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Protecting the LADII Irrigation System from Dreissenid Infestation: A Case Study

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IMC Webinar:

Management Options for Irrigation Systems

March 6th, 2017

Outline

- LADII Irrigation System
  - System Capacity
  - Intake Design
  - Pumphouse Details

Outline

- LADII Irrigation System
- Dreissenids 101
  - Distribution
  - Zebra Mussel Lifecycle
  - Survival Thresholds

Outline

- LADII Irrigation System
- Dreissenids 101
- Infestation & Control Challenges
  - Ideal Environment
  - Average pH Levels
  - Average Temperatures
  - LADII Challenges

Outline

- LADII Irrigation System
- Dreissenids 101
- Infestation & Control Challenges
- pH Adjustment as a Treatment
  - Mortality Test & Results
  - Acid Injection Trial & Results
  - Cost Analysis

Outline

- LADII Irrigation System
- Dreissenids 101
- Infestation & Control Challenges
- pH Adjustment as a Treatment
- Sample Collection & Identification
  - Veliger Identification
  - LADII's Risk of Infestation

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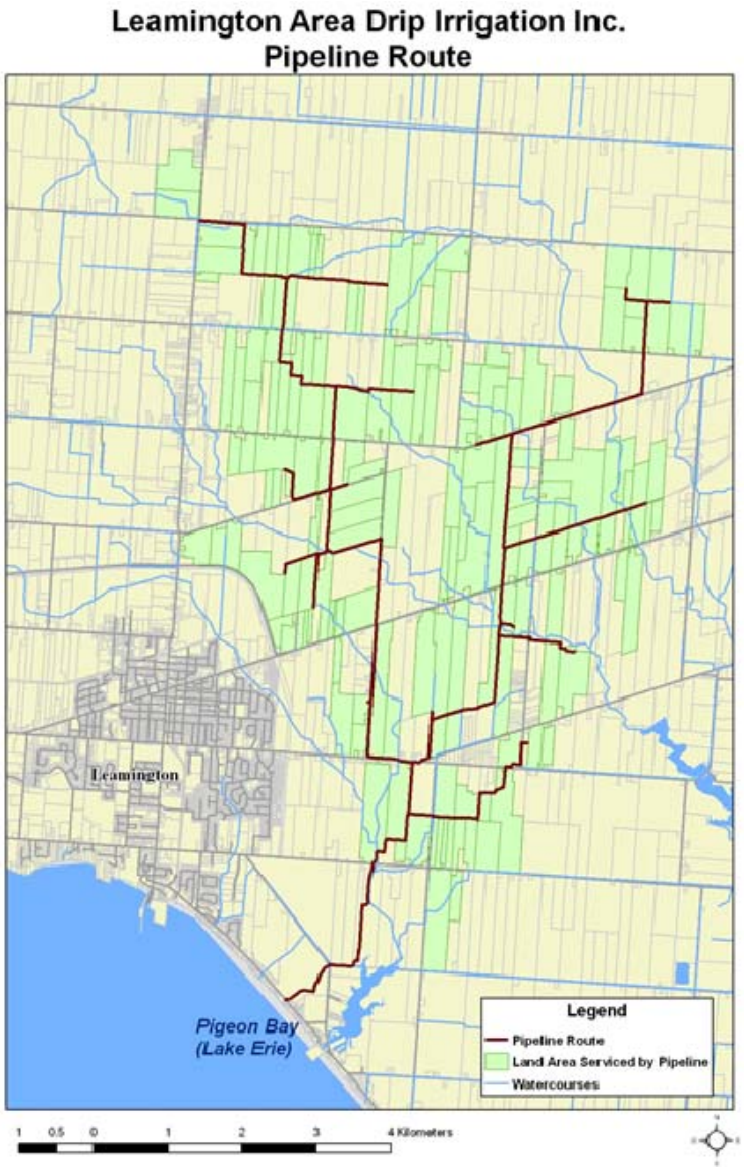
- pH Adjustment as a Treatment
- Sample Collection & Identification
- Next Steps

LADII Irrigation System

- Leamington Area Drip Irrigation Incorporated (LADII) formed in 2006
- Processing tomatoes, corn, beans & potatoes
- Greenhouse tomatoes, cucumbers & peppers
- ~36 km (22 mi) of pipe
- > 2,400 ha (6,000 ac) of cropland



System Capacity

- Designed to provide 1,590 m^3/hr (7,000 US GPM)
- Approved to deliver 1,430 m3/hr (6,300 US GPM)
- Filter to 100 µm for drip systems
- Designed for zebra mussel Control

Intake Design

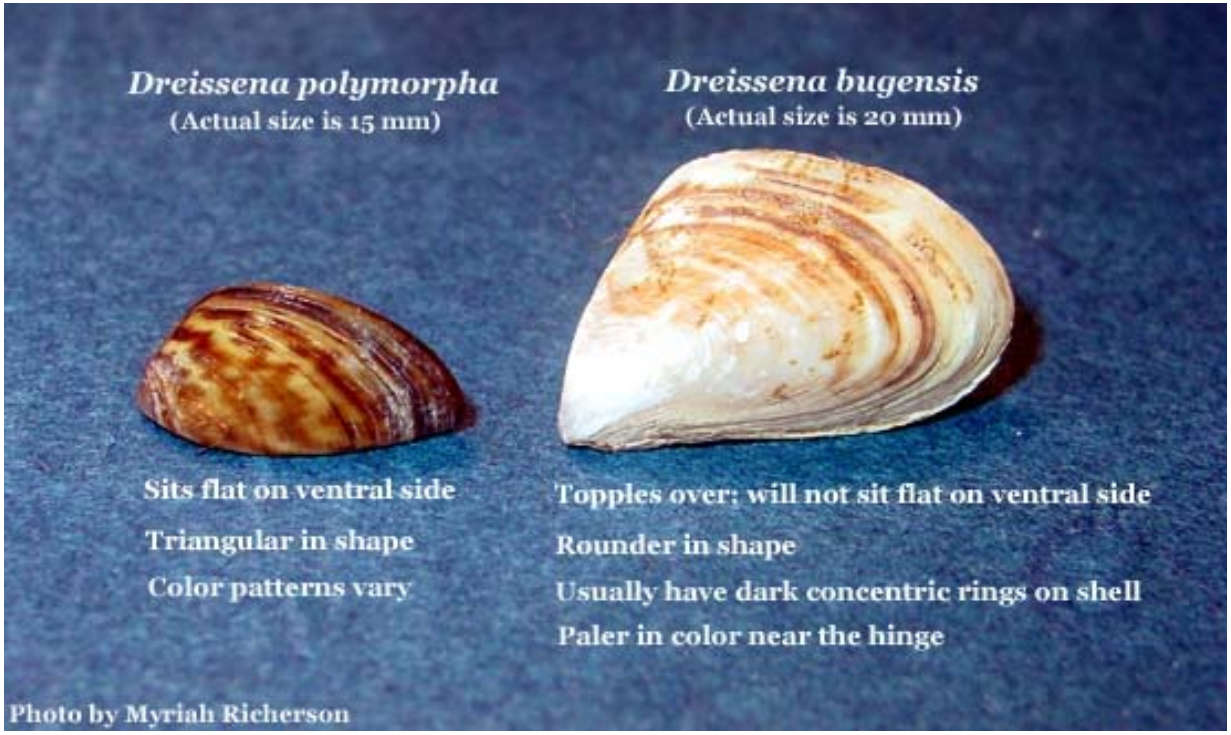
- 150 m (500 ft) from Lake Erie shoreline
- PVC pipe - ranges from 60 cm (24”) to 15 cm (6)”
- 61 tap-off points
- Two booster stations to maintain pressure
- Intake screen coated with Z-Alloy to repel mussels

