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February 4, 2013

MEMORANDUM

TO: Council members

FROM: Jim Ruff – Manager, Mainstem Passage and River Operations

SUBJECT: Presentation on Portland State University research findings related to Dreissena mussels

Background

At the February 13, 2013, Council meeting in Portland, researchers from Portland State University (PSU) will present their findings concerning two research studies related to invasive quagga (*Dreissena bugensis*) and/or zebra mussels (*Dreissena polymorpha*). Both zebra and quagga mussels are invasive freshwater mussels that threaten the ecosystem and infrastructure of the Columbia River Basin. The presenters will be Dr. Mark Sytsma, who is the Associate Vice President for Research at PSU, along with research assistants Brian Adair and Steve Wells.

Study 1 -- The Importance of Calcium and Temperature in Growth of Quagga Mussels in Columbia River Basin Waters

The first study relates to quagga mussel growth and survival in water samples taken from the Columbia and Willamette rivers. Presenters will be Brian Adair and Mark Sytsma.

Methods. In this study, PSU researchers assessed the influence of calcium concentration and temperature on the survival and growth of quagga mussels (*Dreissena bugensis*) in water samples taken from the Willamette and Columbia rivers. To conduct this study, four calcium treatments were prepared by amending the Columbia and Willamette water samples with calcium chloride (CaCl₂). For each treatment, 10 juvenile mussels were reared in individual containers. A control group of mussels was reared in untreated water. Each treatment group was repeated at four different temperature regimes.

Findings. In the Willamette River water, a positive linear relationship was observed between calcium concentration and growth of juvenile mussels. Untreated Willamette River water had an average calcium concentration of 6 mg/L and the calcium chloride treatments increased uniformly up to 25 mg/L. A quadratic relationship was observed between temperature and quagga mussel growth, with the most

significant growth occurring between 16 and 20°C. Average change in weight for quagga mussels was negative in untreated Willamette River water at all temperatures. No trend in growth of juvenile quagga mussels was observed when tested in water from the Columbia River amended with CaCl₂. However, there appeared to be a threshold for optimal mussel growth between 35 and 50 mg calcium/liter. As with the Willamette River assays, a quadratic relationship between mussel growth and temperature was observed. Average change in weight for mussels in untreated Columbia River water was positive at all temperatures.

Study 2 – Field Evaluation of Service Life of Foul-Release Coatings in the Columbia River

The second PSU study pertains to evaluating the effective service life of various foul-release coatings placed on panels under ambient Columbia River conditions. Presenters will be Steve Wells and Mark Sytsma.

The purpose of this study was to determine the cost effectiveness of using foul-release coatings to mitigate the impacts of a zebra or quagga mussel infestation should these invasive species become established in the Columbia River Basin. These invasive freshwater mussels can foul hard substrates and clog water intake pipes and screens. Foul-release coatings are effective and non-toxic and may be part of an integrated control plan for these mussels at hydroelectric facilities in the Columbia River Basin. These coatings are soft, however, and there are concerns about abrasion, gouging, and adhesion failure under ambient conditions.

Methods. In this study, approximately 1,000 coated concrete and steel panels were deployed in the Columbia River in March 2012 to compare various foul-release coatings (including Intersleek 970, Sher Release, and Hempasil X3) to the coatings used presently by the U.S. Army Corps of Engineers (USACE) to protect submerged concrete (CrystalSEAL) and steel (Corps V766E), as well as bare concrete. This experiment is ongoing, and panels are removed at periodic intervals to assess physical damage and fouling resistance.

Findings to date. Panels were removed from the Columbia River after 3-month and 9-month immersion periods. Only the panels from the 3-month period have been evaluated to date. The only physical damage observed after 3 months of immersion was blistering on two Hempasil X3 panels (No. 2 Medium and No. 4 Few). All the panels were fouled by algae. Rinsing the panels with a 15-feet/second stream of water did not remove the algae from the bare concrete, from the CrystalSEAL panels, or from the Corps V766E panels. However, the water rinse did remove the algae and other soft-fouling organisms present on the foul-release coatings, and it did not damage the foul-release coatings.

Quagga mussels did not attach to any of the foul-release coatings in an *in-vitro* test. The maximum force needed to detach mussels from the panels decreased after 3 months immersion on the CrystalSEAL and bare concrete panels. A similar decrease in the mean strength of adhesion was measured, however, there was high within-treatment variation and the differences were not significant.

Panel evaluations will continue with the 9-month immersion treatment, and the 15-month immersion treatment will be removed from the Columbia River in July 2013. An *in-situ* experiment will be conducted in San Justo Reservoir, CA, which is infested with zebra mussels, to measure coating effectiveness under natural conditions. PSU will also be developing a detailed cost estimate for applying a foul-release system to a USACE Columbia River hydropower project.

Zebra/ Quagga Mussels:

BPA TI Research at Portland State University

- Quagga mussel survival and growth
- Field evaluation of foul-release coatings



Mark Sytsma, Steve Wells and Brian Adair
Center for Lakes and Reservoirs
Portland State University
Portland, Oregon

Northwest Power and Conservation Council • February 13, 2013

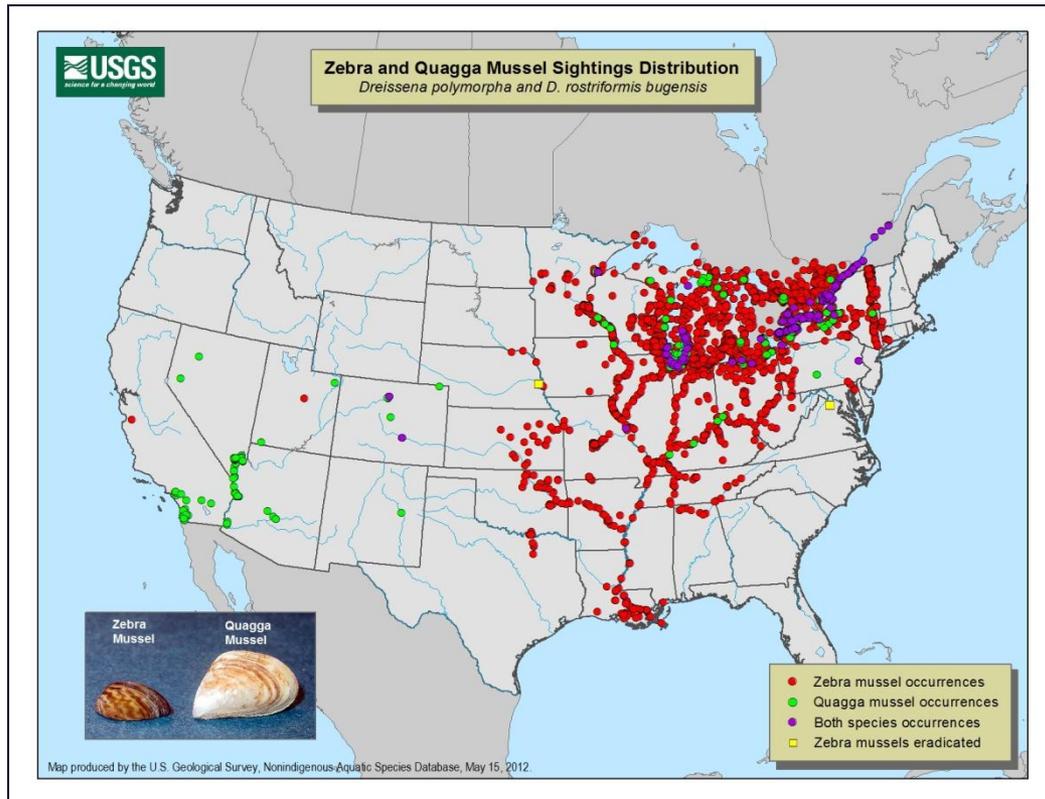
Zebra/ Quagga Mussel Background

- *Dreissena polymorpha* (zebra mussel)
- *D. rostriformis bugensis* (quagga mussel)
- Small, epifaunal, freshwater bivalves



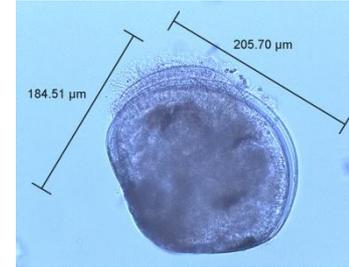
Zebra/ Quagga Mussel Background

- Late 1980's first found in Lake St. Clair
- Spread by hitchhiking adults or floating larvae



Zebra/ Quagga Mussel Background

- Rapid growth (15-20 mm/ yr)
- Prolific reproducers (40K - 1 M eggs/ yr)
- Form dense colonies (200,000+ / m²)



Trash rake @ Parker Dam, Colorado River
after 7 mo. in water.

