Preventing Waterborne Disease

Professor Kristen Jellison

BioS 010

October 18, 2010

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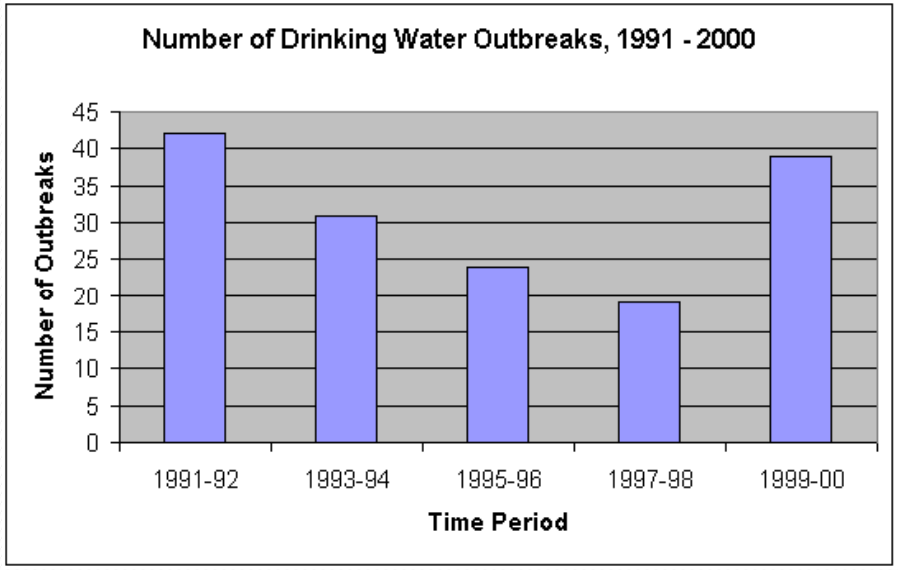
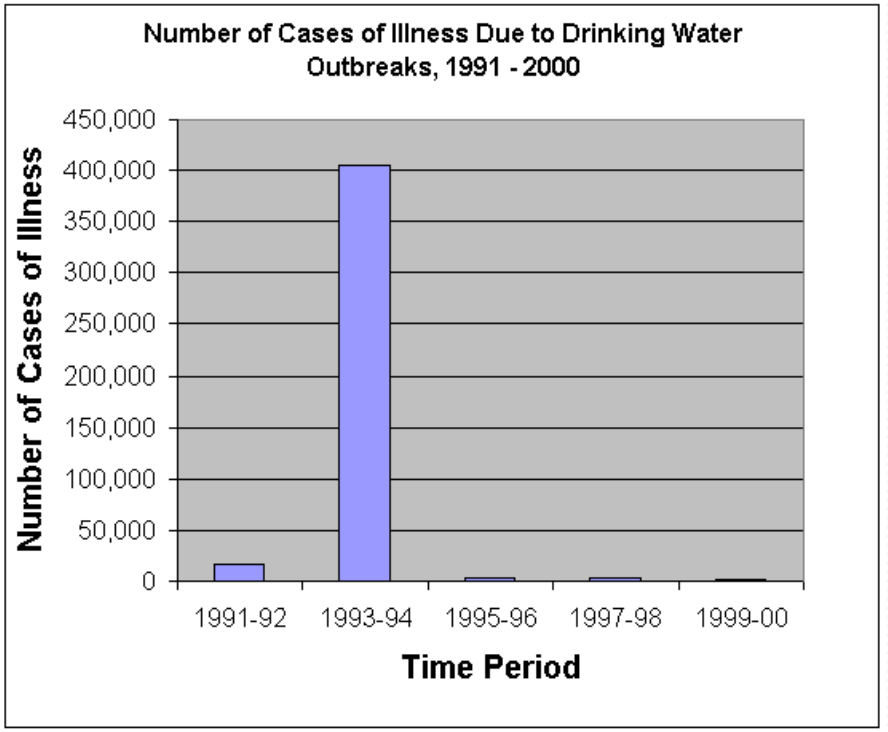
Waterborne Disease - USA





http://www.waterandhealth.org/newsletter/new/spring_2003/waterborne.html

Waterborne Disease – Global Statistics

- *1.1 billion people* lack access to improved water supply
- *2.6 billion people* lack access to improved sanitation
- Between *1.085 to 2.187 million deaths* each year due to diarrheal diseases can be attributed to the 'water, sanitation, and hygiene' risk factor
  - 90% of these deaths are among children under age 5

