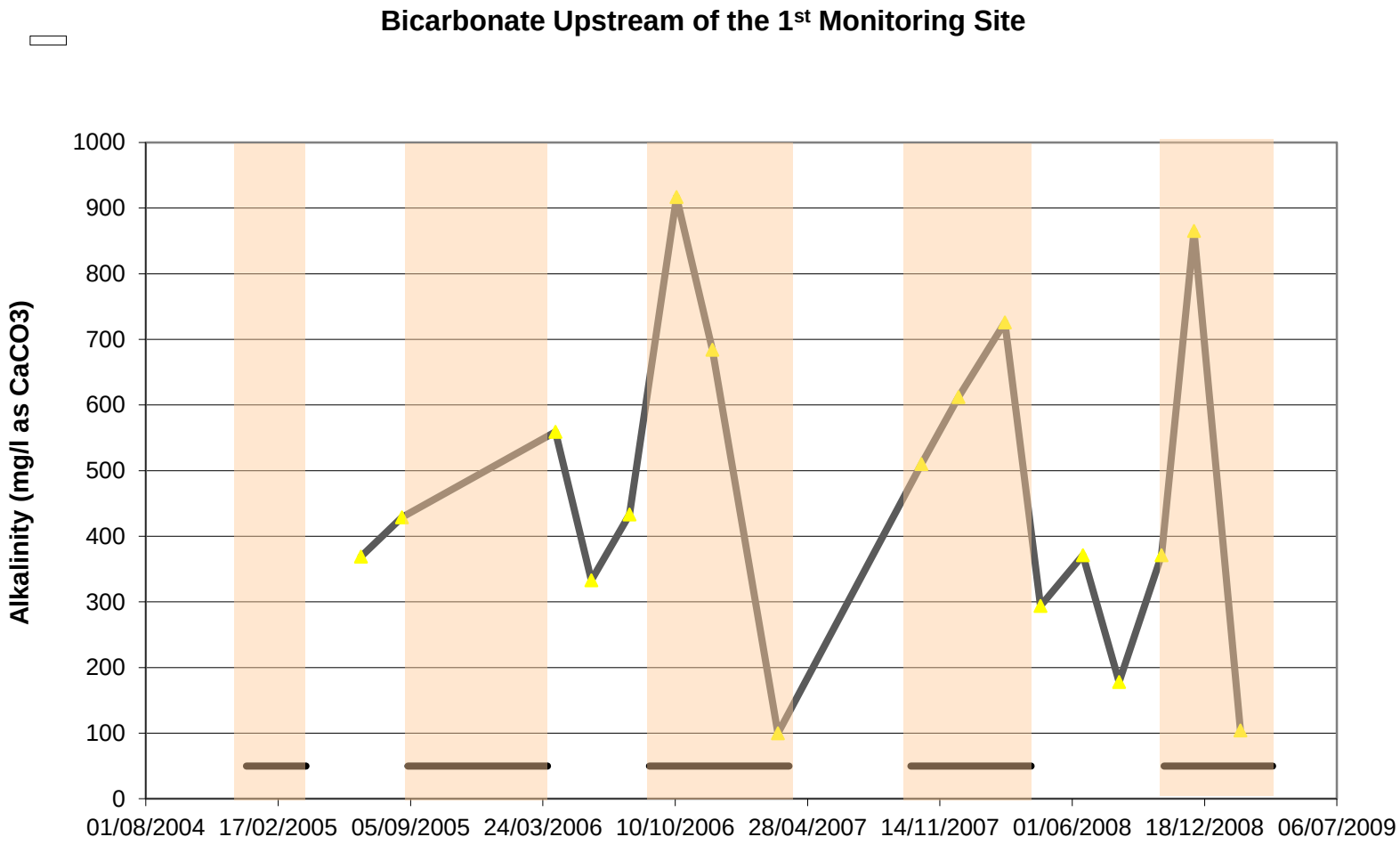
Chemistry In the Receiving Stream



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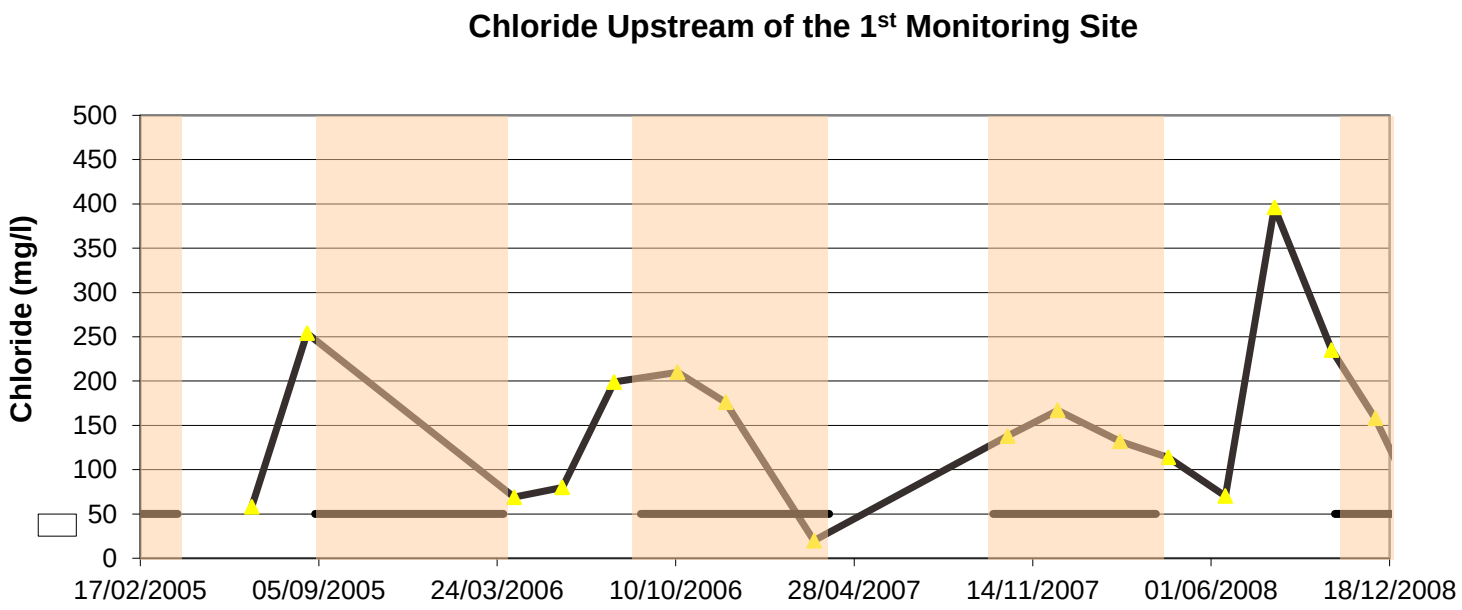