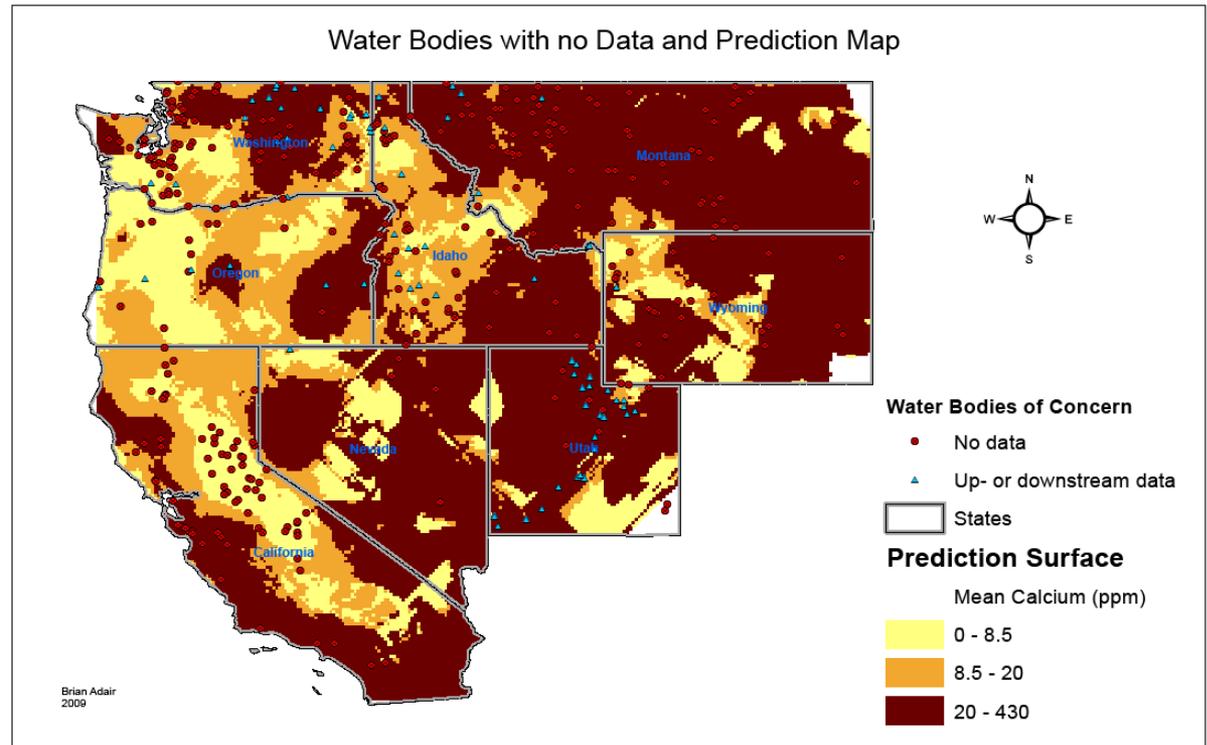
(Photographs provided by USBR)



Zebra/ Quagga Mussel Background

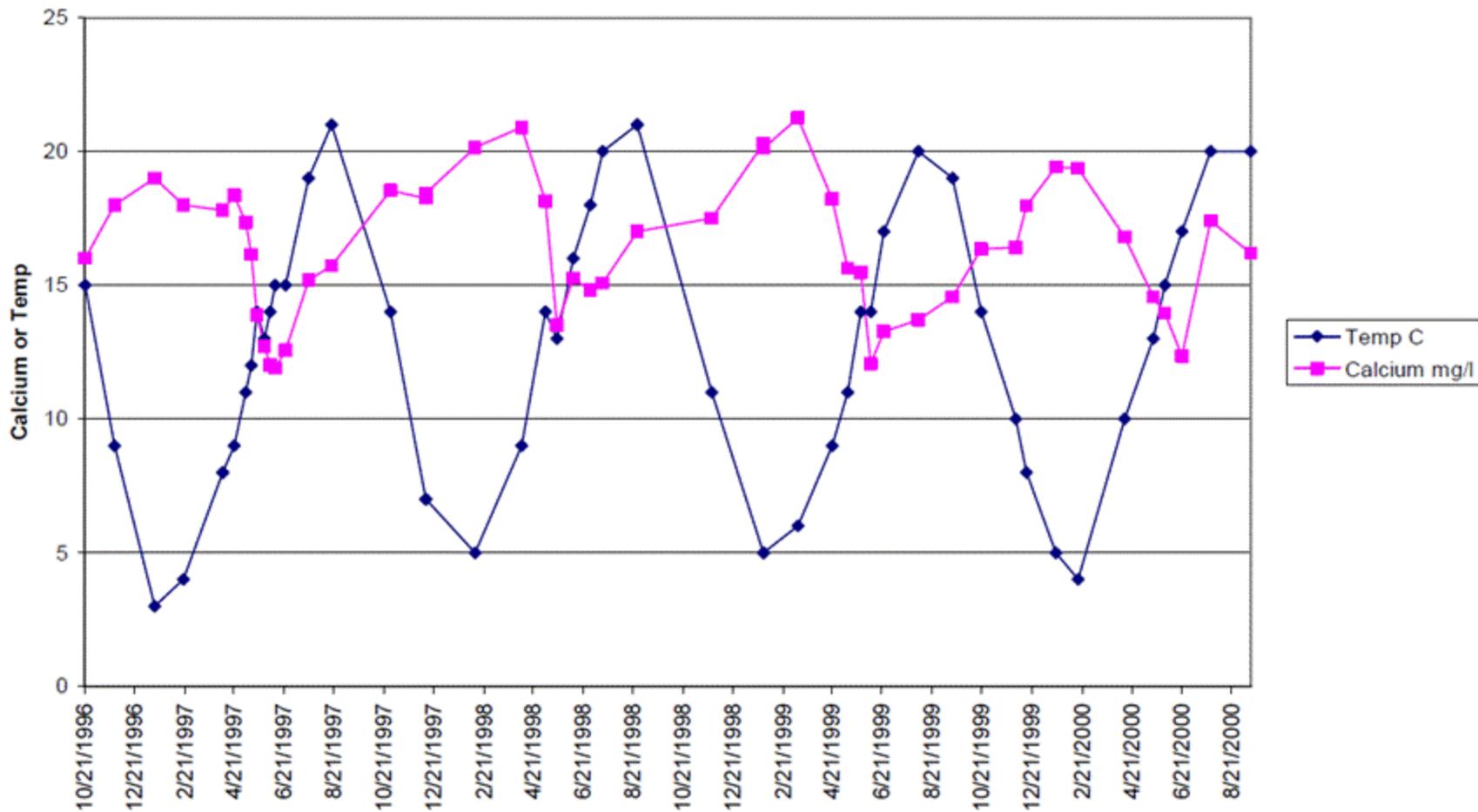
Zebra Mussel Requirements

- Calcium: $> 15 \text{ mg/ L}$
- pH: $6.8 - 9$
- Temp: $<5 - >30 \text{ C}$
- Salinity: $0 - 4 \text{ ‰}$
- Depth: $0 - >130 \text{ m}$
- Oxygen: $>2.4 \text{ mg/ L}$
@ 20° C



Zebra/ Quagga Mussel Background

Figure 6. Calcium and Temperature, Warrendale OR, 1996 to 2000, from NASQAN (Whittier, 2010a)