Pumphouse Details

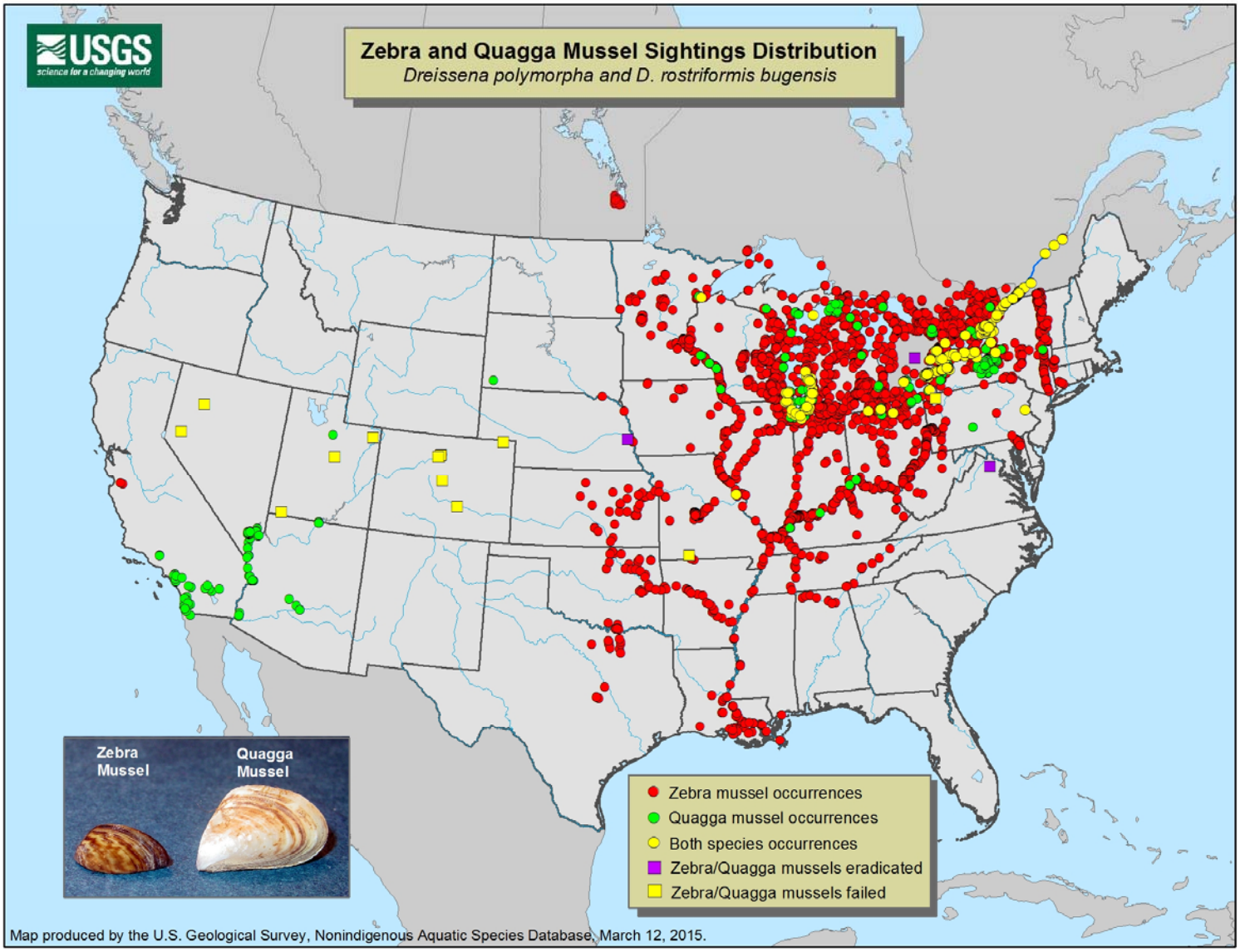
- 5 Variable (speed) frequency driven pumps (150 hp)
- 28 Netafim disc filters (100 µm)
- Closed-loop system for backwash
- 2 chlorine injection points (inlet and mainline)