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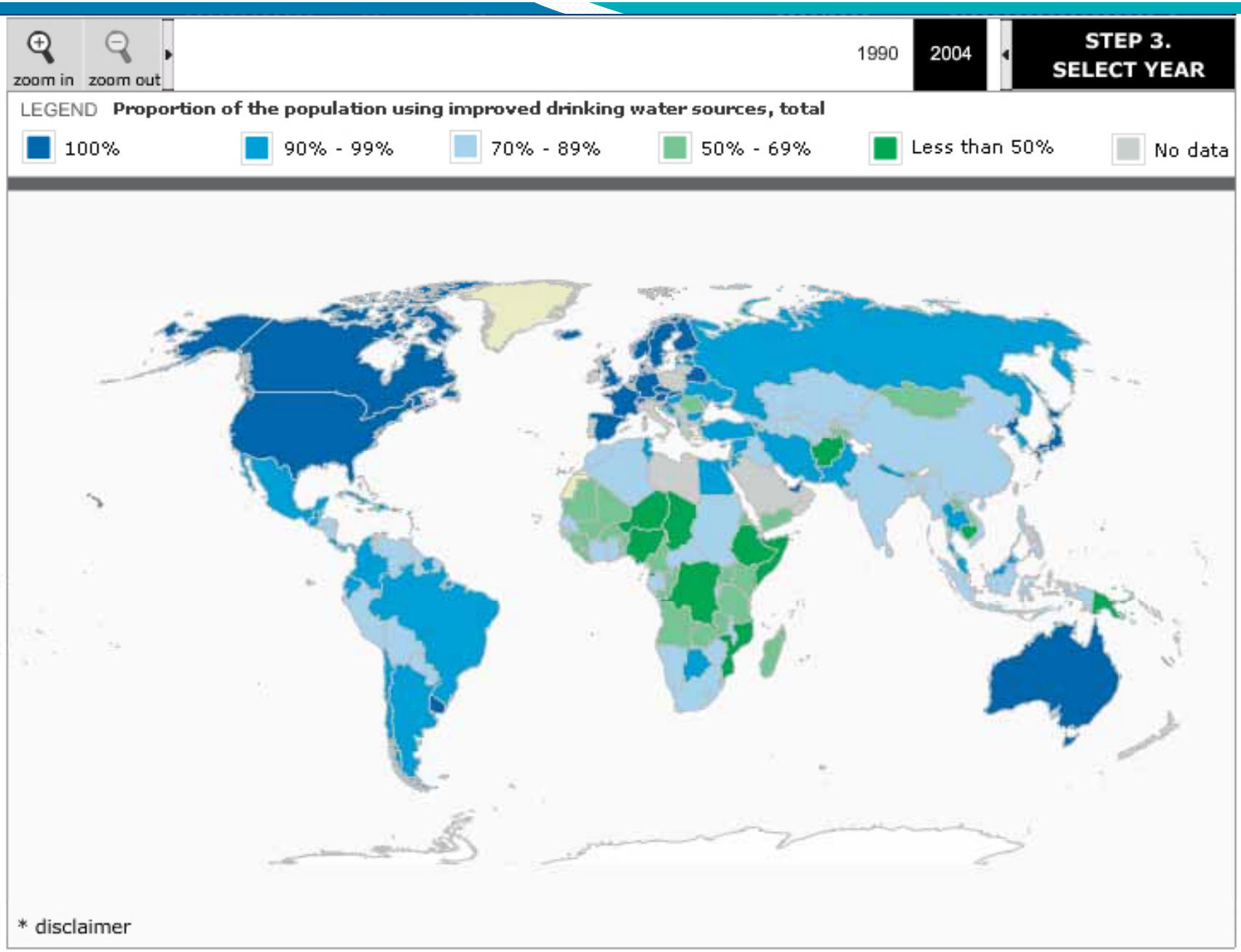

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Burden of Waterborne Disease

- Water-related disease is the 2nd biggest killer of children worldwide (1st = acute respiratory infections)
- At any one time:
  - half of the world's hospital beds are occupied by patients suffering from water-related diseases (WaterAid, 2008)
  - half of the population of the developing world is suffering from one or more diseases associated with inadequate water and sanitation (WaterAid, 2008)

Burden of Waterborne Disease

- 443 million school days lost annually to water-related diseases

- United Nations Millennium Development Goal (2000)
  - to reduce by half the proportion of people without access to safe water and sanitation by 2015
  - An extra $10 billion needed each year to reach the goal (this is about ***half*** of what rich countries spend on mineral water)

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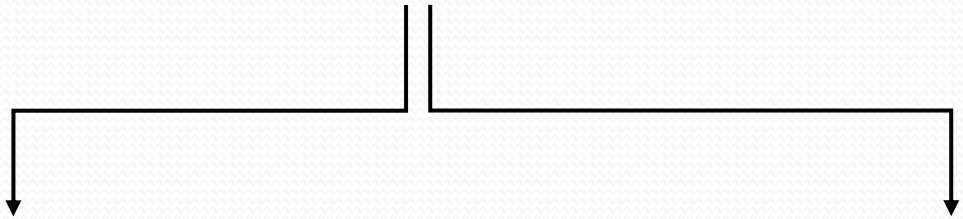
Ultimate goal: Prevention of waterborne disease



Water treatment technologies
(emphasis on developing countries)

-*Chlorination (SWS)*
-*Ceramic filtration*
-*Biosand filtration*

Watershed management

-*Parasite source tracking (Cryptosporidium)*
-*Parasite fate and transport*

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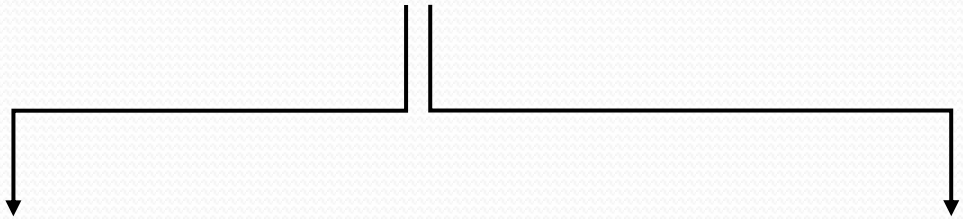

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Safe Water System (SWS)

- Strategy devised by CDC and PAHO to reduce waterborne diarrheal disease
- Three components to SWS
  - Water treatment with dilute sodium hypochlorite
  - Storage of water in a safe container
  - Education to improve hygiene and water and food handling processes

Safe Water System (SWS)

- Sodium hypochlorite (= dilute chlorine bleach)
  - Particles in water will bind to chlorine, reducing the amount of chlorine that is available to disinfect microorganisms
  - By removing particles in water before disinfecting with chlorine, a smaller dose of chlorine can be used to achieve effective disinfection
    - Fewer taste and odor issues
    - Saves money (a bottle of chlorine solution will last longer)