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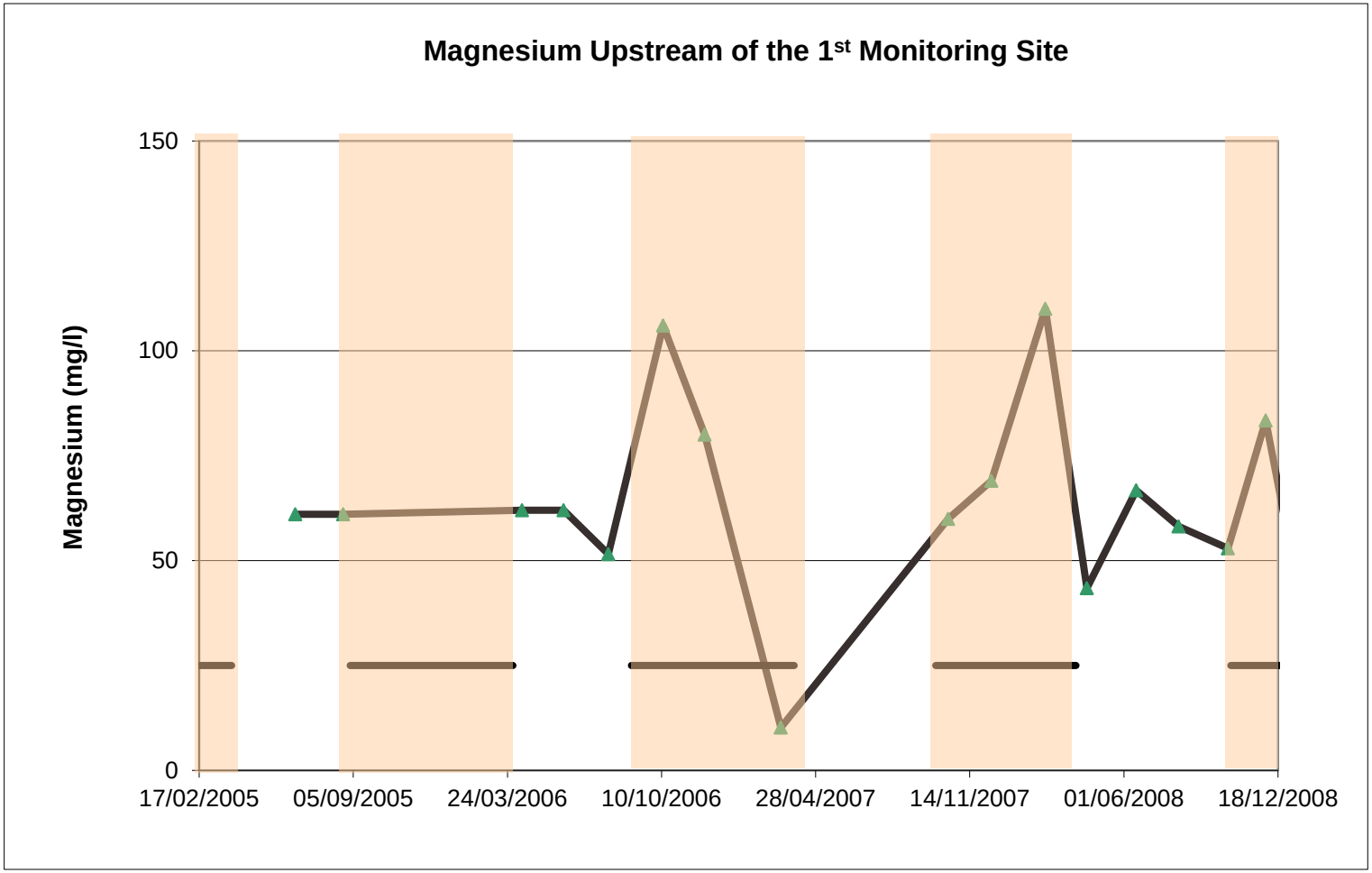