BPA TI Research at PSU

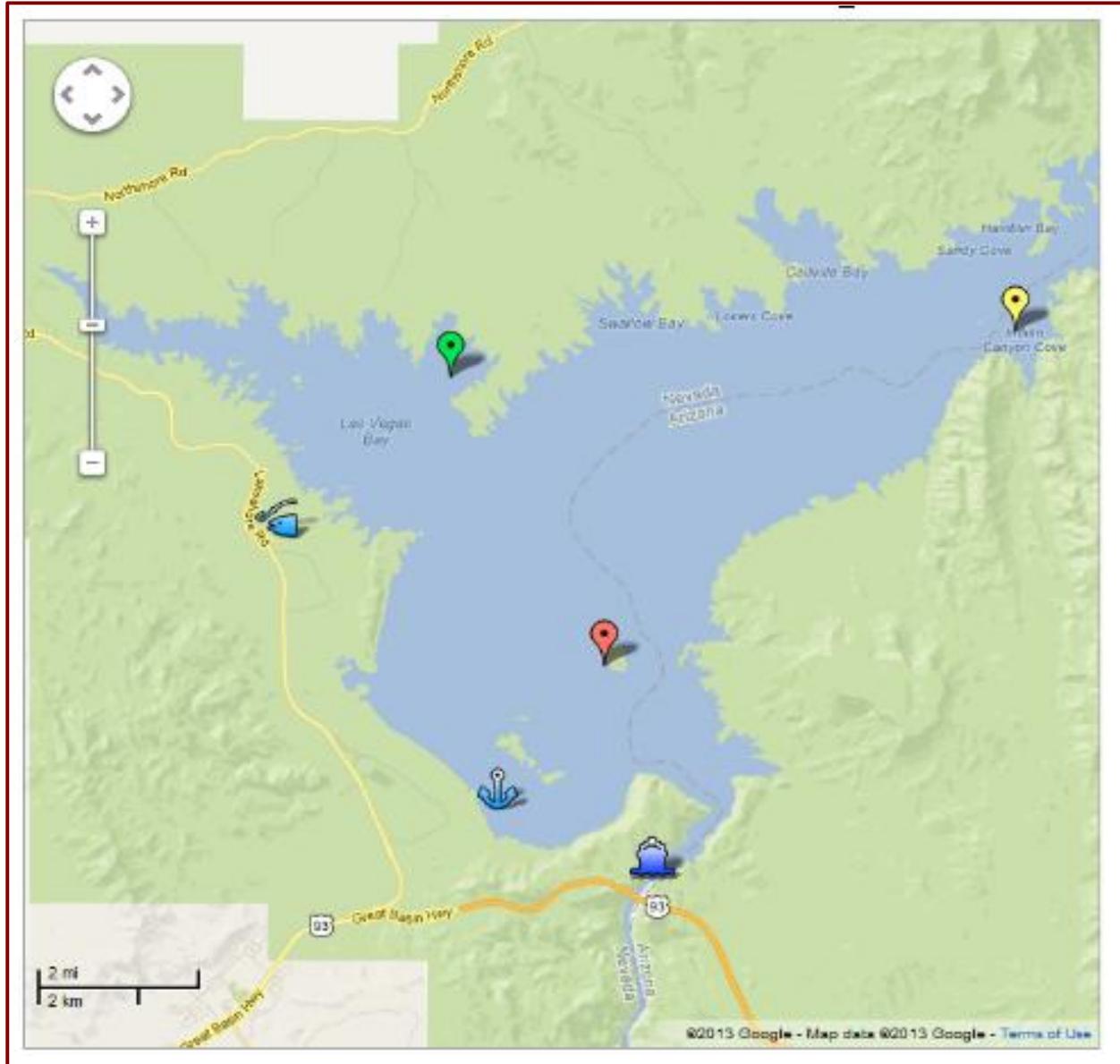
- **Quagga mussel survival and growth**

- Brian Adair (Graduate student in Environmental Science and Management)

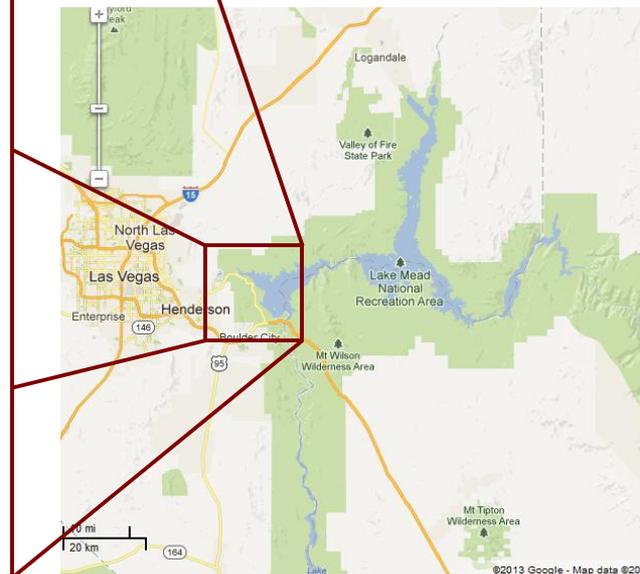
- **Field Evaluation of Foul-release Coatings**

- Steve Wells (Research Assistant)

Survival and Growth



-  Hatchery
-  Las Vegas Bay Marina
-  Hoover Dam
-  Sentinel Island Site
-  Las Vegas Wash Site
-  Indian Canyon Cove Site



Boulder Basin

Survival and Growth



Lake Mead Fish Hatchery – Building # 2469
Description: Exterior of the Upper Rearing Building.

Survival and Growth: Goals

- Develop method for rearing and feeding quagga mussels in the laboratory
- Determine whether or not quagga mussels survive and grow in the Columbia River Drainage
- Determine how calcium and temperature affect growth of quagga mussels
- Create models to predict growth of quagga mussels in the Columbia River Drainage

Survival and Growth: Background

➤ High calcium requirement

- Less efficient osmotic and ionic regulation vs other freshwater bivalves (Dietz et al. 1996)
 - “Leaky epithelium”
 - Rapid mortality in deionized water
- May preferentially invade waters $\text{Ca}^{2+} > 20 \text{ mg/ L}$ (Whittier et al. 2008)

➤ Temperature

- Zebra/ quagga growth rates and maximum size (Schneider 1992)
 - Important regulator of freshwater invertebrate growth

Survival and Growth: Study Sites

- Laboratory Experiments were conducted at the Lake Mead fish hatchery
- In Lake Studies were conducted at three location in Boulder Basin
- Quagga Mussels were collected from docks, pipes and lines at Las Vegas Bay Marina

Survival and Growth: Study Sites



Survival and Growth: Study Sites



Survival and Growth: Study Sites

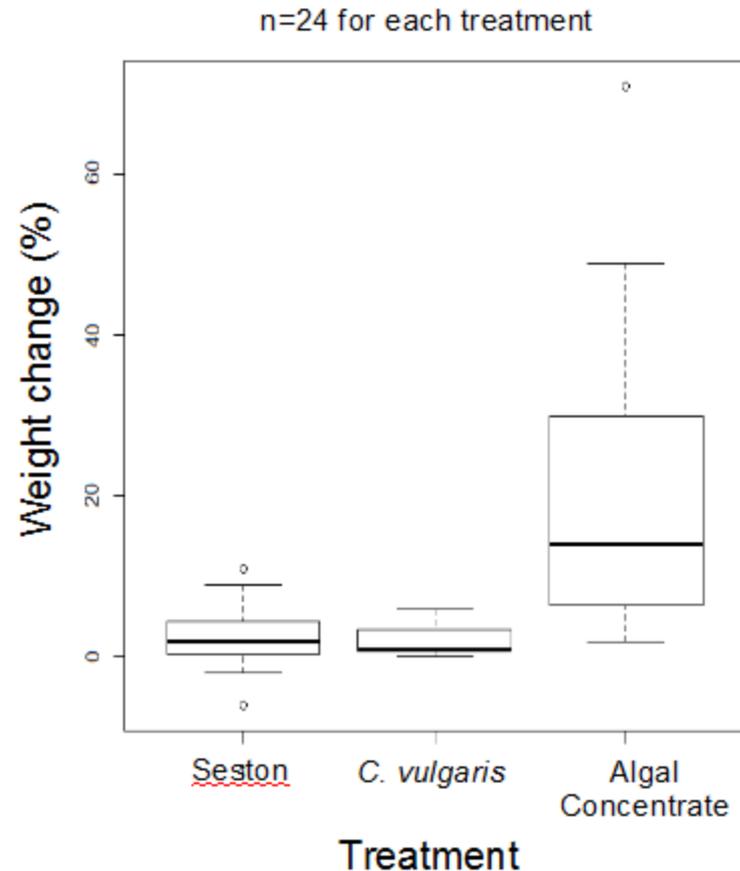


Survival and Growth: Study Sites



Survival and Growth: Diet Study

- Three diets tested
 - Natural seston
 - Freeze-dried *C. vulgaris*
 - Commercial algal concentrate
- Mussels grew best on the algal concentrate
- Growth best at highest conc., 9.6 mg dry-weight/ d (4.8 mg \approx Lake Mead)
- Some lost weight on natural seston



Survival and Growth: Calcium & Temp

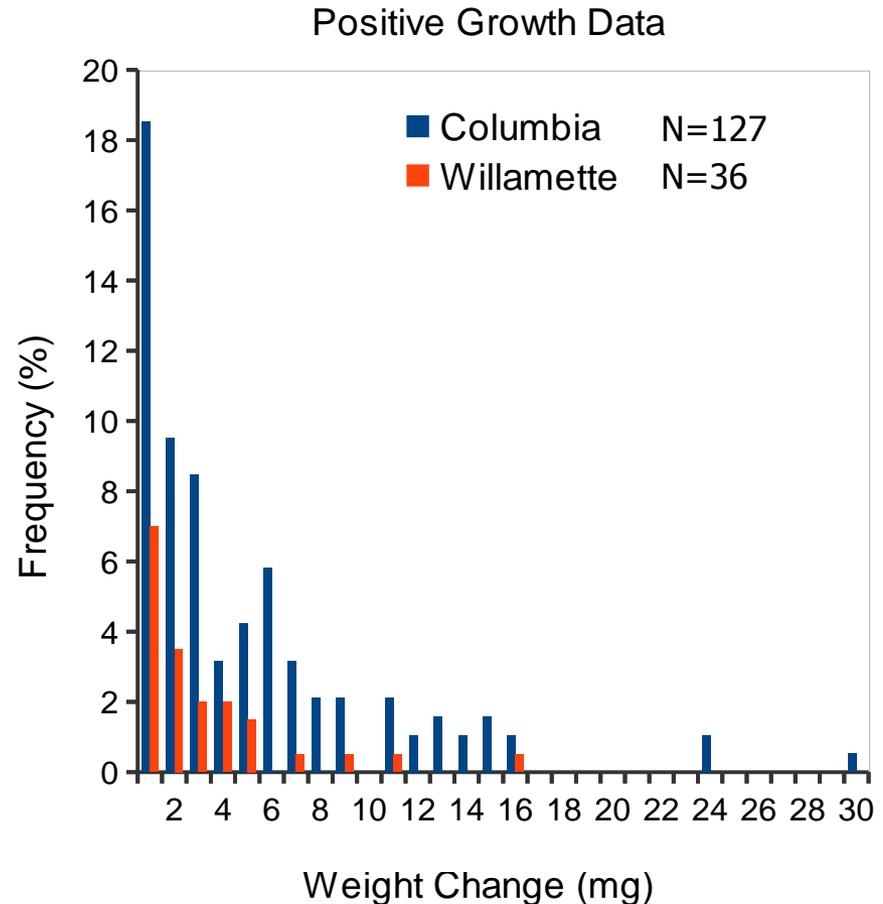
➤ 68% of mussels reared in untreated water from the Columbia gained weight