Safe Water System (SWS)

- Jellison lab undergraduate research project with the U.S. Centers for Disease Control
  - Evaluate water pretreatment methods for the potential to

    (i) remove particulates

    (ii) reduce the amount of sodium hypochlorite solution necessary to maintain a safe disinfection residual
    - Current SWS recommendations: add single capful of SWS solution per 20 L water (add two capfuls per 20 L for turbid water)

Safe Water System (SWS)

- Some common water pretreatment methods
  - Physical pretreatment
    - Cloth filtration
    - Sand filtration
    - Settling/Decanting

Safe Water System (SWS)

- Some common water pretreatment methods
  - Chemical pretreatment
    - Coagulants – alum, moringa seeds




Safe Water System (SWS) - Conclusions

- Turbidity reduction
  - all five clarification methods were effective
- Chlorine demand reduction/maintaining safe chlorine residual at 24 hrs
  - Sand filtration, settling & decanting, and alum coagulation were effective across all turbidity levels
  - Cloth filtration and moringa coagulation were not effective

Safe Water System - Recommendations

- Recommended sodium hypochlorite dosages after pre-treatment of the source water:
  - After sand filtration = 1.875 mg/L (single capful)
  - After settling/decanting = 1.875 mg/L (single capful)
    - 24 hr settling time recommended
  - After cloth filtration = 3.75 mg/L (double capful)
  - After alum coagulation = 1.875 mg/L (single capful)

- Using raw moringa seeds for pre-treatment before chlorine is no longer recommended

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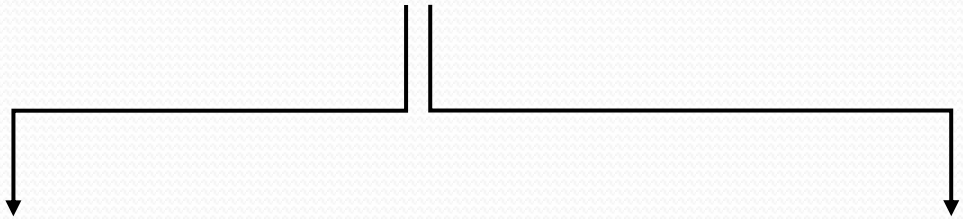

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Ceramic Filtration

- Potters for Peace filter
  - 2 separate parts: (i) ceramic pot and (ii) plastic container that the pot sits inside
  - Ceramic pot has colloidal silver coating (germicide)
  - Ceramic has very small pores which entrap contaminants as water passes through

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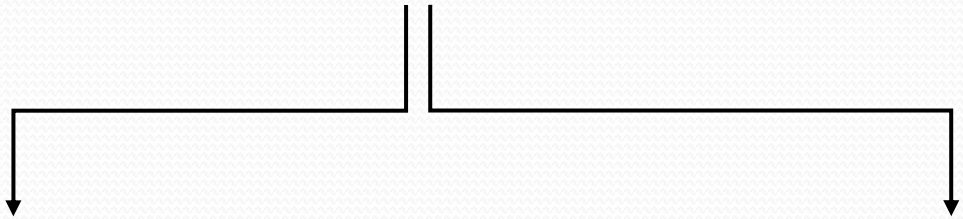
Ultimate goal: Prevention of waterborne disease



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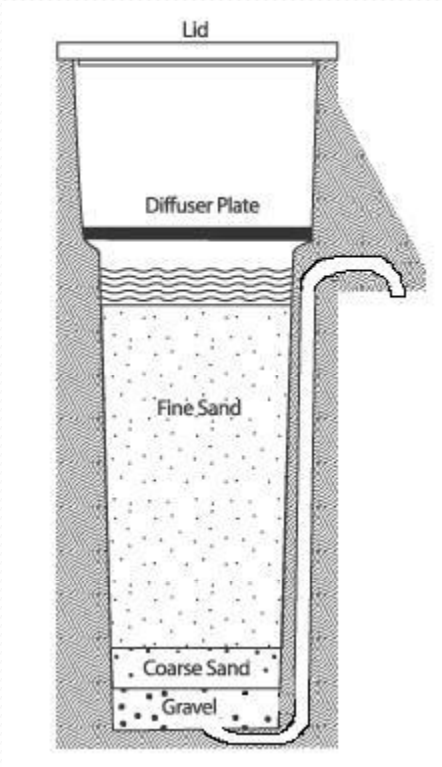
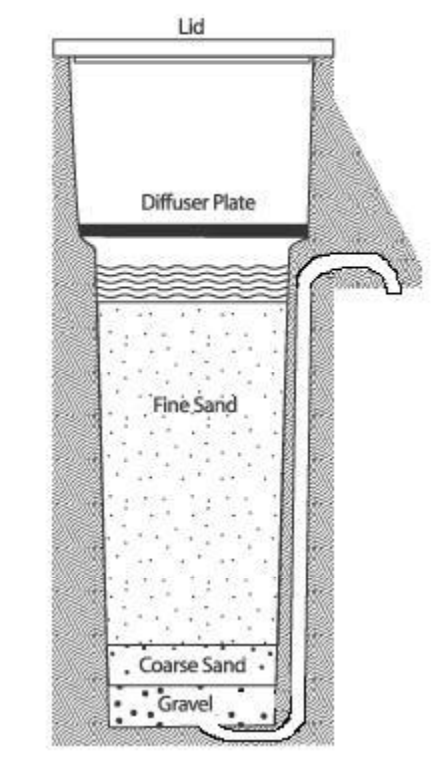
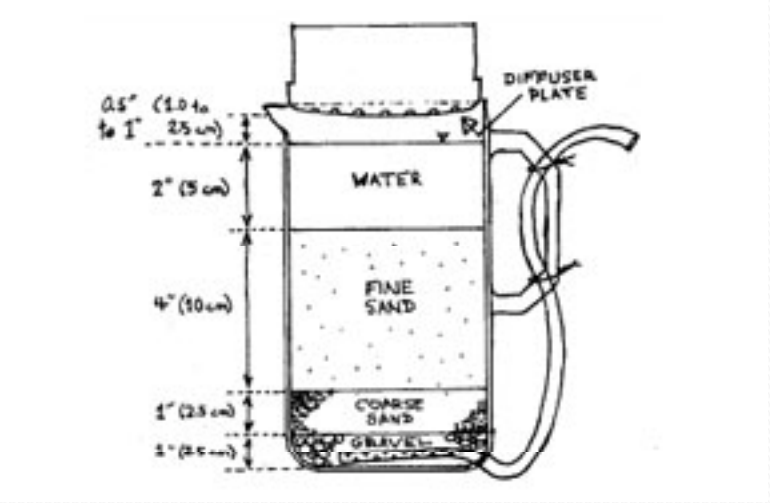
Biosand Filtration