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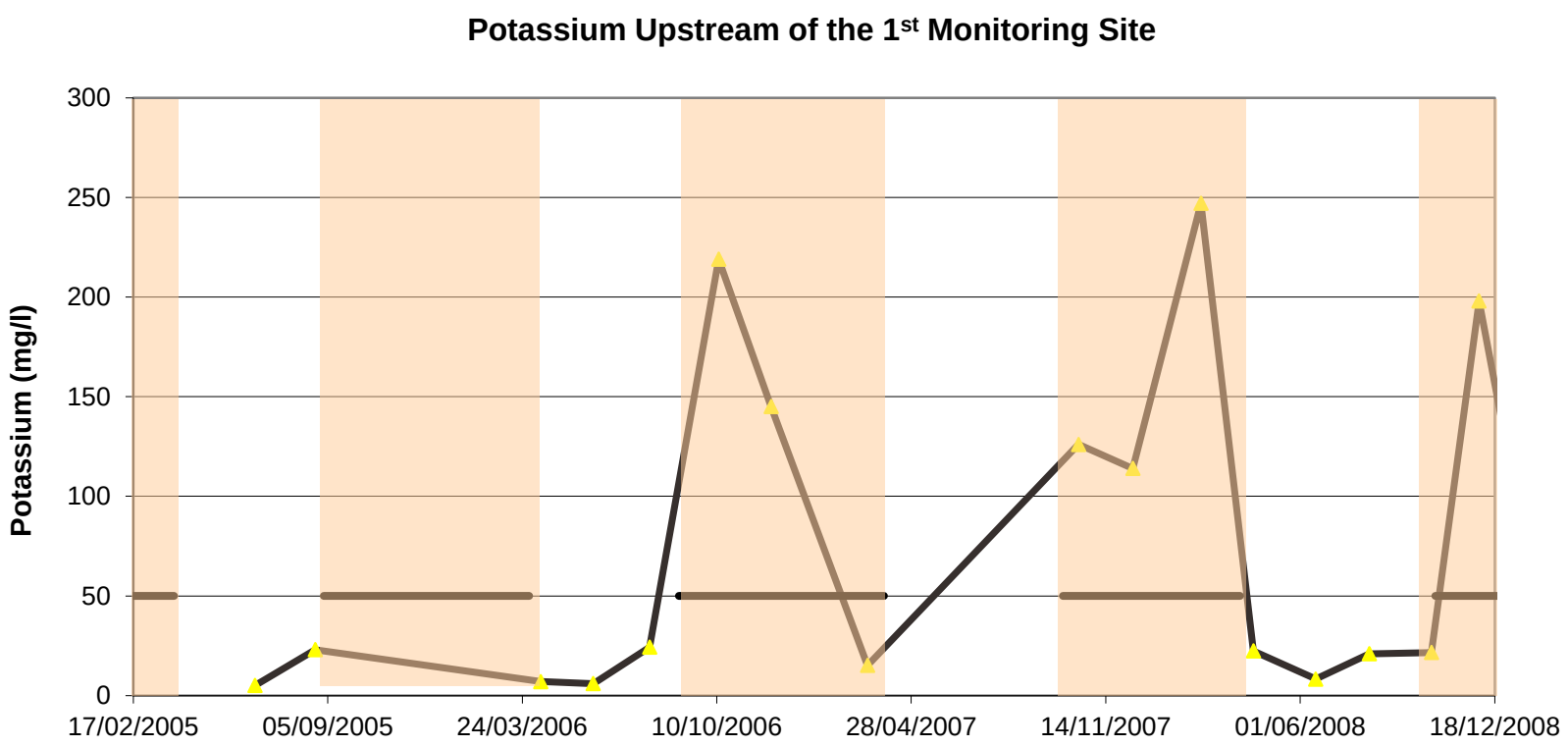
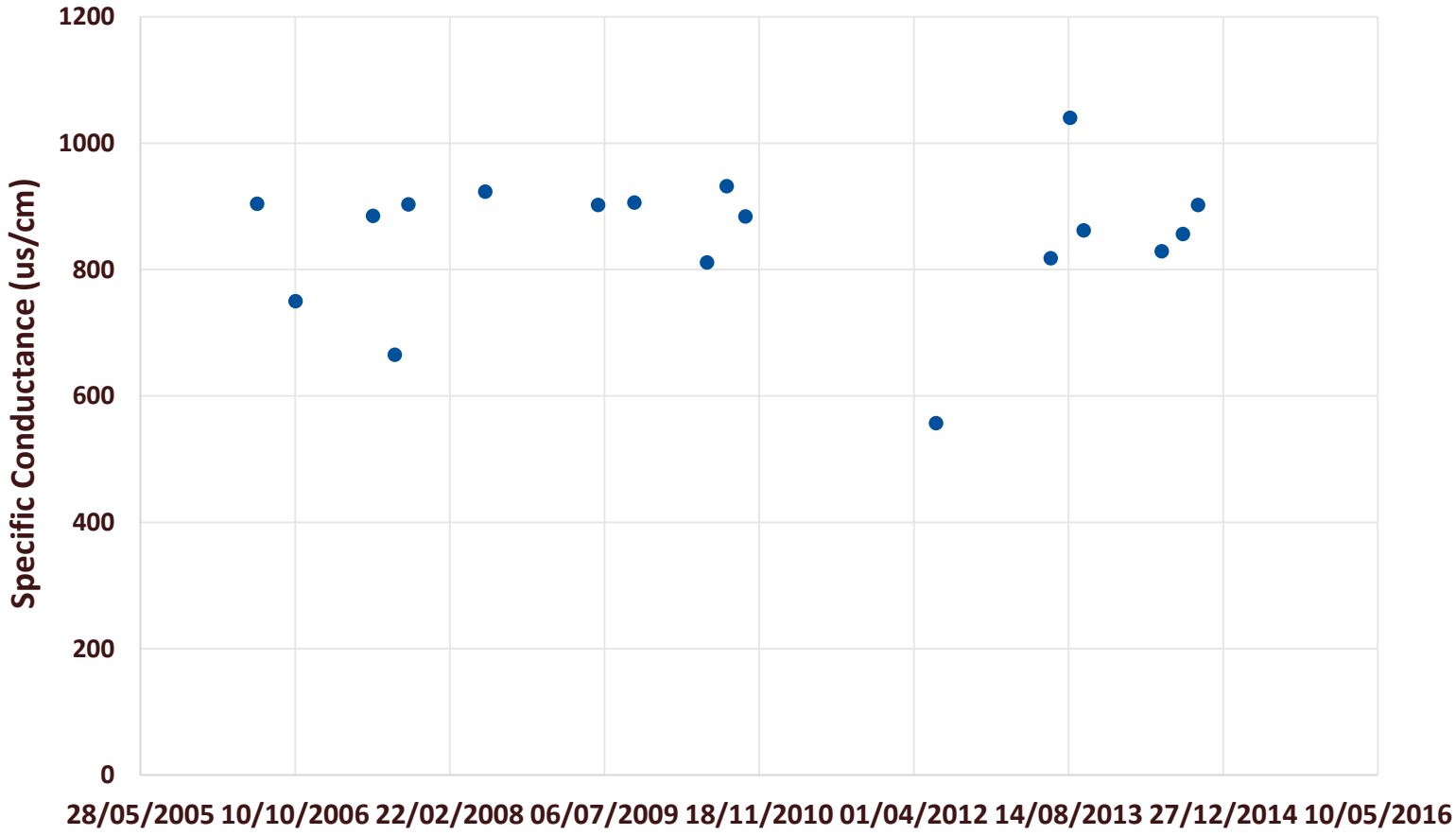
Chemistry In the Receiving Stream