Dreissenids 101

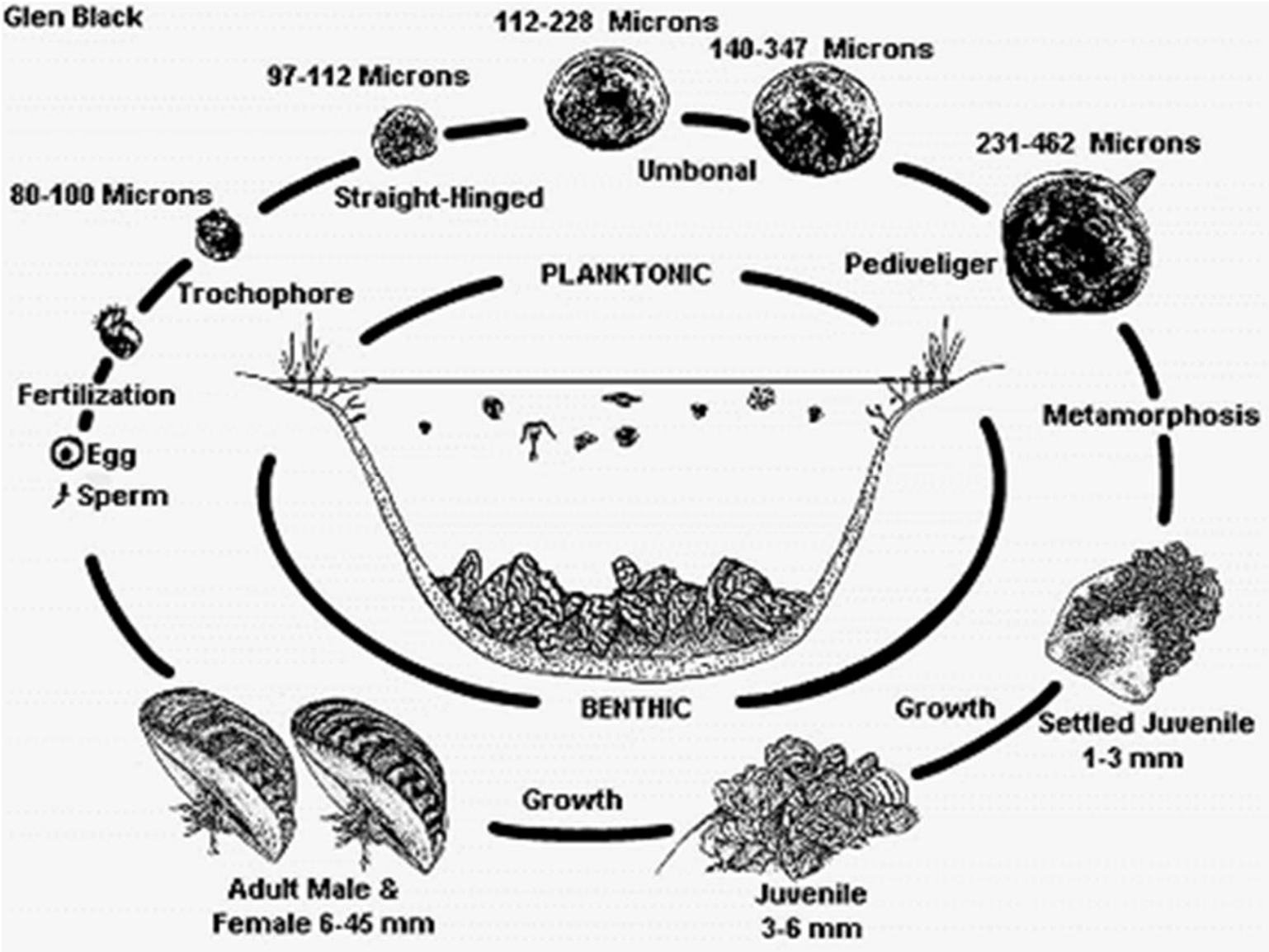
- Dreissenidae - 3 Species
  - Zebra Mussels (Dreissena polymorpha)
  - Quagga Mussels (Dreissena bugenis)
  - Conrad's False Mussel (Myilopsis leucophaeata)



Distribution



Zebra Mussel Life Cycle



Taken from Quagga and Zebra Mussel Biology And History of Invasion, Glen Black, 1996

Survival Thresholds

Parameter	**Adults do not survive long-term**	Uncertainty of veliger survival	Moderate Infestation Level	High Infestation Level
Calcium mg/L	<8 to <10	<15	16-24	≥24
Alkalinity mg $CaCO_3$/L	< 30	30-55	45-100	>90
Total Hardness mg $CaCO_3$/L	<30	30-55	45-100	≥90
pH	<7.0 or >9.5	7.1-7.5/ 9.0-9.5	7.5-8.0 or 8.8-9.0	8.2-8.8
Mean Summer Temperature ^{o}F	<64	64-68 or >83	68-72 or 77-83	72-75
Dissolved Oxygen mg/L (% saturation)	<3 (25%)	5-7 (25-50%)	7-8 (50-75%)	≥8 (>75%)
Conductivity µS/cm	<30	<30-60	60-110	≥100
Salinity g/L (ppt)	>10	8-10 (<0.01)	5-10 (0.005-0.01)	<5 (<0.005)
Secchi depth m	<0.1 >8	0.1-0.2 or >2.5	0.2-0.4	0.4-2.5
Chlorophyll a µg/L	<2.5 or >25	2.0-2.5 or 20-25	8-20	2.5-8
Total phosphorous µg/L	<5 or >50	5-10 or 30-50	15-25	25-35

Infestation & Control Challenges

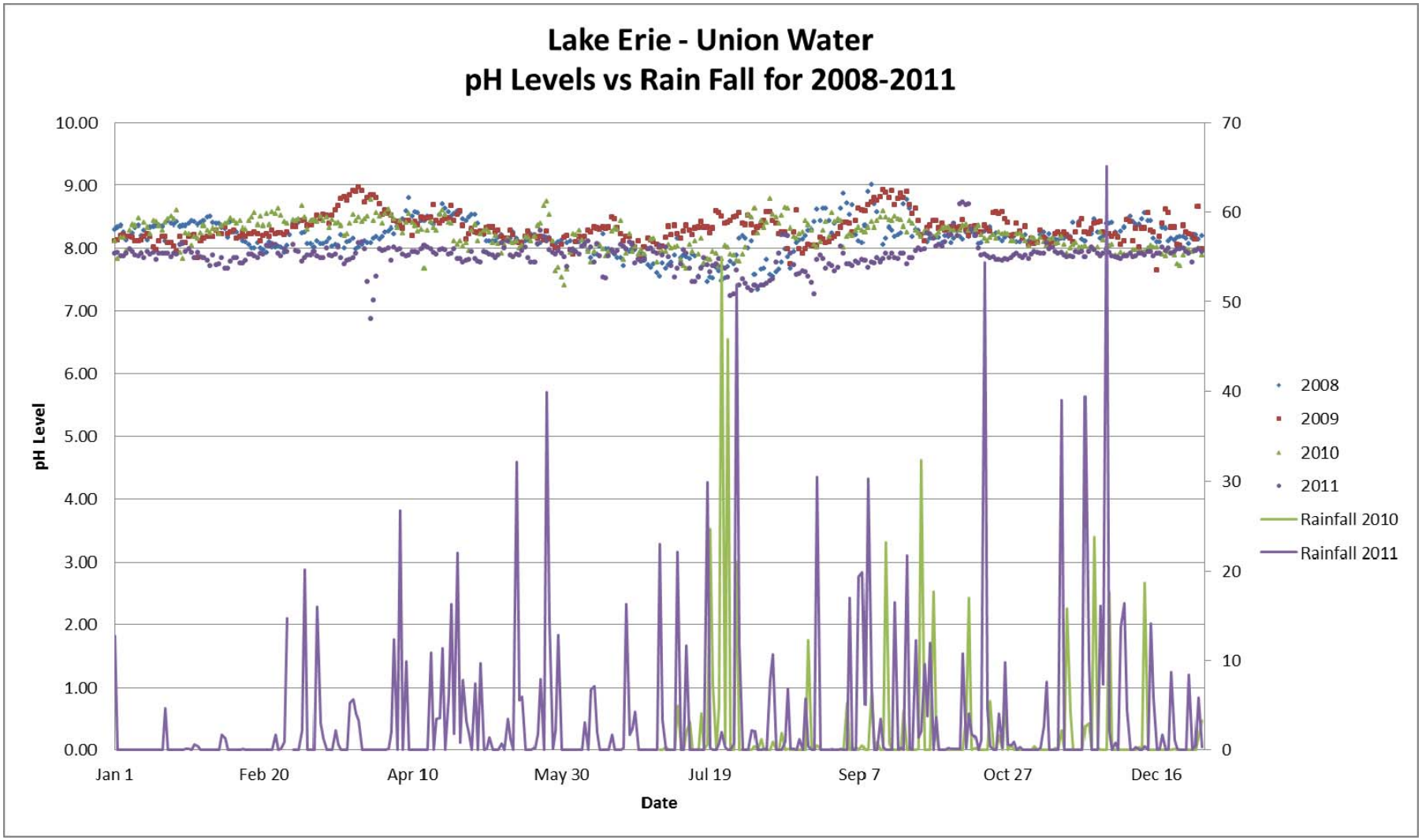
Ideal Environment (Lake Erie)