- 0.3m x 0.3m x 0.9m
- Weight: 170 lbs.
- Costs: $10-45 USD

Biosand Filtration





2 L Pitcher Filter

Biosand Filtration

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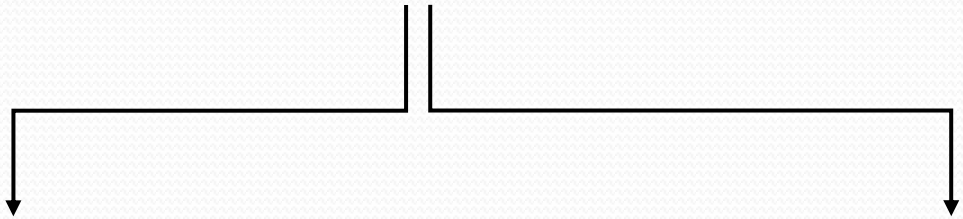
Ultimate goal: Prevention of waterborne disease



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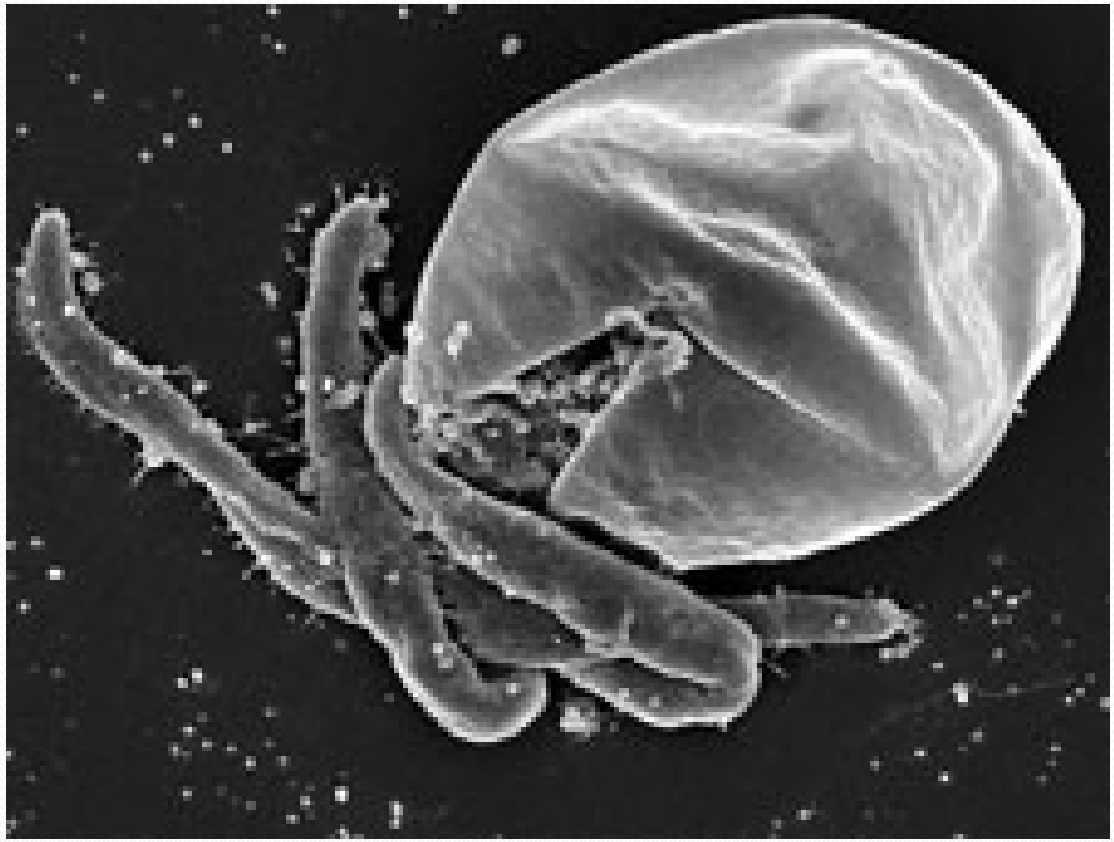
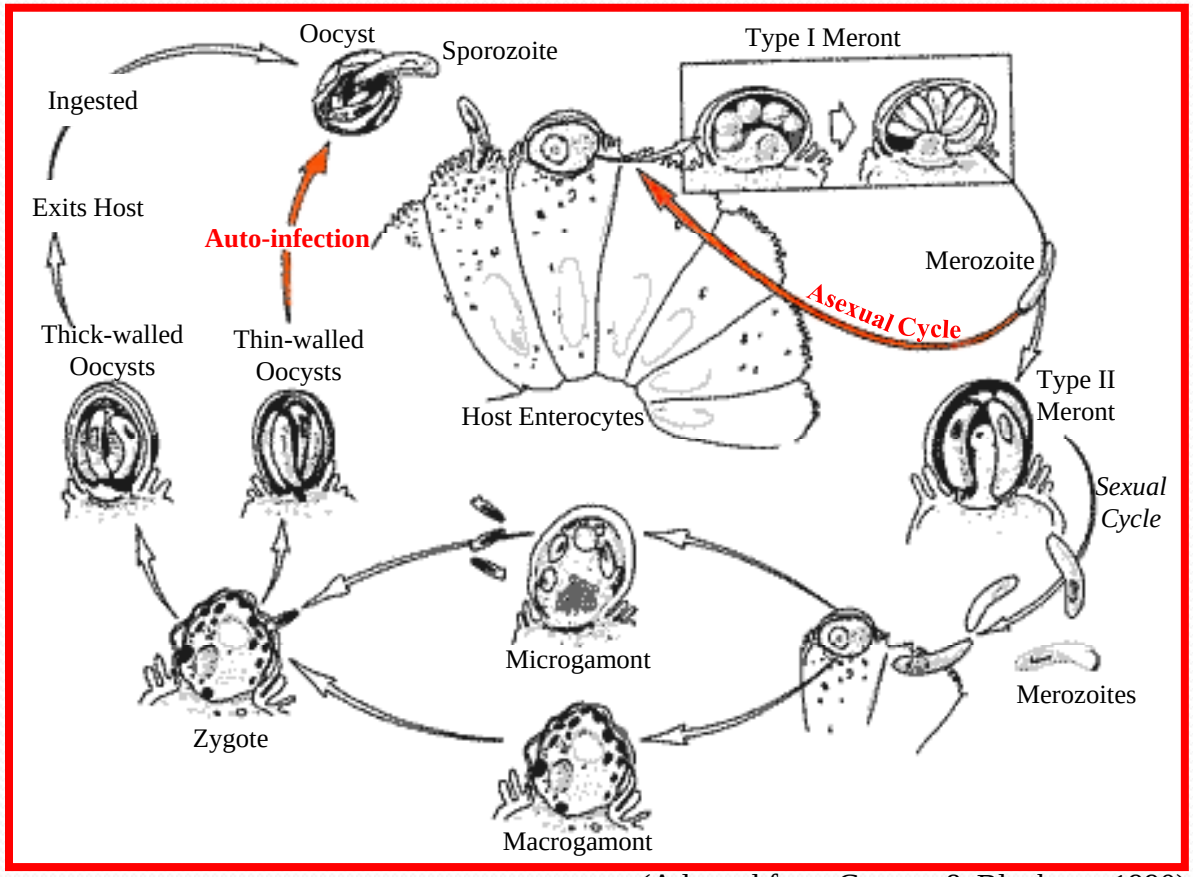
Cryptosporidium