- Mean weight gain = 3.2 mg
- Max = 30 mg

➤ 19% of mussels reared in untreated water from the Willamette gained weight

- Mean weight gain = 2.2 mg
- Max = 16 mg

Frequency of Weight Change: Quagga Mussels



Survival and Growth: Calcium & Temp

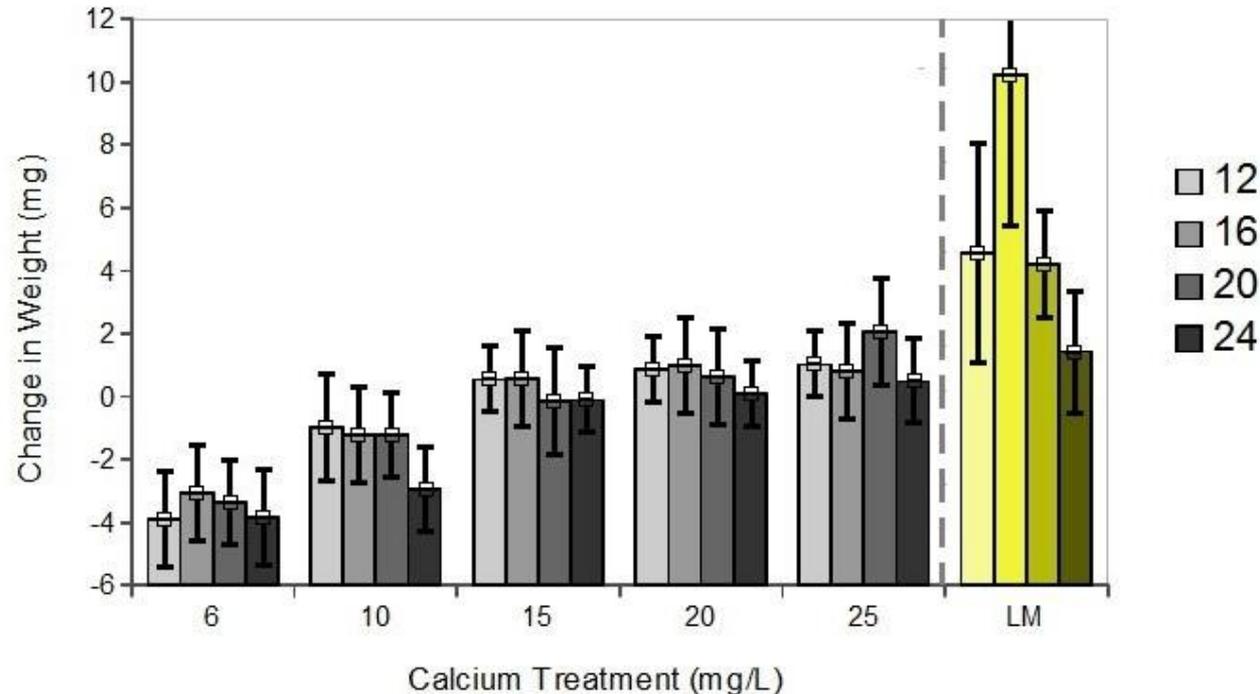
Comparison of growth rates among treatments in lab at 16 ° C and growth in Lake Mead during Winter (14-16 ° C)

<u>Treatment</u>	<u>n</u>	<u>Mean Weight Gain</u>	<u>SD</u>
Willamette River (Untreated)	47	-3.1	5.1
Columbia (Untreated)	47	3.8	5.0
Columbia (80 mg/L)	48	4.1	7.9
Lake Mead in Trough	10	7.2	7.3
Lake Mead in Lake (Winter)	12	23.1	8.4

Survival and Growth: Calcium & Temp

Growth vs Calcium and Temperature

Willamette River Bio-assay

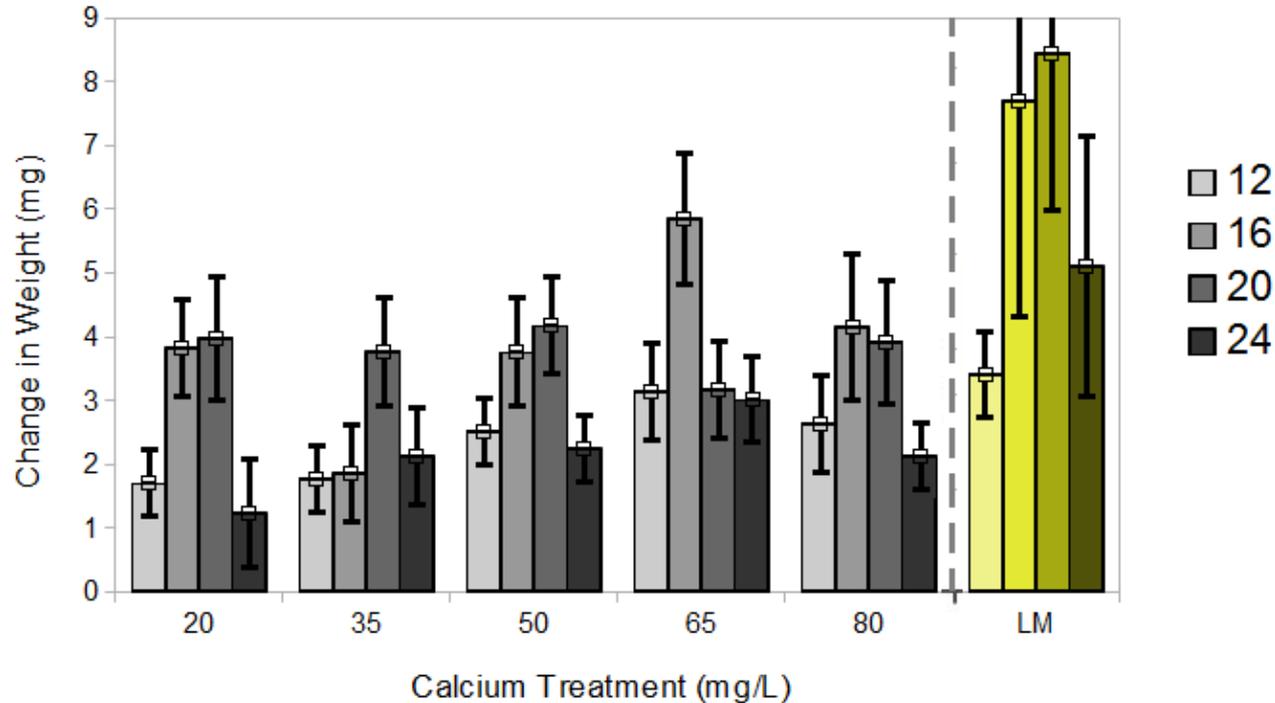


- Positive linear trend observed between calcium and growth.
- Weak quadratic relationship observed between temperature and growth.