Table 3
Summary statistics for linear fits of Great Lakes chemical data from 1965 to 2009. Strong fits are indicated by bold-face and shading (P-value$<1\times10^{-4}$), and moderate fits by bold-face (<0.05). Note that the statistic $s_{y/x}$ is the standard error of the estimate (i.e., the root-mean-squared error of the residuals, adjusted for the two estimated coefficients).

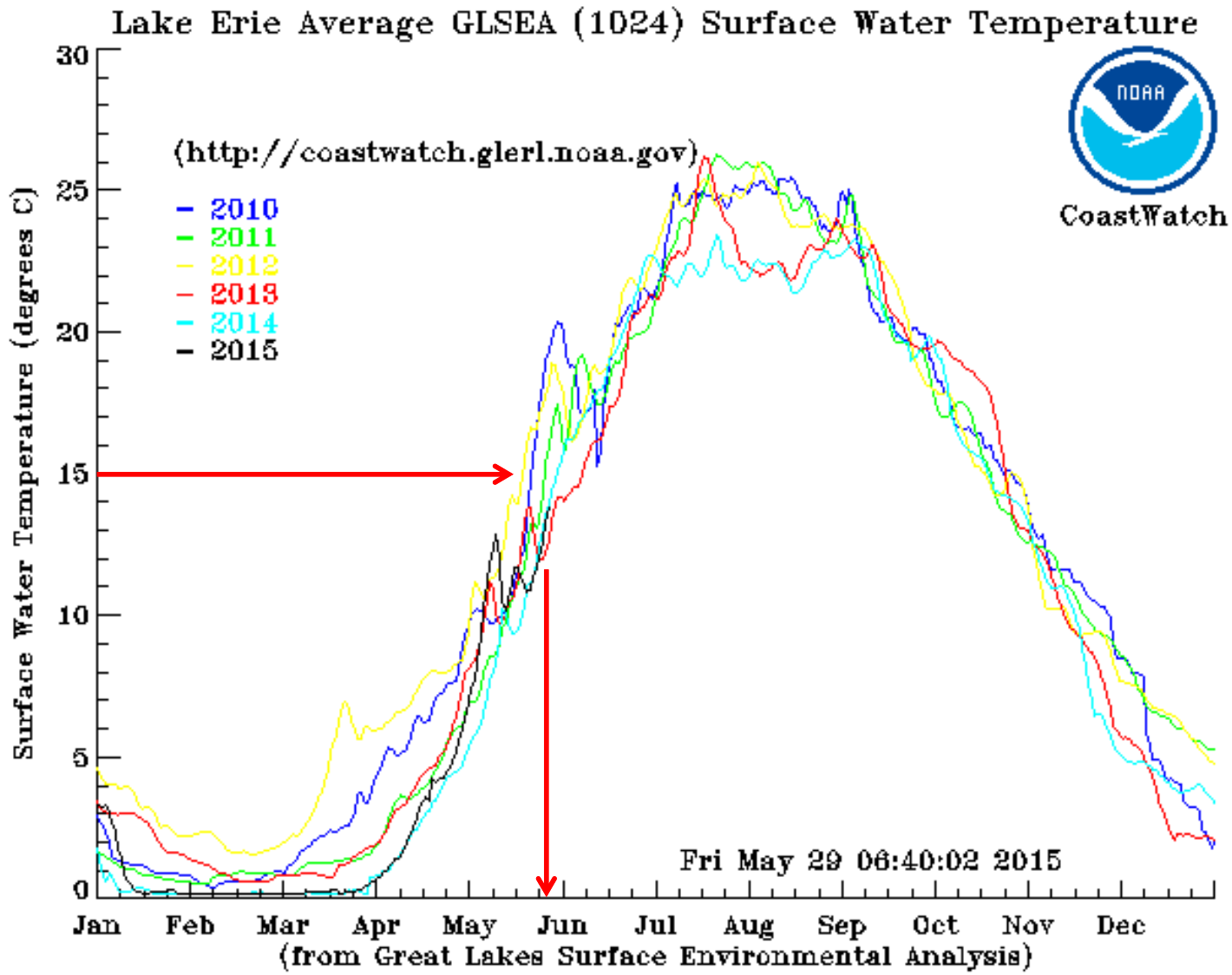
Lake	Statistic	Ca (mg L^{-1})	Mg (mg L^{-1})	Na (mg L^{-1})	K (mg L^{-1})	Cl (mg L^{-1})	SO_4 (mgSO_4L^{-1})	Spec. conduct. (µS cm^{-1})	Alkalinity (mg$CaCO_3L^{-1}$)
Superior	n	**22**	**21**	**21**	19	**34**	**20**	33	33
	$c(1970)$	**12.98**	**2.62**	**1.25**	0.484	**1.17**	**2.61**	97.3	41.1
	$c(2009)$	**13.62**	**2.83**	**1.44**	0.505	**1.42**	**3.85**	102.3	41.9
	rate	**0.0162**	**0.0053**	**0.0048**	0.00053	**0.0064**	**0.0319**	0.128	0.020
	r^2	**0.680**	**0.445**	**0.736**	0.064	**0.353**	**0.671**	0.104	0.051
	$s_{y/x}$	**0.149**	**0.081**	**0.040**	0.02 70	**0.106**	**0.290**	4.66	1.00
	P-value	**2.3×10^{-6}**	**9.6×10^{-4}**	**6.5×10^{-7}**	0.294	**2.1×10^{-4}**	**1.0×10^{-5}**	0.068	0.207
Michigan	n	16	15	**16**	13	**25**	13	**25**	25
	$c(1970)$	35.13	11.09	**4.45**	**1.096**	**6.53**	**20.46**	**272.18**	110.4
	$c(2009)$	35.95	11.28	**6.26**	**1.406**	**12.05**	**24.01**	**296.99**	107.9
	rate	0.0209	0.0048	**0.0464**	**0.00795**	**0.1414**	**0.0910**	**0.6363**	0.062
	r^2	0.017	0.015	**0.703**	**0.389**	**0.963**	**0.680**	**0.816**	0.093
	$s_{y/x}$	1.344	0.319	**0.255**	**0.0525**	**0.207**	**0.306**	**2.271**	1.46
	P-value	0.630	0.658	**4.9×10^{-5}**	**0.023**	**5.2×10^{-18}**	**5.2×10^{-4}**	**6.3×10^{-10}**	0.138
Huron	n	32	**31**	**31**	**29**	**43**	29	**42**	44
	$c(1970)$	26.45	**6.84**	**2.99**	**0.809**	**4.99**	15.60	**204.8**	77.0
	$c(2009)$	26.40	**7.46**	**3.86**	**0.939**	**6.58**	15.83	**215.9**	78.5
	rate	0.0014	**0.0158**	**0.0222**	**0.00334**	**0.0408**	0.0062	**0.284**	0.039
	r^2	0.000	**0.311**	**0.632**	**0.293**	**0.812**	0.024	**0.136**	0.048
	$s_{y/x}$	0.955	**0.237**	**0.170**	**0.0500**	**0.207**	0.379	**7.73**	1.84
	P-value	0.937	**1.1×10^{-3}**	**9.1×10^{-8}**	**2.4×10^{-3}**	**1.8×10^{-16}**	0.423	**0.016**	0.154
East Erie	n	**26**	**26**	26	**24**	**36**	**24**	**40**	**35**
	$c(1970)$	**37.52**	**7.75**	9.56	**1.235**	**20.64**	**24.80**	**309.22**	**94.7**
	$c(2009)$	**32.11**	**8.89**	8.58	**1.431**	**14.58**	**22.81**	**274.06**	**88.9**
	rate	**0.1389**	**0.0292**	0.0250	**0.00503**	**0.1553**	**0.0511**	**0.9018**	**0.149**
	r^2	**0.560**	**0.525**	0.081	**0.296**	**0.340**	**0.322**	**0.467**	**0.259**
	$s_{y/x}$	**1.465**	**0.331**	1.006	**0.0909**	**2.494**	**0.878**	**13.329**	**3.01**
	P-value	**1.1×10^{-5}**	**2.9×10^{-5}**	0.160	**6.0×10^{-3}**	**1.9×10^{-4}**	**3.8×10^{-3}**	**1.2×10^{-6}**	**1.8×10^{-3}**
Ontario	n	**36**	**36**	**36**	**34**	**48**	**35**	**52**	**47**
	$c(1970)$	**42.03**	**7.91**	**12.74**	**1.407**	**28.30**	**28.58**	**337.82**	**95.96**
	$c(2009)$	**33.55**	**8.61**	**11.56**	**1.501**	**19.56**	**25.54**	**305.32**	**90.08**
	rate	**0.2173**	**0.0179**	**0.0305**	**0.00241**	**0.2243**	**0.0781**	**0.8334**	**0.1507**
	r^2	**0.893**	**0.568**	**0.302**	**0.151**	**0.763**	**0.434**	**0.430**	**0.301**
	$s_{y/x}$	**0.741**	**0.153**	**0.456**	**0.0535**	**1.314**	**0.826**	**11.450**	**2.371**
	P-value	**4.6×10^{-18}**	**1.1×10^{-7}**	**5.1×10^{-4}**	**0.023**	**5.3×10^{-16}**	**1.7×10^{-5}**	**1.3×10^{-7}**	**6.5×10^{-5}**