Cryptosporidium Life Cycle



(Adapted from Current & Blagburn, 1990)

Methods

Surface Water Filtration

Fecal Sample Collection

Immunomagnetic Separation

DNA Extraction

Nested PCR

Clone & Sequence

Phylogenetic Analysis

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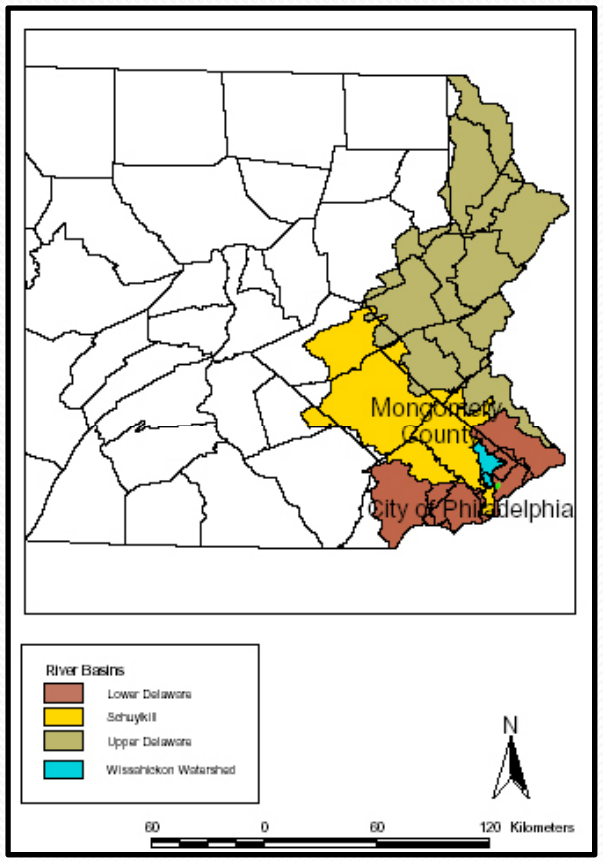
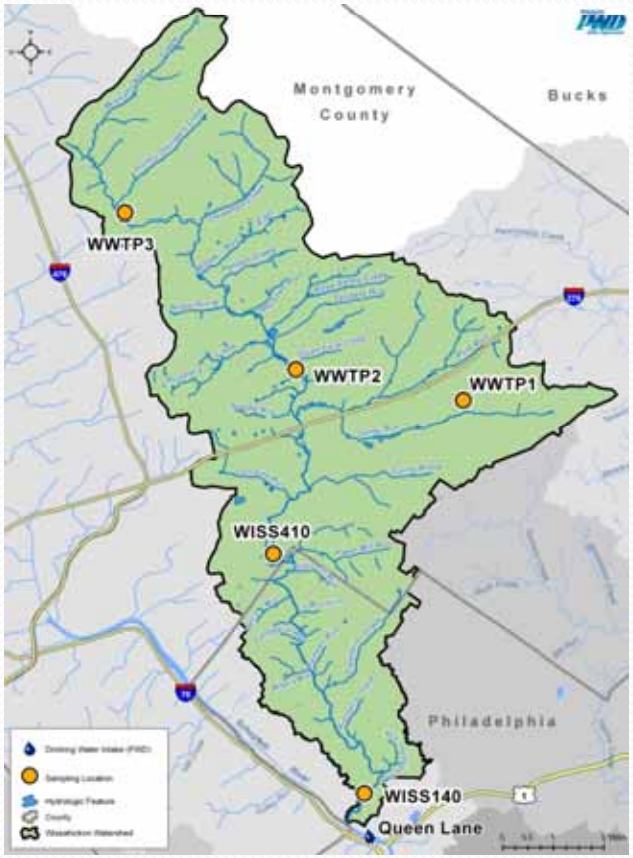
Wissahickon Creek Watershed