Reference Site Specific Conductance



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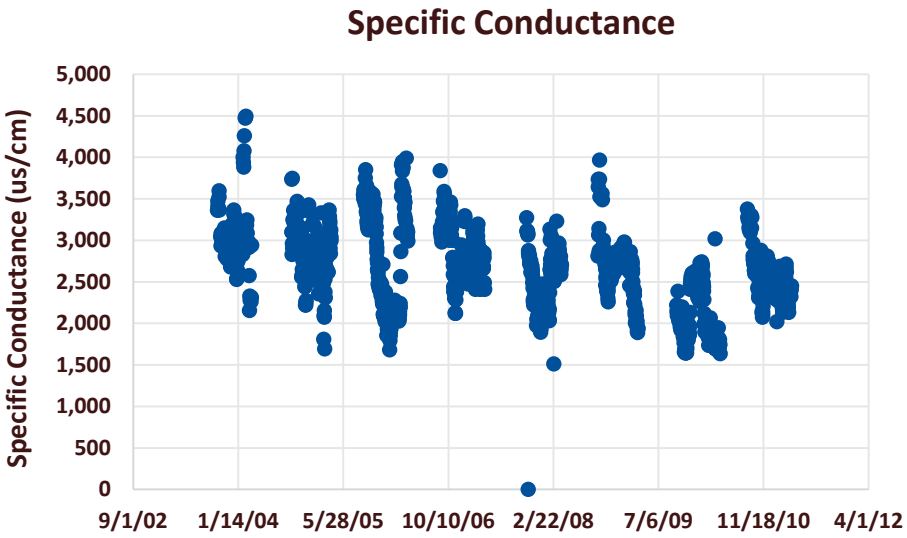
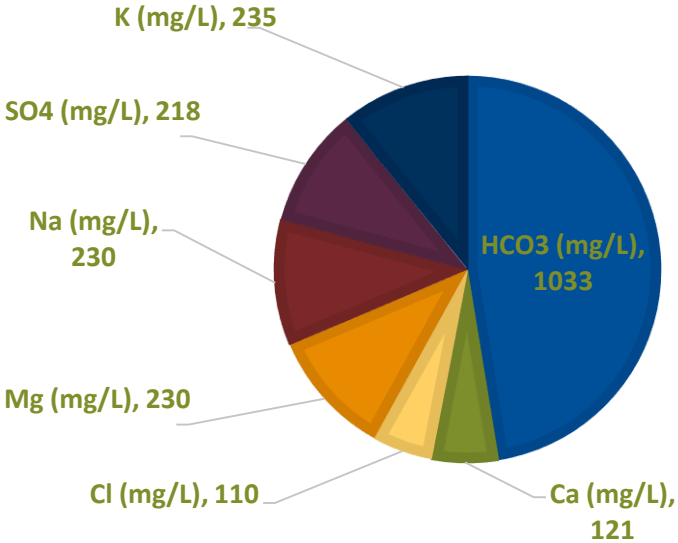
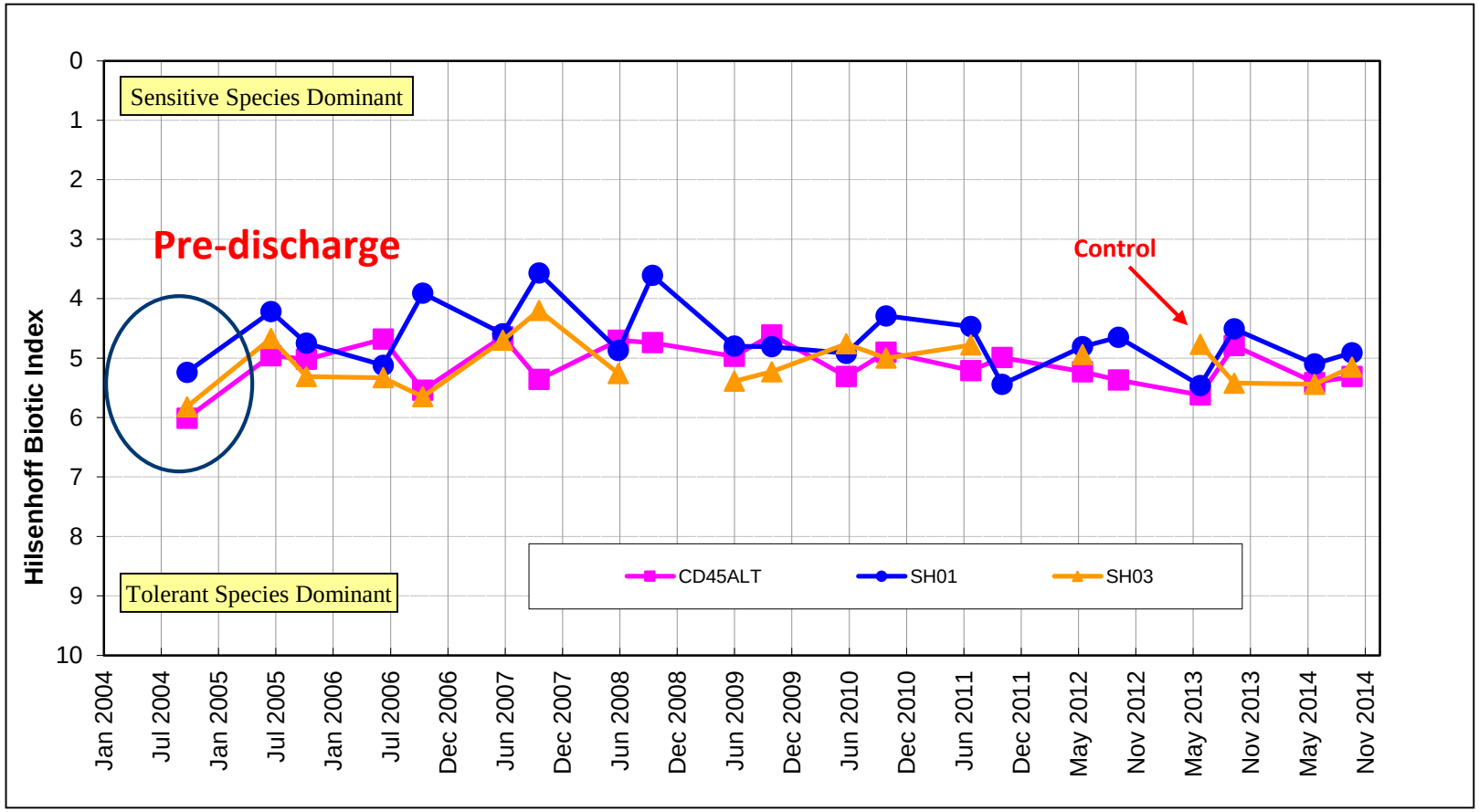
Discharge Chemistry





Macroinvertebrate Indices

Hilsenhoff Biotic Index Scores, 2004-2014.