Taken from Chapra et al. (2012) Journal of Great Lakes Research 38 (550–560)

Average pH Levels (Lake Erie)

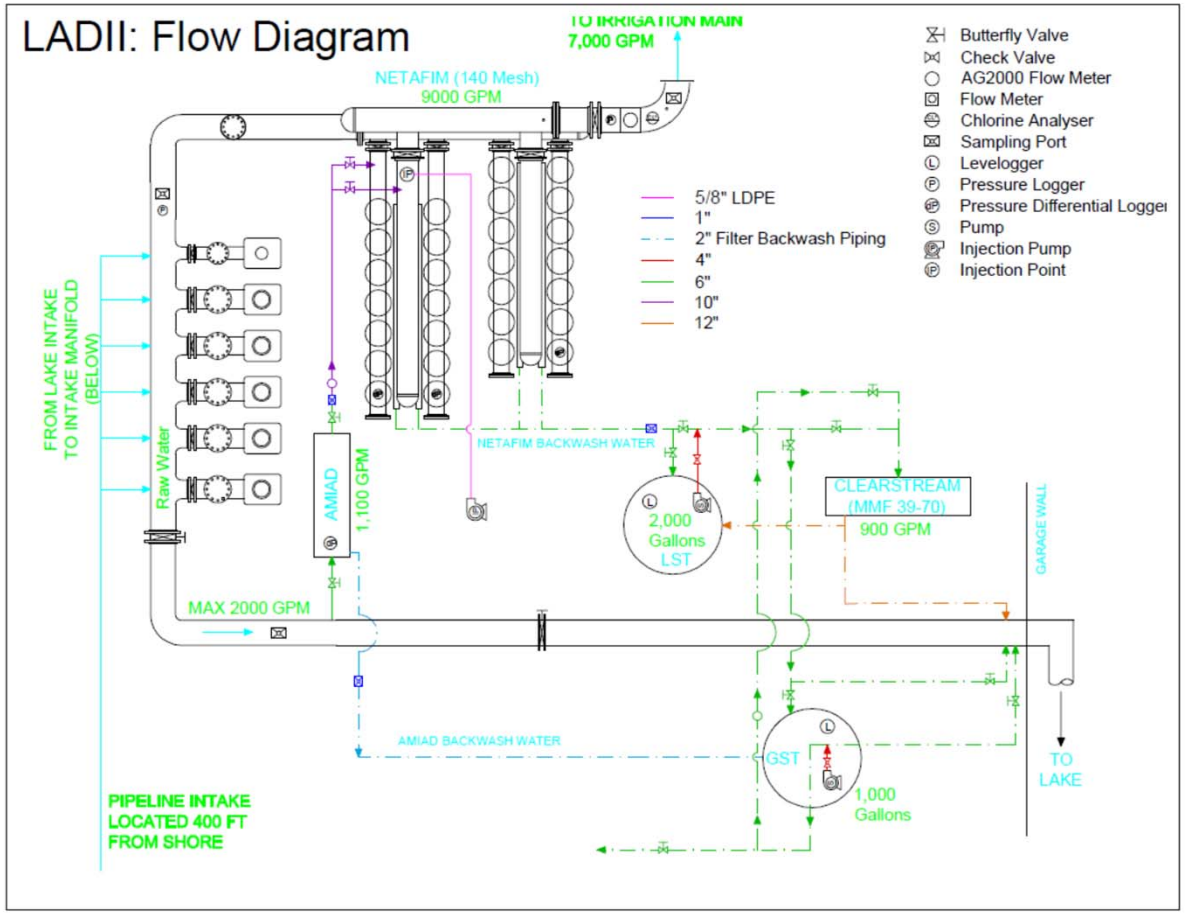


Average Temperatures (Lake Erie)