(From: National Institute for Environmental Renewal, 1999)



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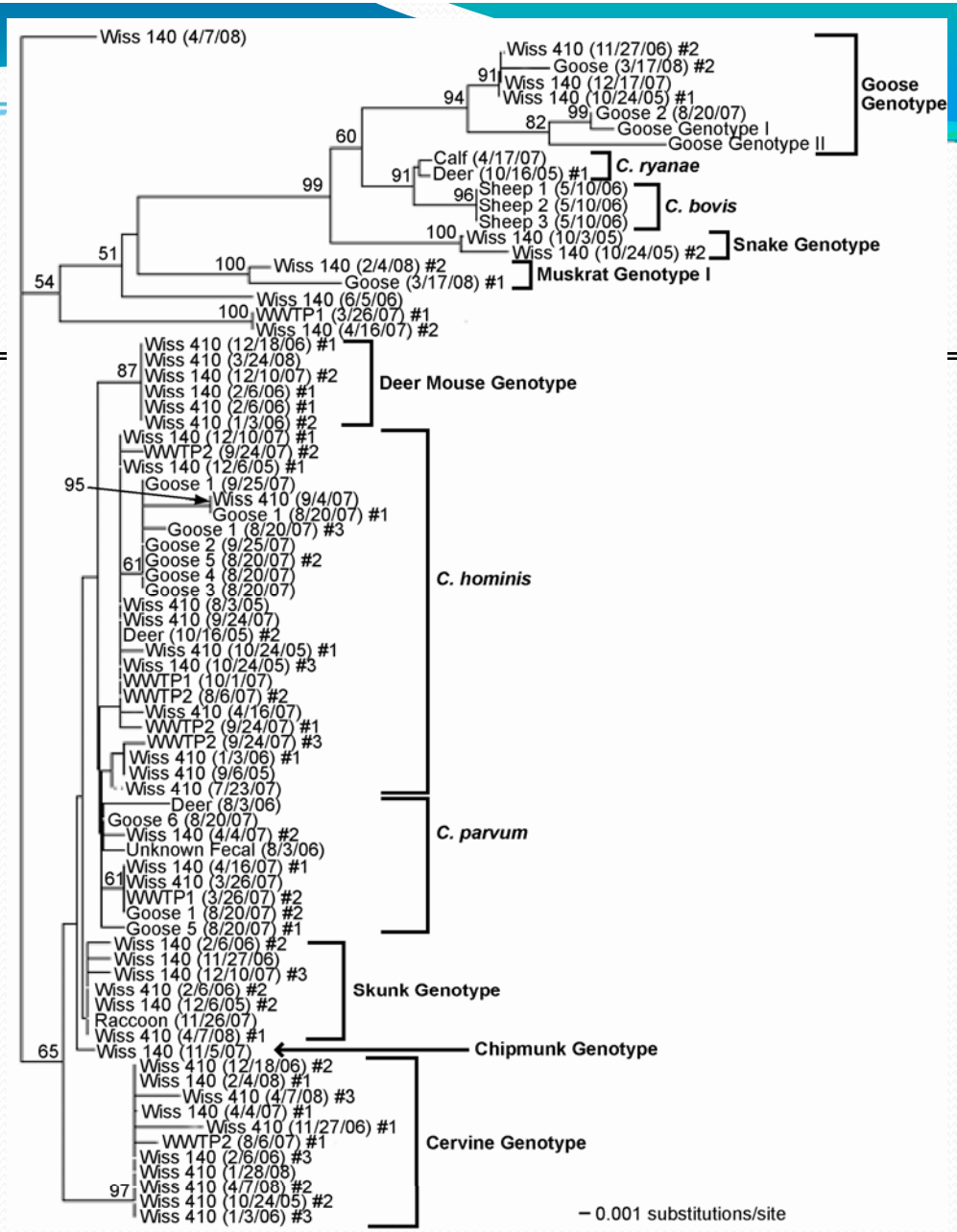