Survival and Growth: Calcium & Temp

Growth vs Calcium and Temperature

Columbia River Bio-assay



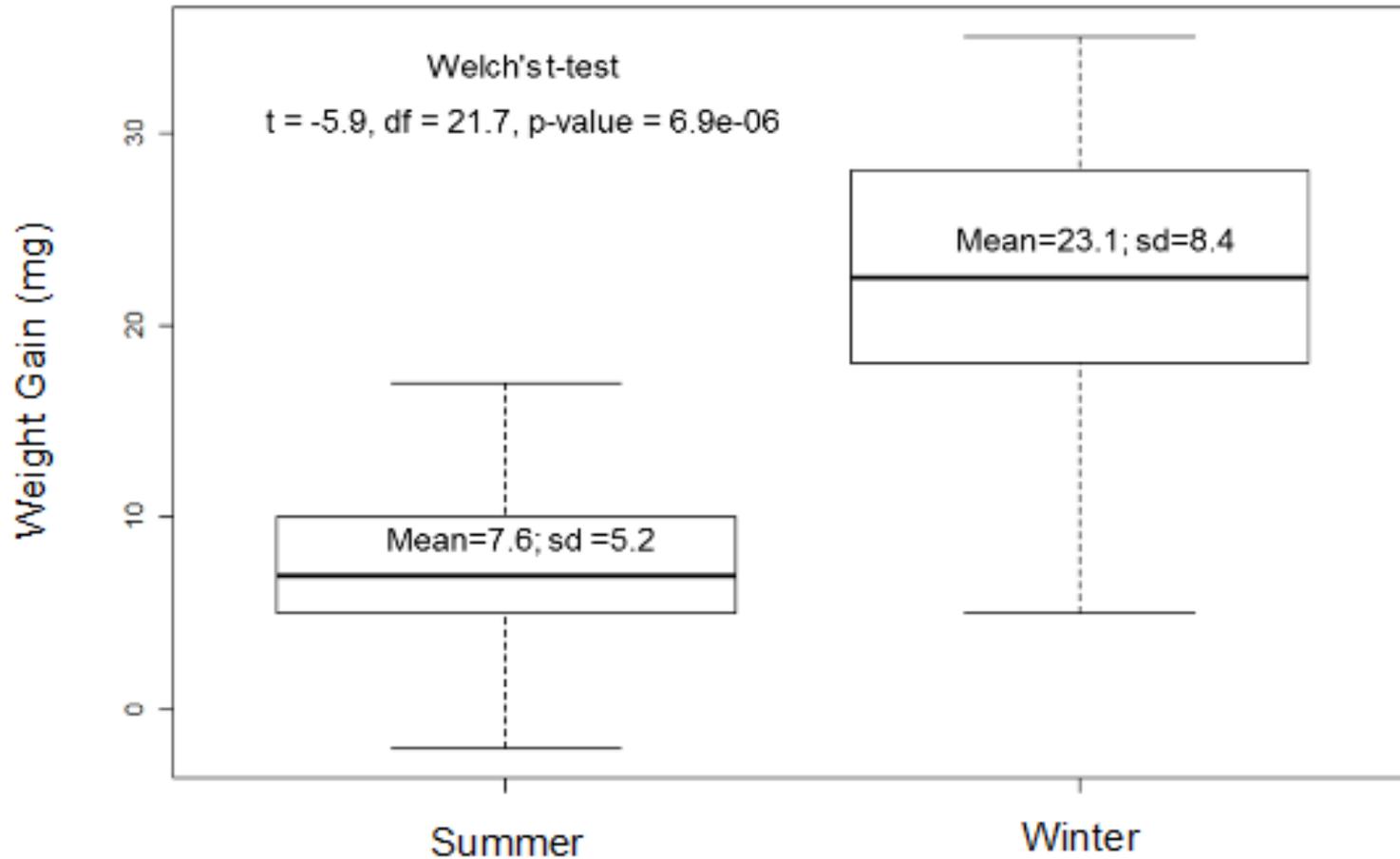
- No trend observed between calcium and growth, but possibly a threshold between 35 mg/L and 50 mg/L
- Quadratic relationship observed between temperature and growth.

Survival and Growth: Calcium & Temp

- Growth in Willamette Water was significantly lower than growth in Columbia water at comparable Ca^{2+} concentration
- Willamette trials were conducted during summer and early fall
 - Water temperature in lake was high (24-28 ° C)
 - Limited growth in lake
 - High mortality during acclimation period
- Columbia trials were conducted during fall, winter and early spring
 - Water temperature in lake was low (14-16 ° C)
 - High growth in lake
 - Low mortality during acclimation period

Survival and Growth: Calcium & Temp

Comparison of Growth at Las Vegas Bay Marina by Season



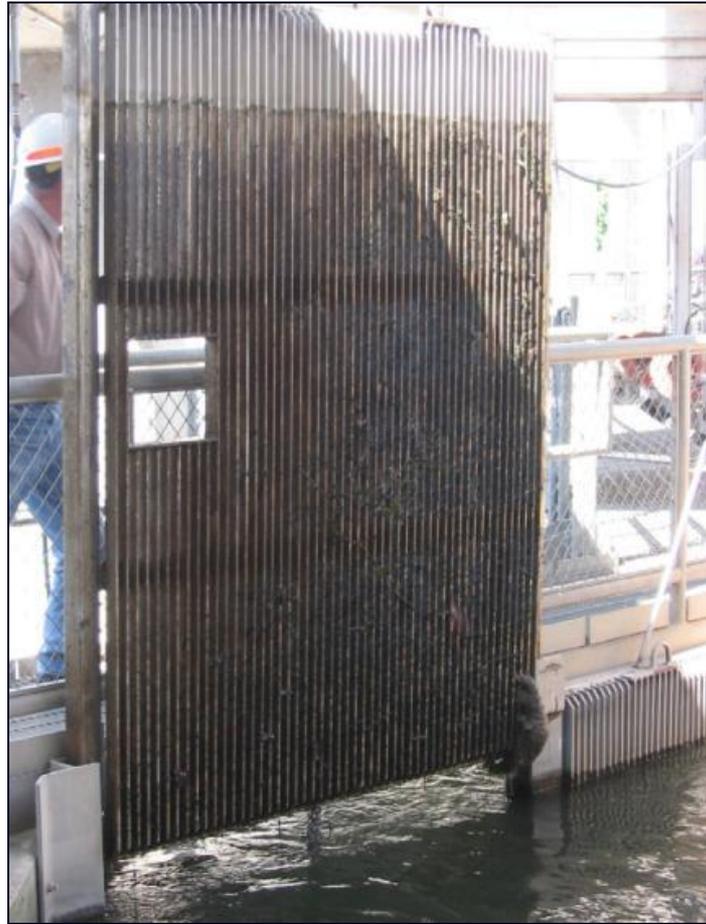
Survival and Growth: Conclusions

- The Columbia River appears to be suitable for quagga mussels
 - 68% of mussels survived (N=50)
 - Mean growth of 3.2 mg over a 6 week period
- The Willamette River may be marginal habitat. However, there is a potential for regional adaptation
 - 19% of mussels survived (N=50)
 - Mean growth of 2.2 mg over a 6 week period
- Both calcium and temperature are significant predictors of mussel growth
 - Relationships are not simple linear relationships
 - There appears to be a “treatment effect” (e.g. time of year)

Survival and Growth: Next Steps

- Finish analysis of data using mixed linear analysis
- Develop predictive models that describe the growth potential of mussels in the Columbia Basin
- Finish the final report

Field evaluation of foul-release coatings



Foul-release: Methods

➤ Efficacy of 3 foul-release coatings on concrete and steel panels in CR conditions

- Intersleek 970 (International)
- SherRelease (Fuji/ SW)
- HempasilX3 (Hempel)

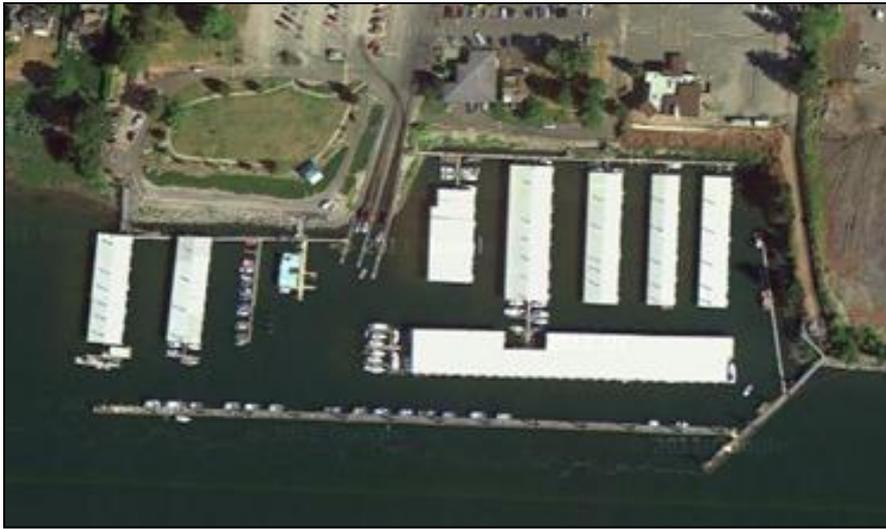


- CrystalSEAL, Corps V766E and bare concrete as control surfaces

➤ Developing detailed cost estimates for application to FCRPS hydro facility

Foul-release: Methods

Field deployment – March/April 2012



Foul-release: Methods

Post deployment analyses:

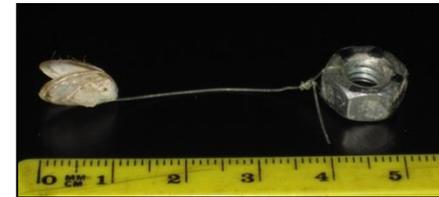
➤ Resistance to damage by field deployment

- % cover soft fouling, e.g. algae (ASTM D6990-05, image analysis)
- Physical damage, e.g. blistering (ASTM D772-05, D6990-05, D660-05, D661-05, D662-05, D714-02, Pictorial Standards of Coating Defects Handbook)
- Adhesion strength to substrate (ASTM D6677-07)
- Erosion (ASTM D4938-07 and Skaja 2012)
- Surface roughness (ASTM D7127-05)
- Undercutting corrosion (ASTM D1654-05 & Weaver and Beitelman (2001))



➤ Resistance to mussel attachment

- Detachment force to remove mussels (ASTM D5618-11)



Foul-release: Deliverables

- Panel retrieval & evaluation after 0, 3,9, 15, 21, 27, 33, 39 mo. immersion
 - 108 per immersion treatment
- Summary and presentation of data
- Cost and timeline to apply to CRB hydro facility
- Extra panels for evaluations > 39 mo.