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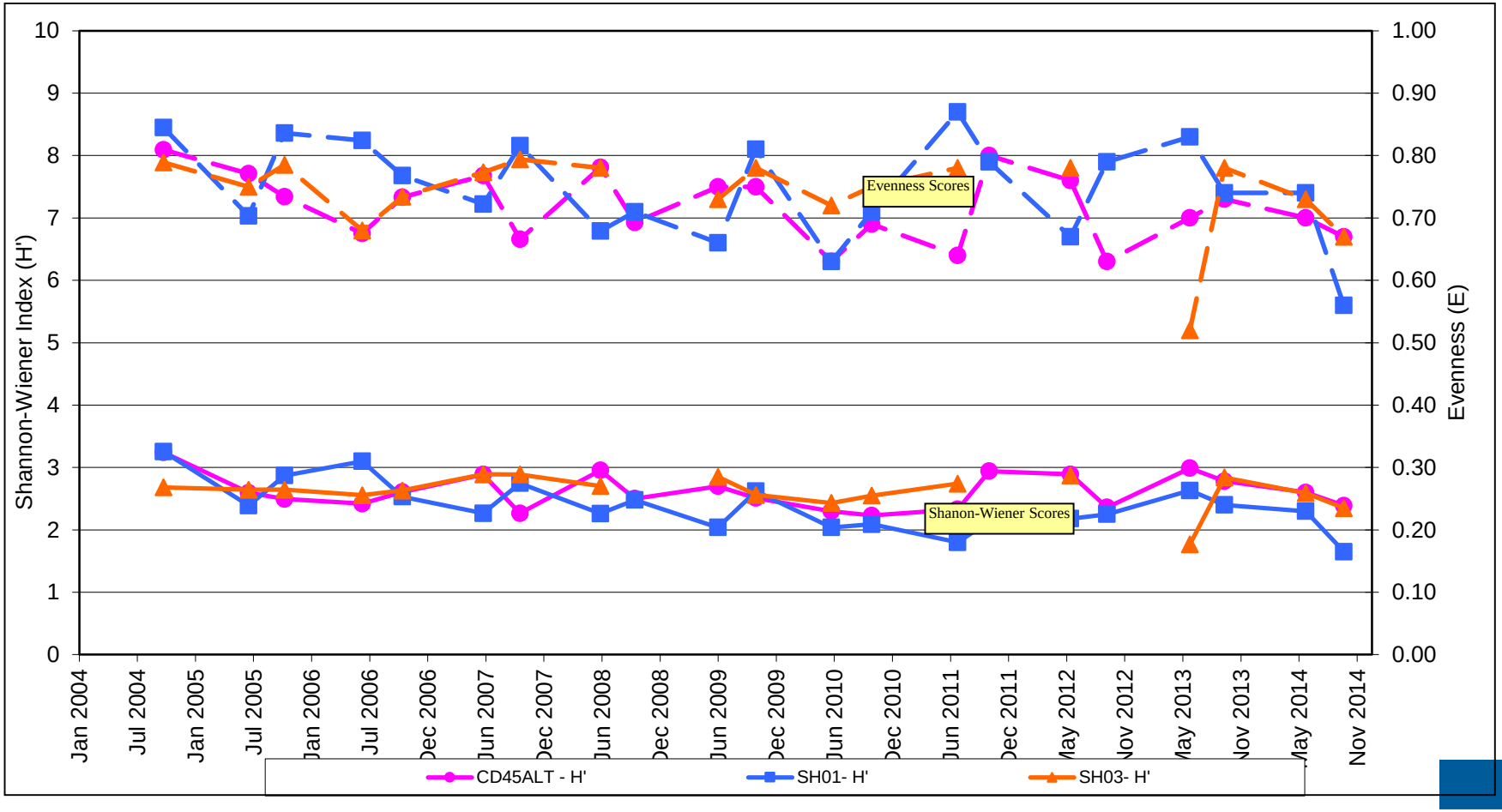
Macroinvertebrate Indices

Macroinvertebrate Shannon-Wiener and Evenness Scores, 2004-2014.



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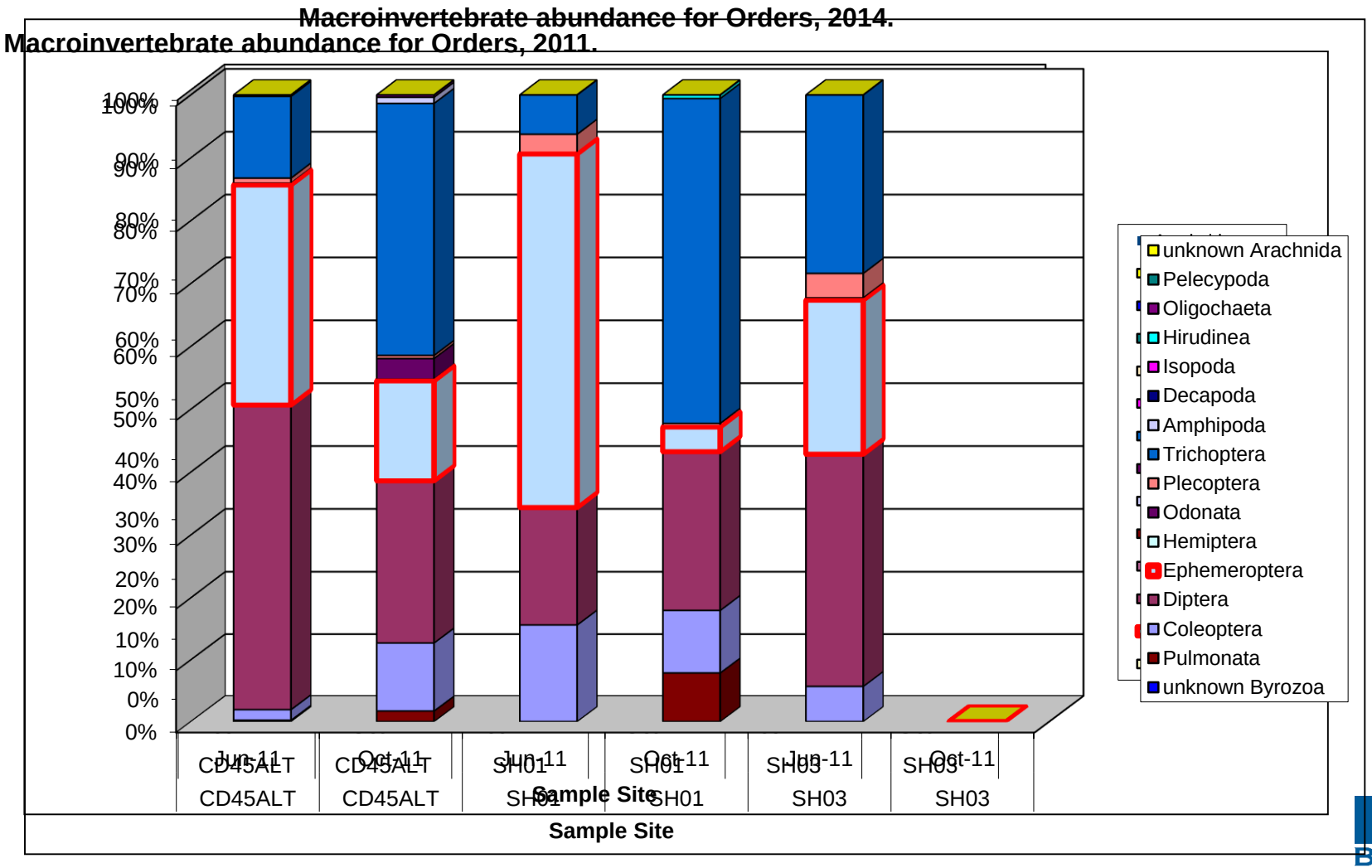
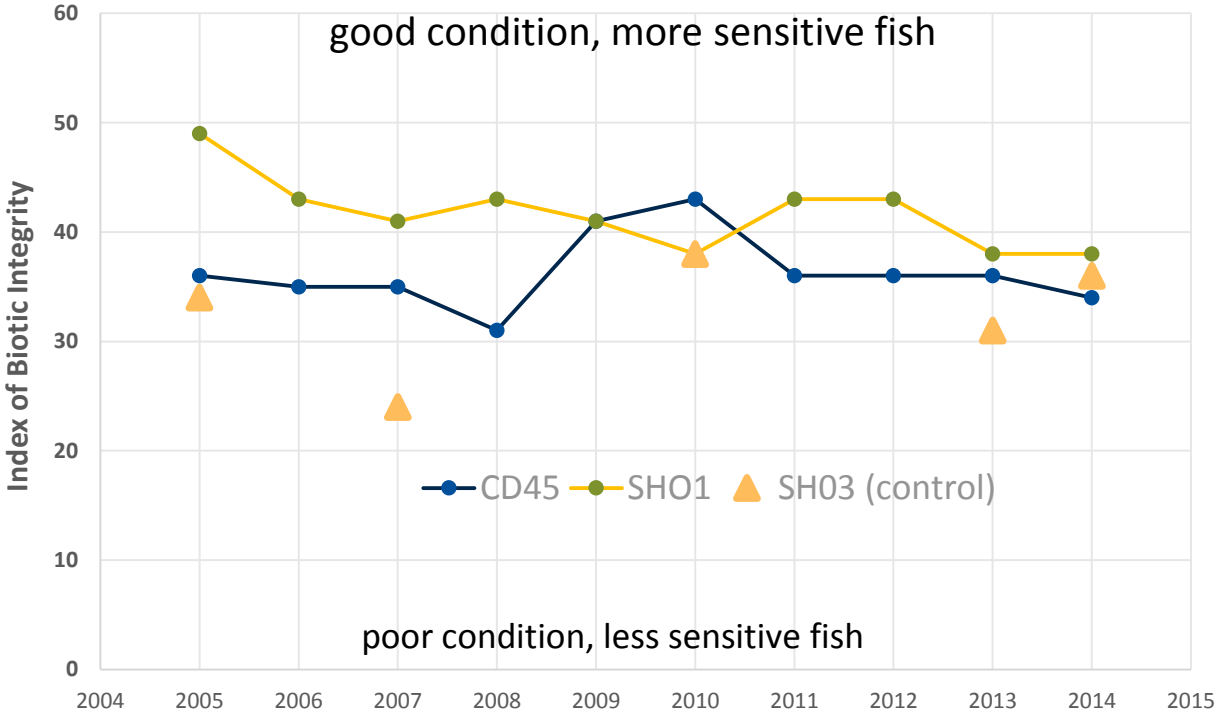
Macroinvertebrate Groups