LADII Challenges

- Closed-loop design failed
- Chlorine not allowed at intake
- Need to consider safe chemicals for edible food



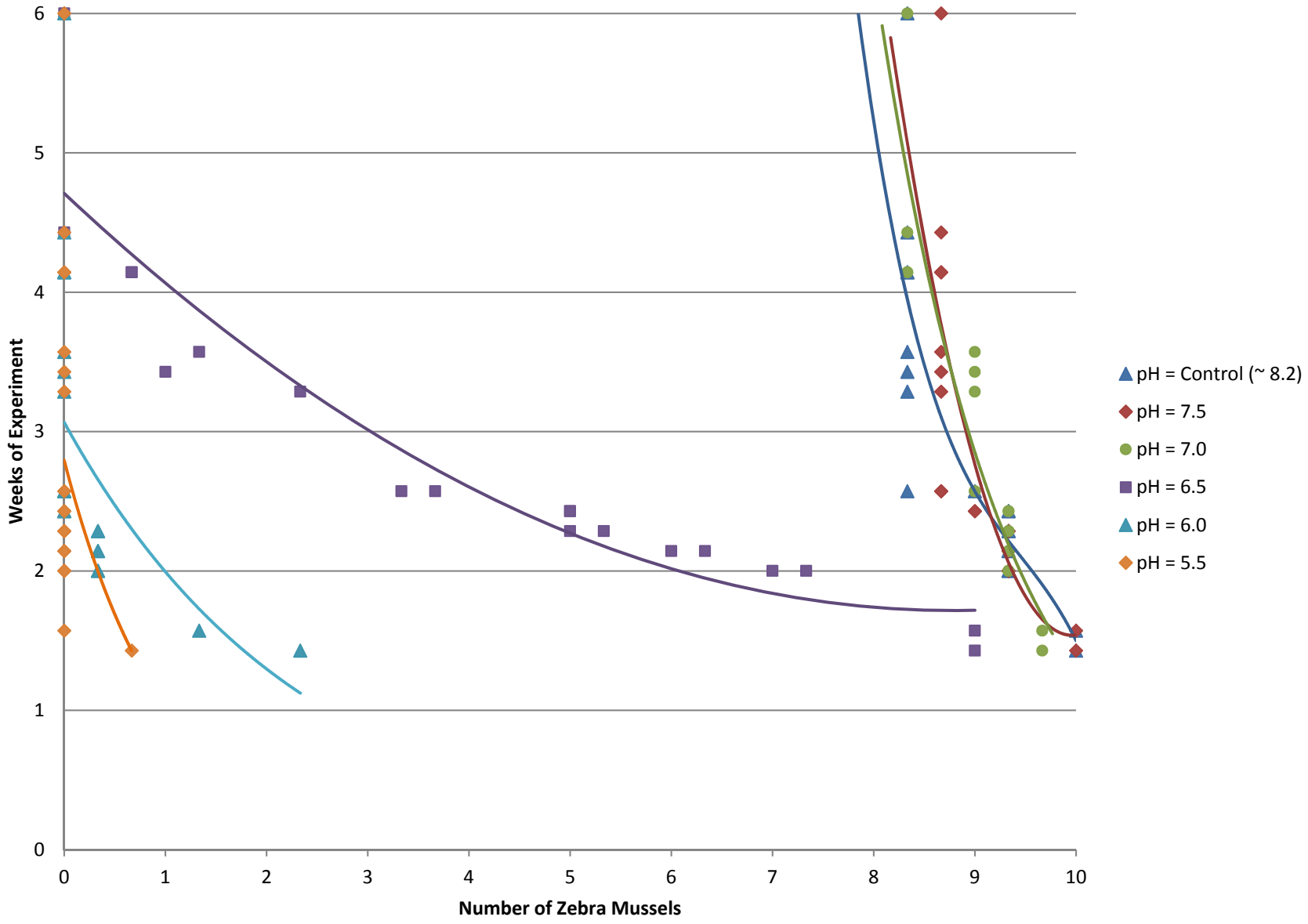
pH Adjustment as a Treatment

- Examined two uses for phosphoric acid:
  - pH control to prevent veligers from settling
  - pH control to kill adults
- Two step process
  - Mortality test
  - pH control on the irrigation system
- Veliger Identification in the system
  - Bio-boxes and visual inspections

Mortality Test

- Test consisted of looking at 5 different pH controlled environments, as well as 1 control using Lake water
  - pH 7.5, 7.0, 6.5, 6.0, 5.5 and a Control (~pH=8.2)
  - Three replicates per pH
- Each environment had 10 adult zebra mussels
- pH was monitored and corrected through-out the day for a duration of 6 weeks
- Zebra mussel mortality was monitored daily