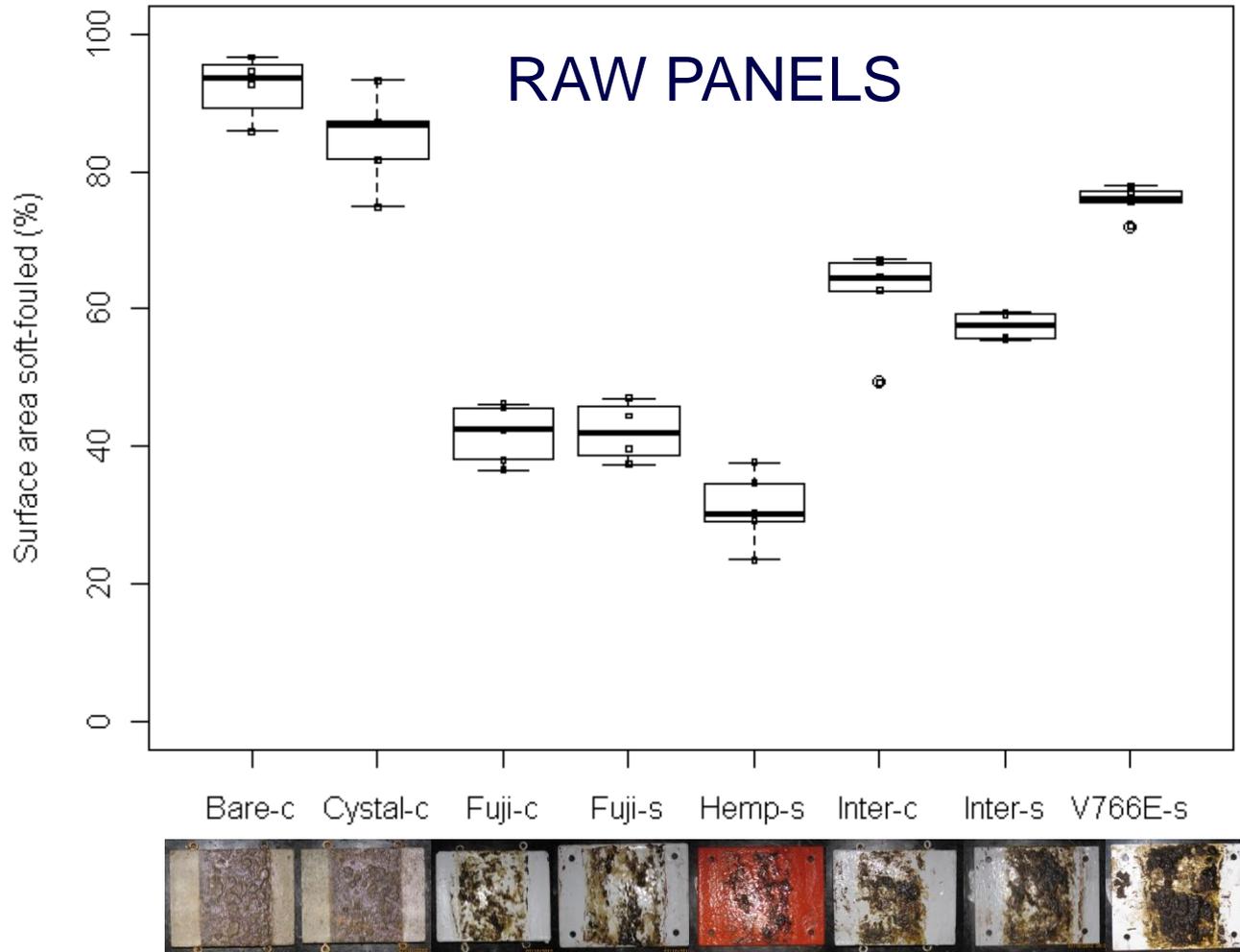
Foul-release: Preliminary Results

- 3 & 9 mo. panel retrieval (July 2012, Jan. 2013)



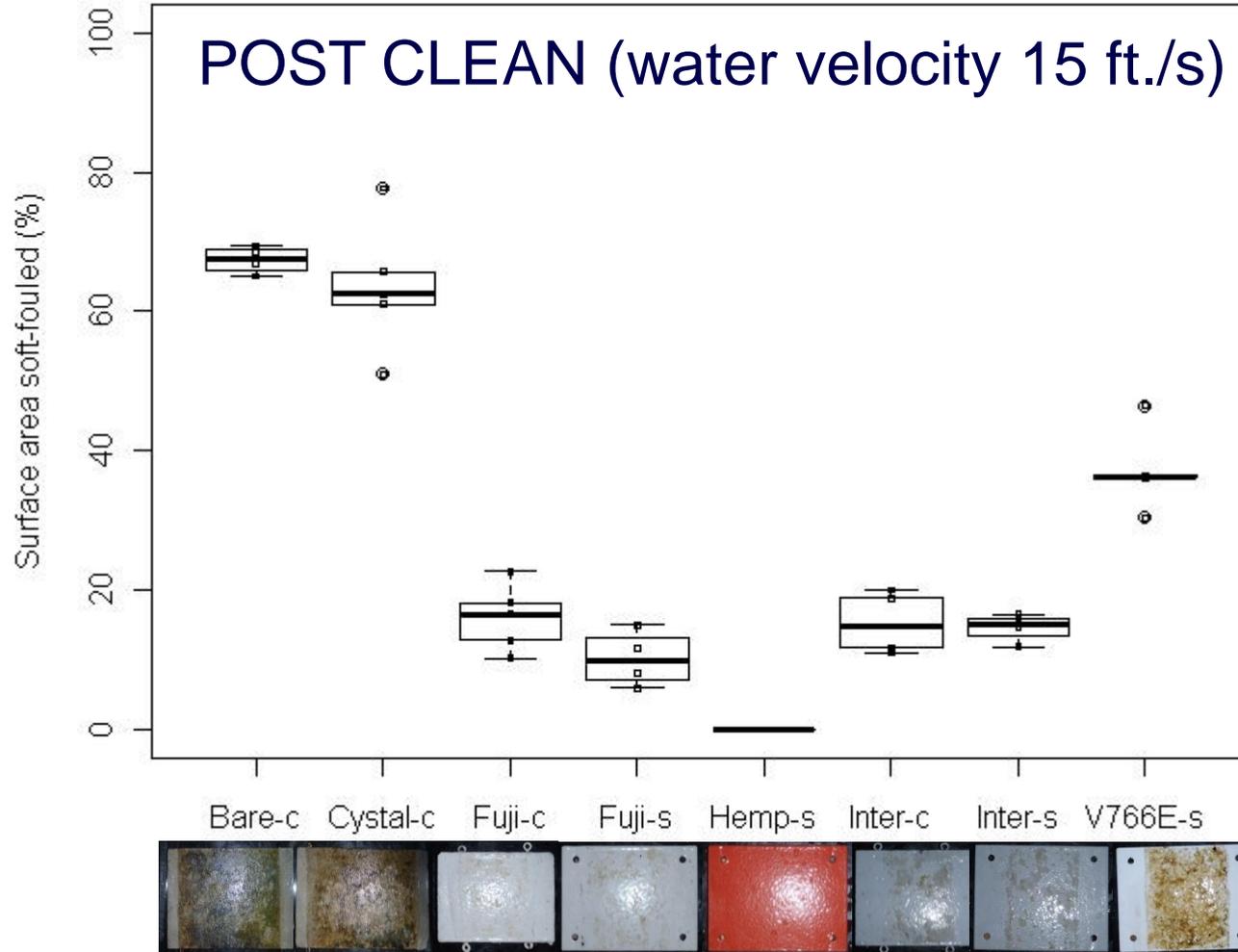
Foul-release: Preliminary Results

- 3 mo. % surface area soft-fouling



Foul-release: Preliminary Results

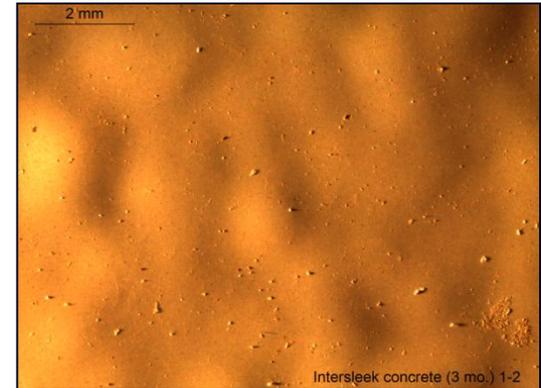
- 3 mo. % surface area soft-fouling



Foul-release: Preliminary Results

➤ 3 mo. physical damage

- Alligatoring:.....none
- Flaking:.....none
- Peeling:.....none
- Wearing:.....none
- Cracking:.....none
- Checking (visible):.....none
- Checking (microscopic):..none
- Blistering:..... 2 Hempasil panels