Fish



Metric	Description
#1	Total number of native fish species
#2	Number of darter species
#3[2]	Number of sunfish species if the watershed >100 sq. mi.[2]
#4	Number of minnow species excluding common carp, creek chub and fathead minnow at sites if the watershed <100 sq. mi.
#5	Number of intolerant species
#6	Proportion of tolerant individuals
#7	Proportion of individuals that are omnivores
#8	Proportion of individuals that are specialized insectivores
#9	Proportion of individuals that are top carnivores if the watershed >100 sq. mi.2
#10	Catch per unit effort (time = fish/hour)
#11	Proportion of individuals that are simple lithophils
#12	Proportion of individuals with deformities, eroded fins, lesions and tumors (DELT)

[1]The metrics used for this study were described in Bailey et. al., 1992.

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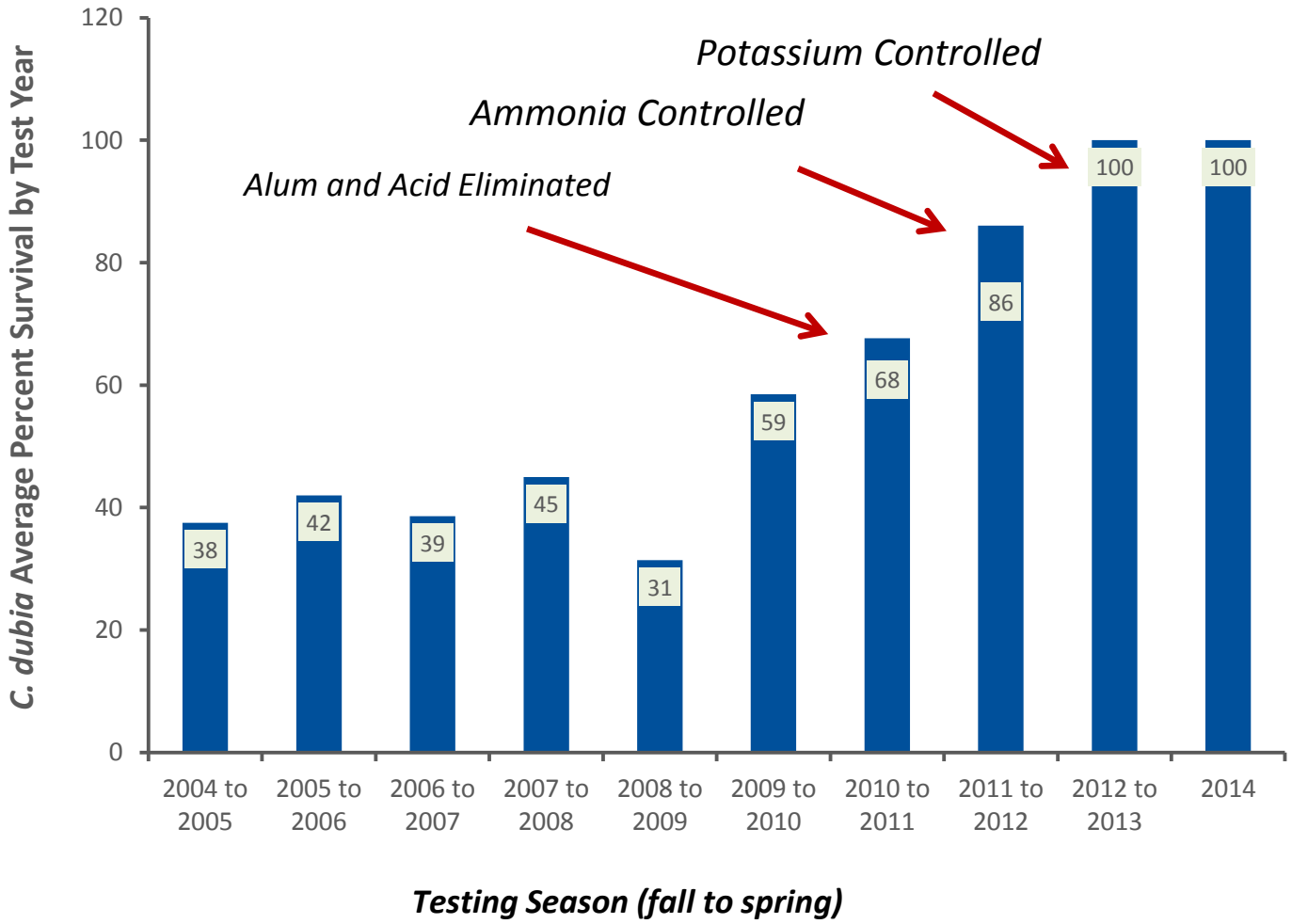
Whole Effluent Toxicity (acute)