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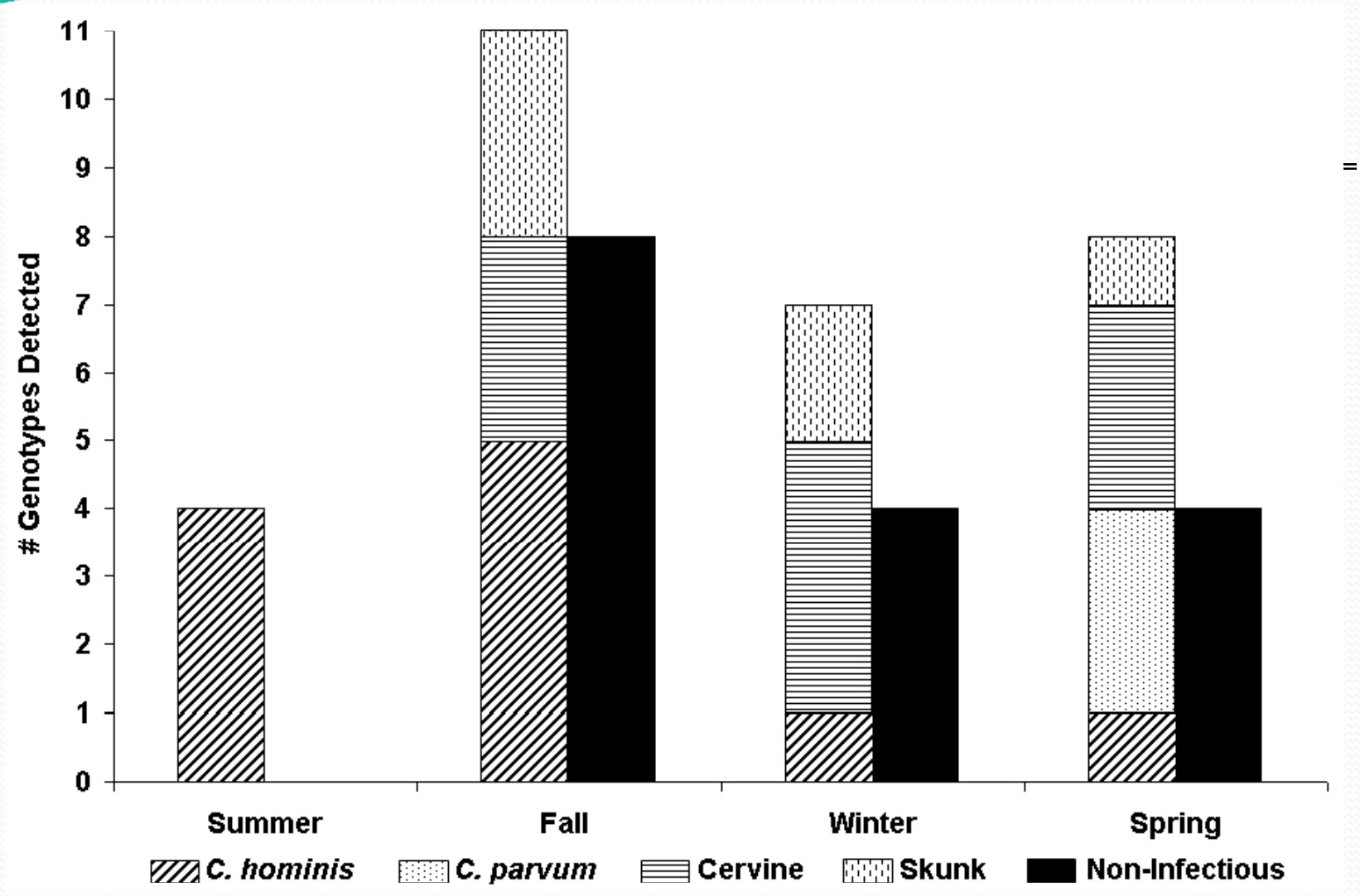
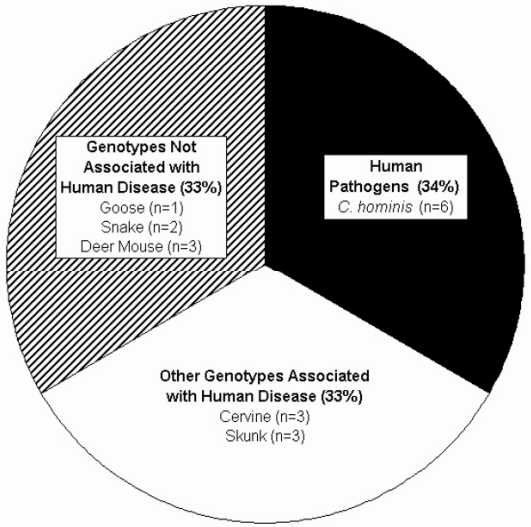
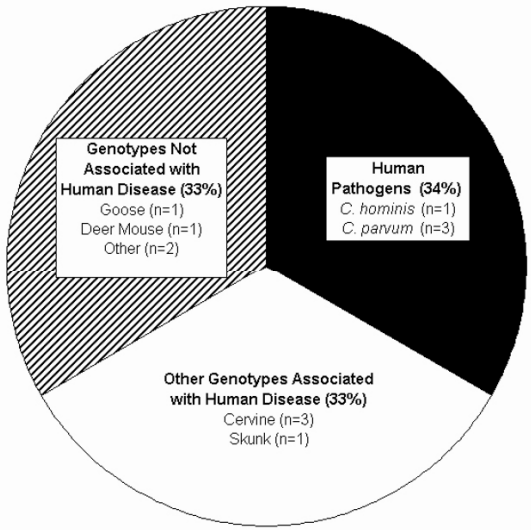

Genotypes Detected
11
10
9
8
7
6
5
4
3
2
1
0
Summer
Fall
Winter
Spring
C. hominis
C. parvum
Cervine
Skunk
Non-Infectious