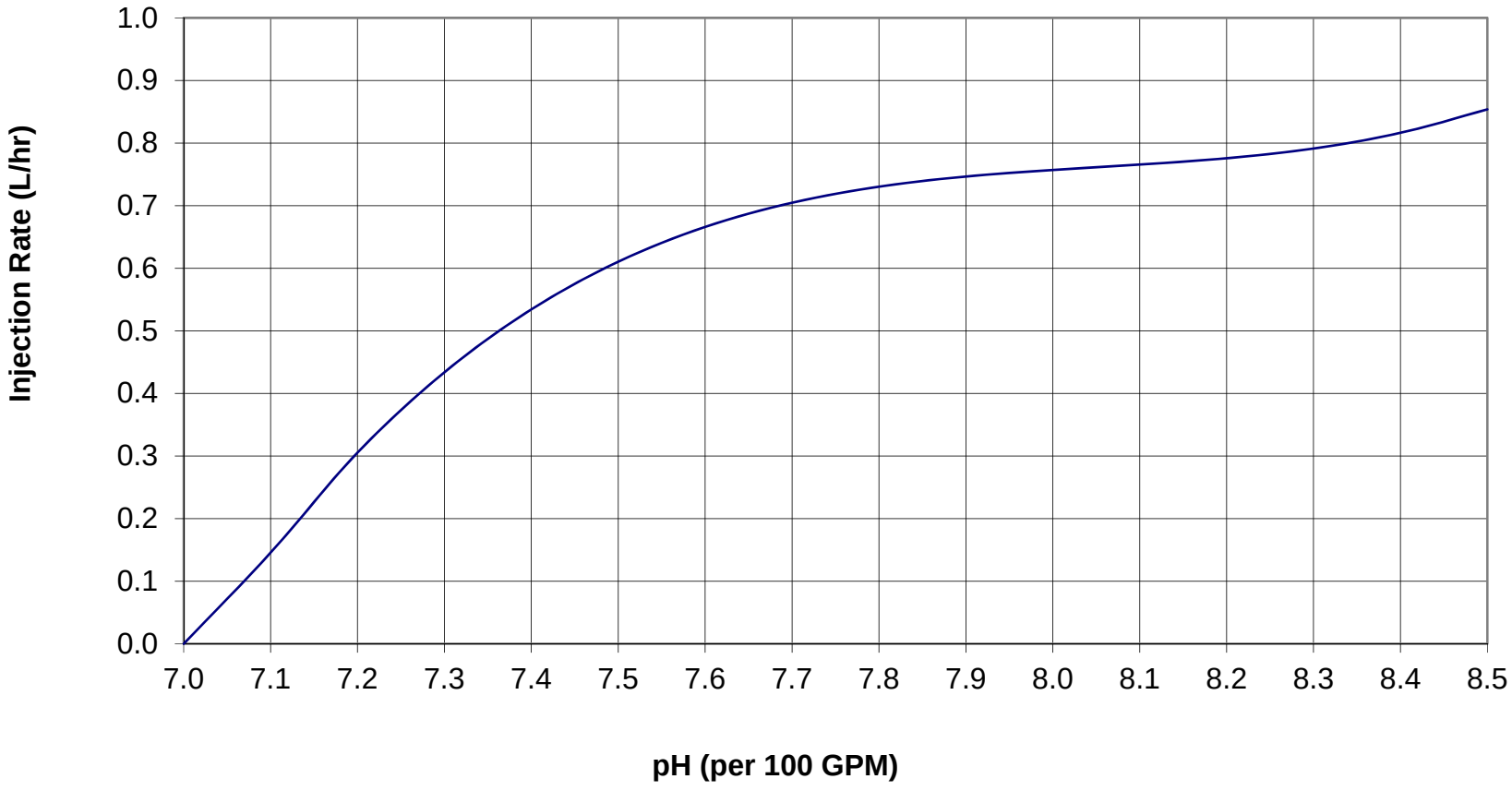
Zebra Mussel Mortality Rate



Acid Injection Trial

- Using the results of the zebra mussel mortality test, an acid injection trial was conducted to try and maintain a pH of 6.9 in the system
- An acid injection curve was developed using the pH corrections completed during the mortality test
- Diluted 85% Phosphoric acid to 40% to avoid corrosive effects on equipment
- Two trials :
  - November 2011
  - June 2012

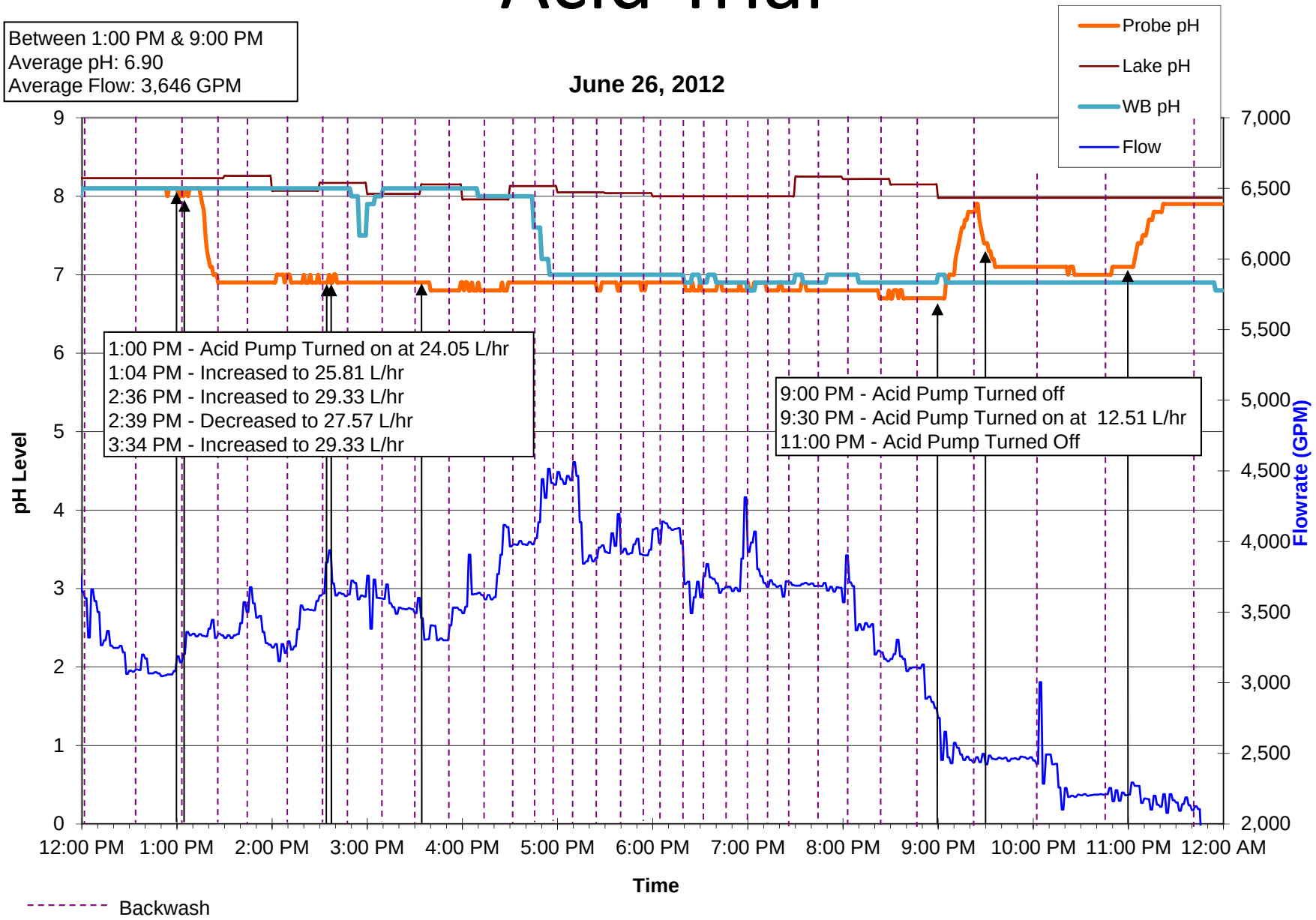
Phosphoric Acid (40%) Curve



Acid Injection Trial Results

	Average Initial pH (Lake)	Average Q (GPM)	Average Final pH (Metcon)	Calculated Injection Rate (L/hr)	Average Actual Injection Rate (L/hr
Day 1 (Nov 9)	8.19	866	6.90	6.71	6.24
Day 2 (Nov 10)	8.24	1166	6.88	9.11	8.32
Day 3 (Nov 28)	7.70	981	7.30	6.91	5.27
Day 4 (Nov 29)	7.62	1734	6.89	11.70	12.71
Day 5 (Nov 30)	7.87	963	6.83	7.15	9.55