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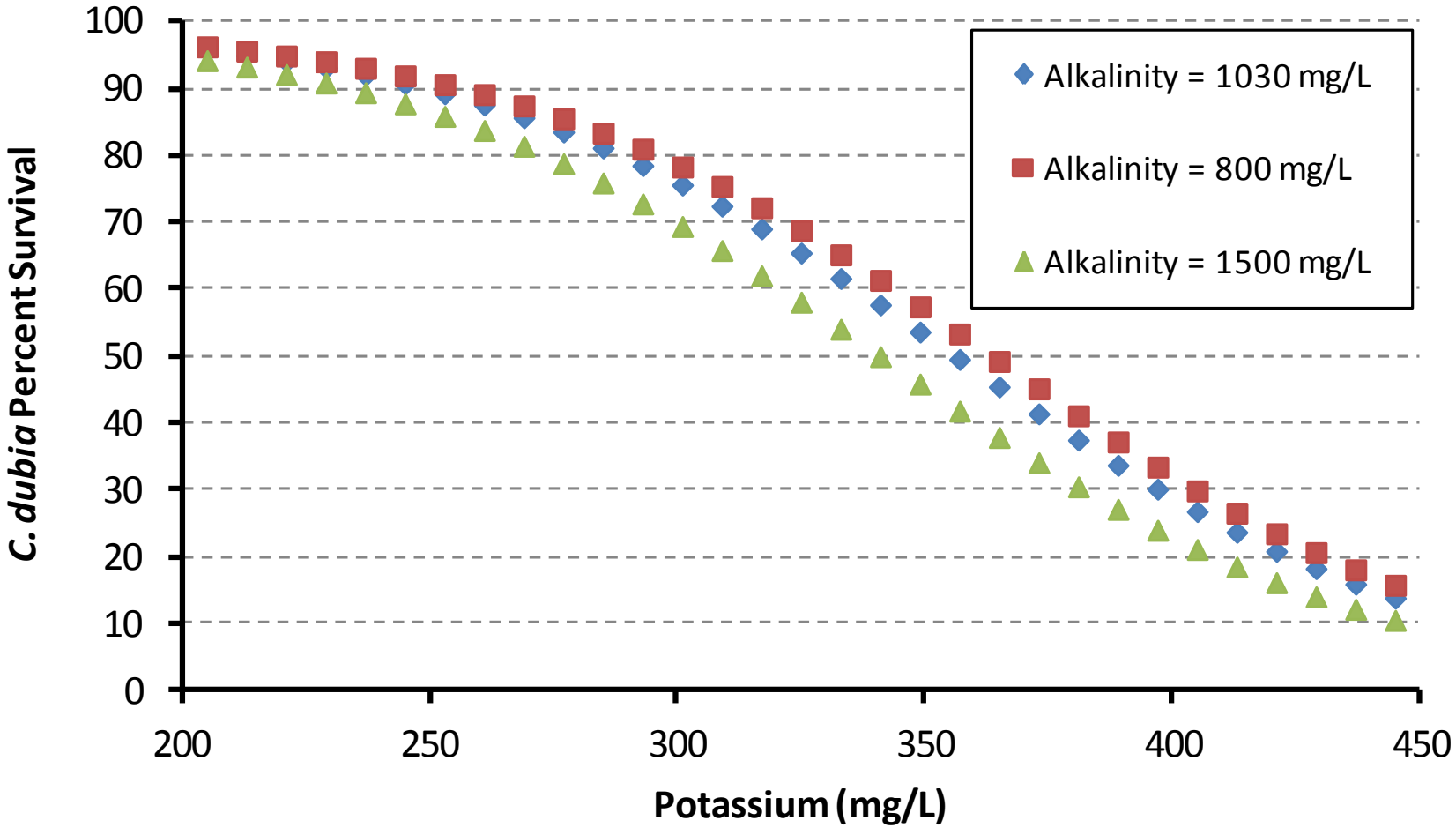
What About the High Alkalinity