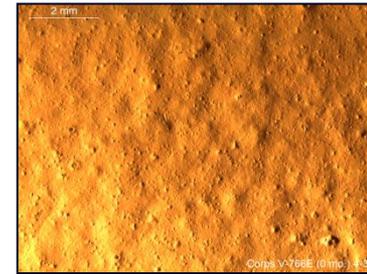
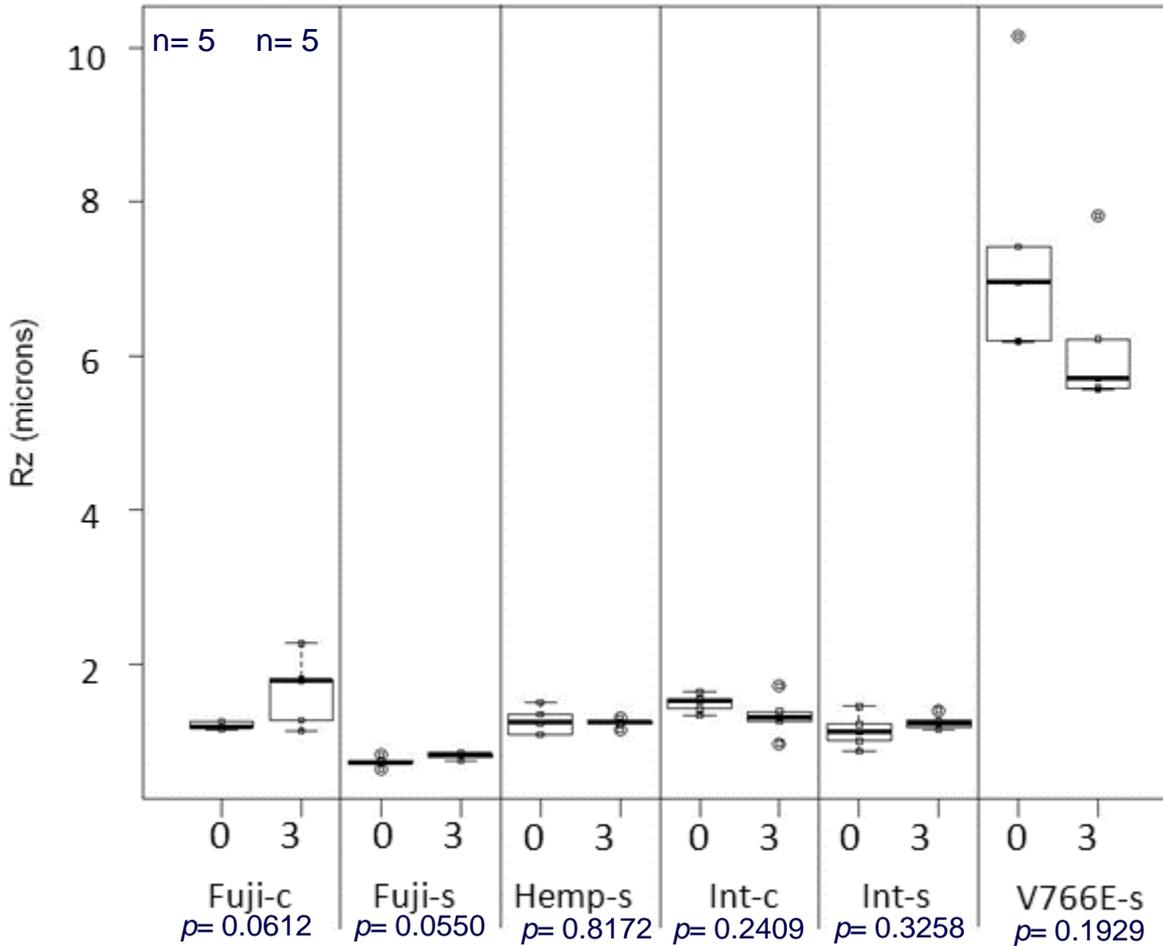
Photomicrograph of Intersleek on concrete w/ no damage.



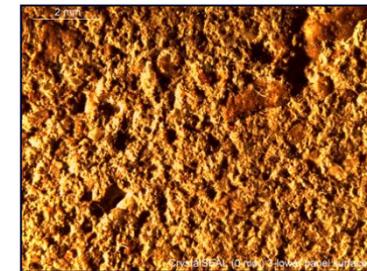
Photographs of Hempasil X3 w/ No 2. Medium blisters

Foul-release: Preliminary Results

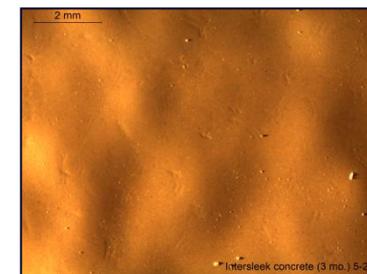
➤ 3 mo. surface roughness



V766E steel
(0 mo.)



CrystalSEAL
concrete
(0 mo.)

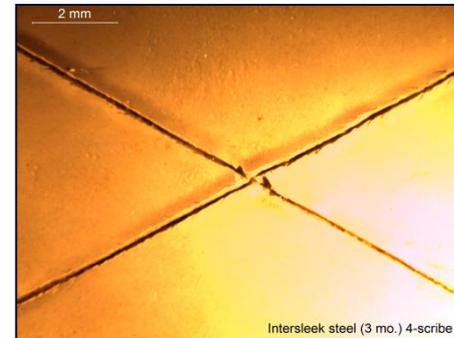


Intersleek
concrete
(3 mo.)

Foul-release: Preliminary Results

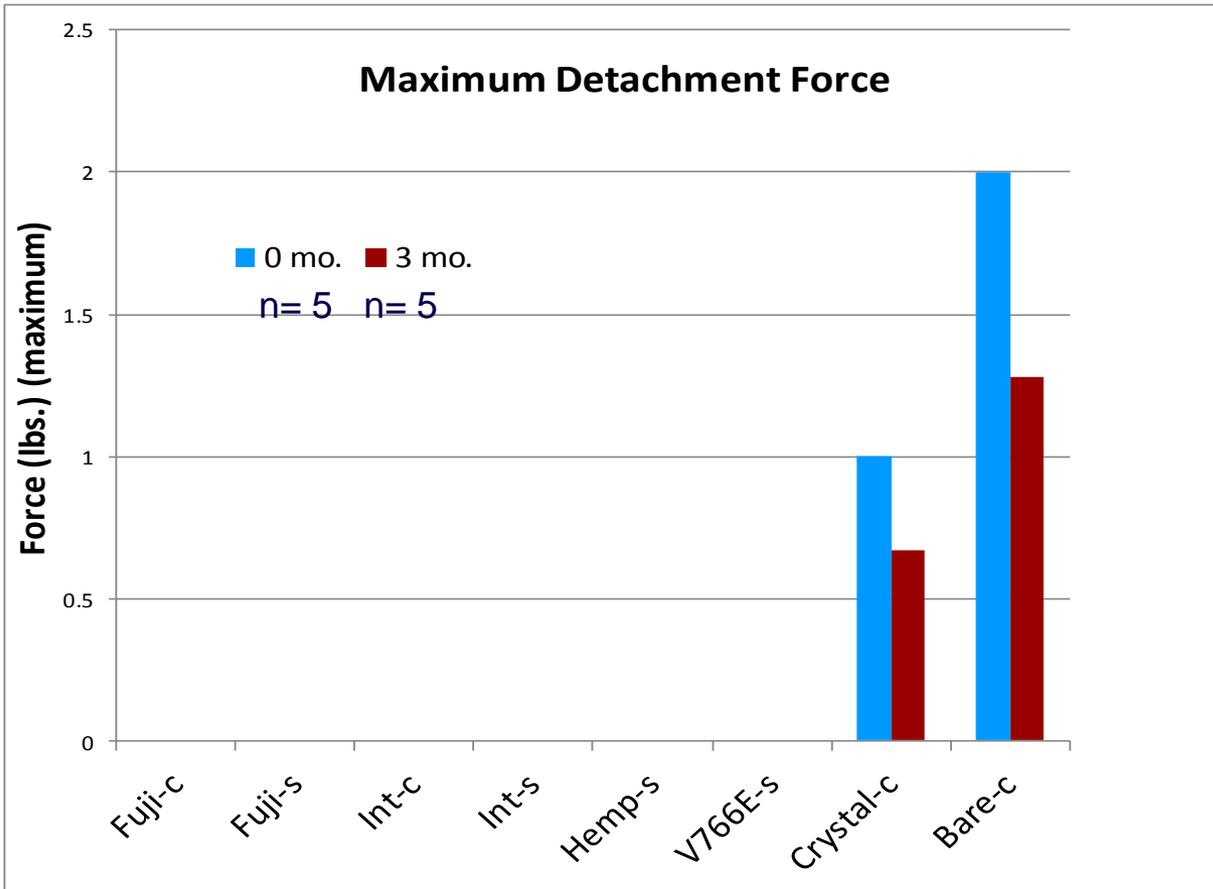
➤ 3 mo. scribe undercutting corrosion

Coating	Mean (mm)	SD (mm)	Max (mm)	n	# panels
Fuji-s	0	0	0	144	3
Hemp-s	0.05	0.1547	0.8	144	3
Int-s	0	0	0	144	3
V766E-s	0	0	0	192	4