Acid Trial


Between 1:00 PM & 9:00 PM
Average pH: 6.90
Average Flow: 3,646 GPM
June 26, 2012
Probe pH
Lake pH
WB pH
Flow
1:00 PM - Acid Pump Turned on at 24.05 L/hr
1:04 PM - Increased to 25.81 L/hr
2:36 PM - Increased to 29.33 L/hr
2:39 PM - Decreased to 27.57 L/hr
3:34 PM - Increased to 29.33 L/hr
9:00 PM - Acid Pump Turned off
9:30 PM - Acid Pump Turned on at 12.51 L/hr
11:00 PM - Acid Pump Turned Off
pH Level
Flowrate (GPM)
Time
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Backwash

Acid Injection Cost Analysis

Year 2011	L Acid 40%	L Acid 85%	Cost Acid (85%)	Gallons Water	Cost/1,000 G
January	926	440	$968	7,112,196	$0.14
February	936	445	$978	7,146,290	$0.14
March	1,084	515	$1,133	7,945,769	$0.14
April	1,183	562	$1,237	8,628,804	$0.14
May	1,479	703	$1,546	11,486,965	$0.13
June	4,370	2,076	$4,567	34,534,013	$0.13
July	10,095	4,796	$10,551	80,322,852	$0.13
August	4,273	2,030	$4,465	33,025,435	$0.14
September	1,328	631	$1,388	9,446,641	$0.15
October	1,181	561	$1,234	9,032,030	$0.14
November	1,122	533	$1,173	8,706,556	$0.13
December	275	131	$287	2,133,334	$0.13
Total	28,252	13,421	$29,527	219,520,885	(AVG) $0.14

Sample Collection & Identification

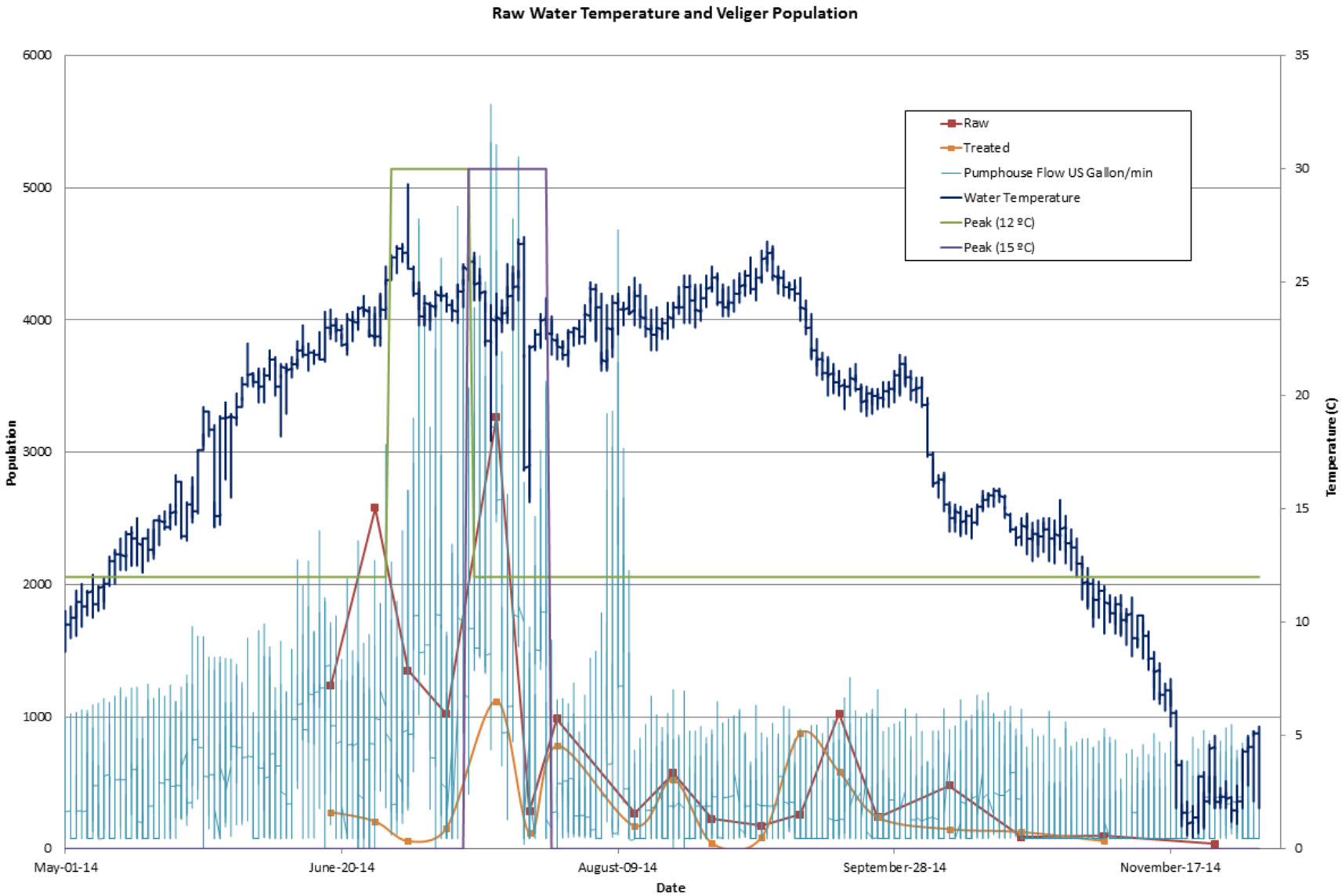
- Two sampling points
  - Raw (unfiltered)
  - Treated (after filters)
- A plankton net connected to a 20 µm filter was used to collect samples
- Using prepared samples, veliger observations made using a cross polarized light microscope

Veliger Identification

Raw June 18, 2014

Treated June 18, 2014

LADII's Risk of Infestation



Next Steps

- Continue to monitor the veliger population in the raw and treated water at LADII
- Monitor at areas further down the irrigation pipeline (booster stations, tap-offs and ponds)
- Run trials for different chemicals:
  - Hydrogen Peroxide
  - Potash
- Examine cost effectiveness of prevention vs. cleaning procedures

Acknowledgements

- My colleagues at AAFC
  - Sonja Fransen
  - Andrew Jamieson
- LADII Members
- Union Water
- RNT Consulting
  - Renata Claudi