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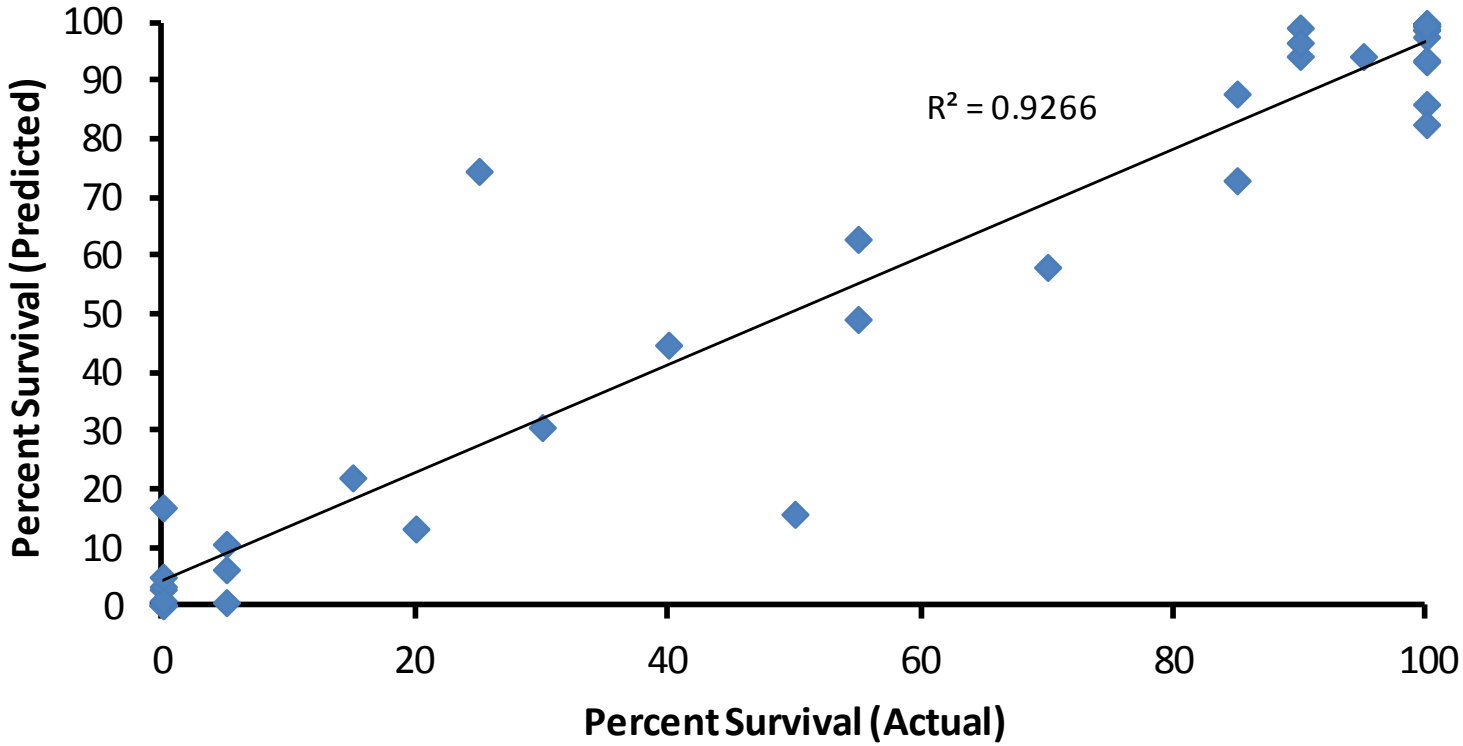

Percent Survival = 100*1/(1 + exp(-(8.685-0.001*Alkalinity+0.004*Chloride-0.956*Ammonia as N+0.015*Sulfate+1.008*Aluminum -0.020*Potassium-0.008*Sodium)

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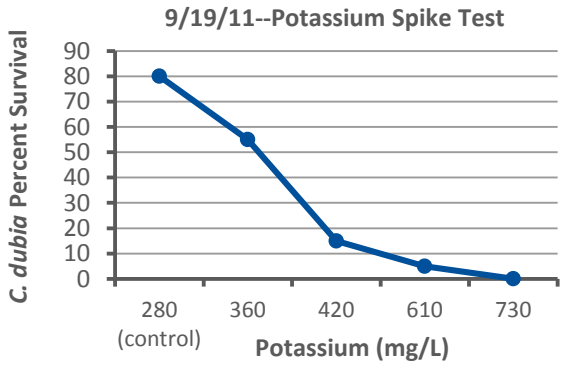
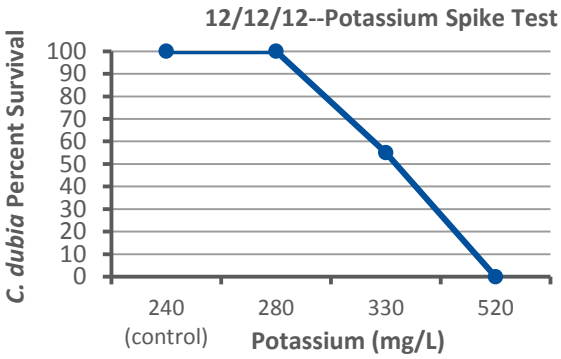
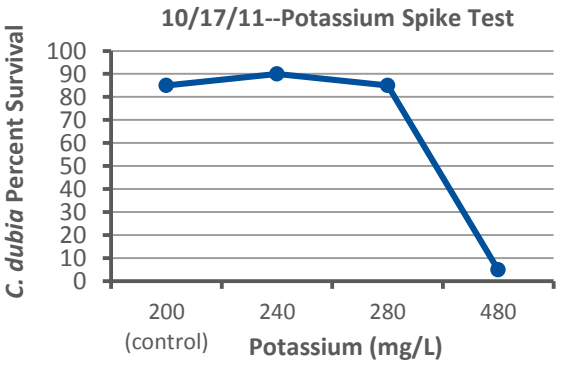
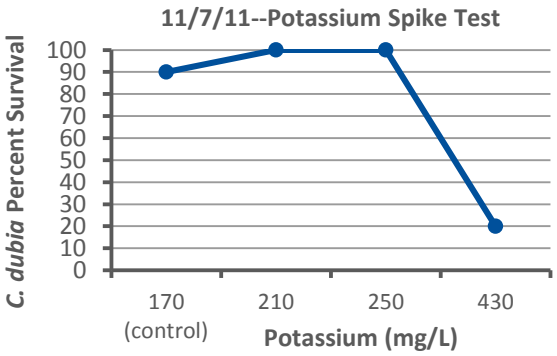
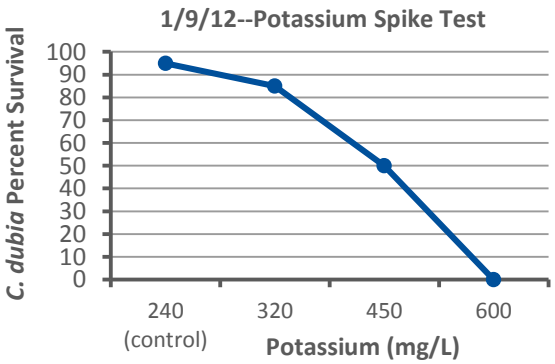
Relative Effect of Potassium in Effluent Matrix

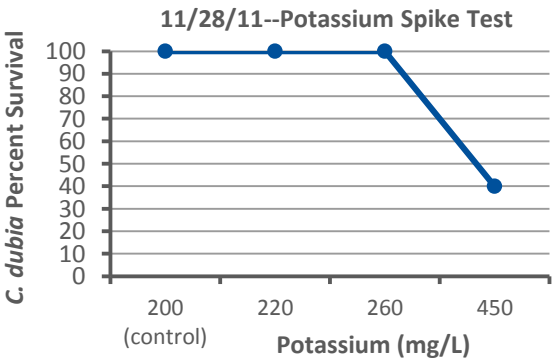












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Synopsis

- Be careful!
- Things that modify dissolved solids toxicity:
  - Hardness, chloride, pH, organic carbon (NOM), micronutrient (trace metals), acclimatized population
- My toxicity ranking
  - HCO_3^- = $SO4^{-2}$ = Cl^{-2}
  - K > Mg > Ca = Na
- Use multivariate logistic regression

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