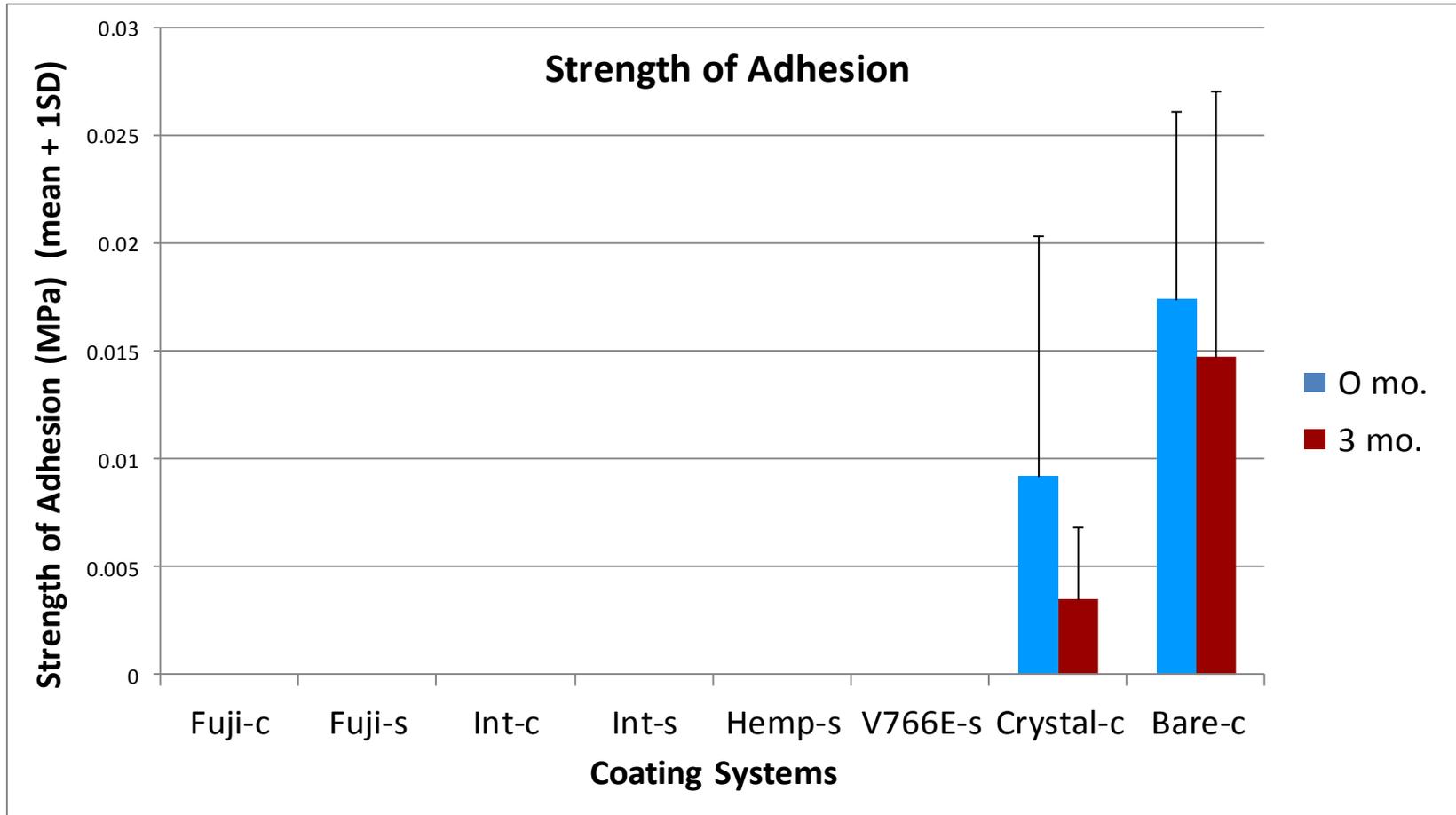
Foul-release: Preliminary Results

➤ 3 mo. mussel adhesion strength



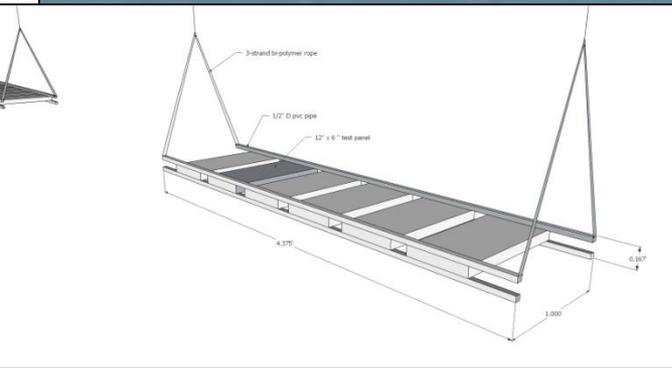
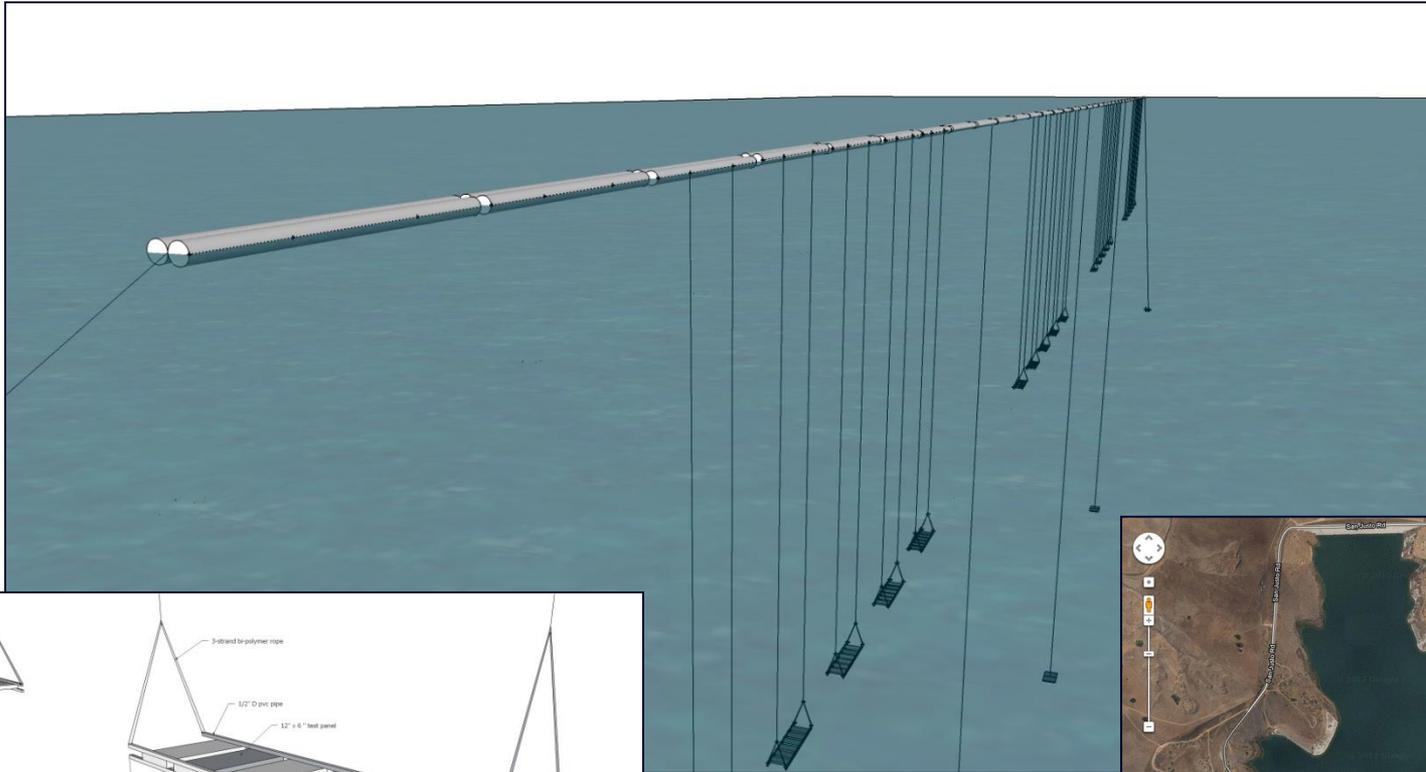
Foul-release: Preliminary Results

➤ Mussel adhesion strength



Foul-release: Next Steps

In-situ mussel adhesion test in San Justo, CA



Foul-release: Next Steps

- *In-vitro* erosion testing
- 9 mo. evaluations
- 15 mo., etc. panel retrieval and evaluations
- Cost estimate for applying FR coatings CRB hydro facility



Questions

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