Wissahickon Creek, May 2005- April 2006



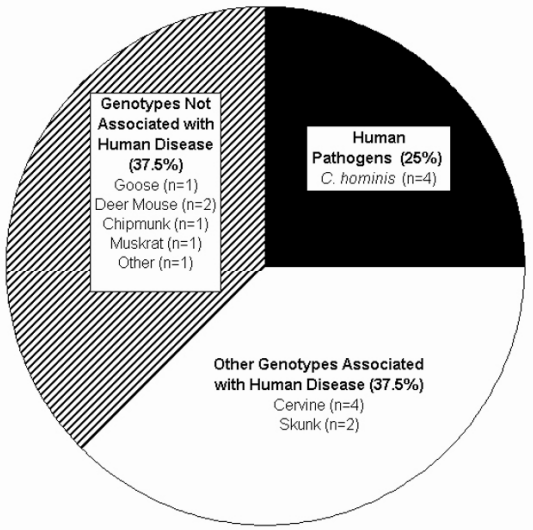
n=18

Wissahickon Creek, May 2006-April 2007



n=12

Wissahickon Creek, May 2007-April 2008



n=16

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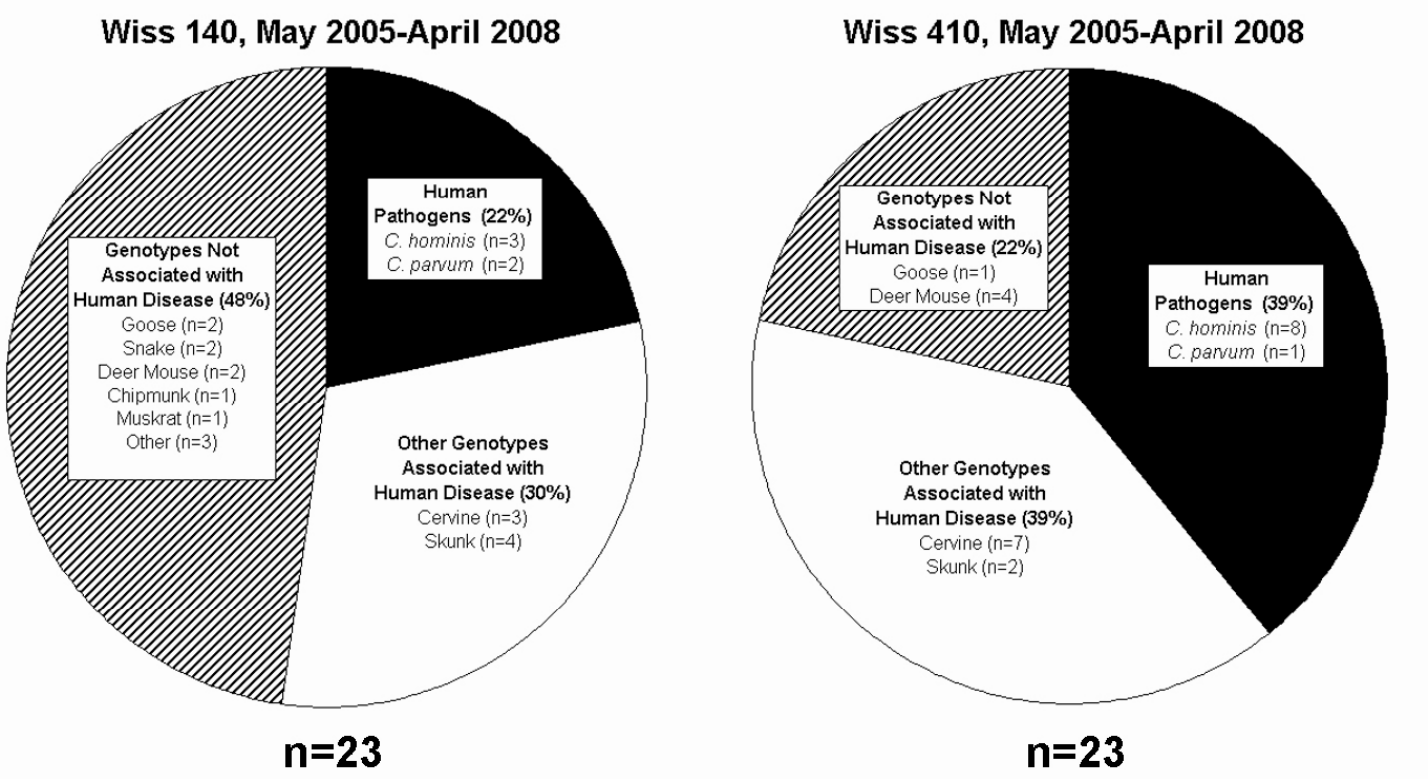
Wiss 140, May 2005-April 2008
Human Pathogens (22%)
C. hominis (n=3)
C. parvum (n=2)
Genotypes Not Associated with Human Disease (48%)
Goose (n=2)
Snake (n=2)
Deer Mouse (n=2)
Chipmunk (n=1)
Muskrat (n=1)
Other (n=3)
Other Genotypes Associated with Human Disease (30%)
Cervine (n=3)
Skunk (n=4)
n=23
Wiss 410, May 2005-April 2008
Genotypes Not Associated with Human Disease (22%)
Goose (n=1)
Deer Mouse (n=4)
Human Pathogens (39%)
C. hominis (n=8)
C. parvum (n=1)
Other Genotypes Associated with Human Disease (39%)
Cervine (n=7)
Skunk (n=2)
n=23

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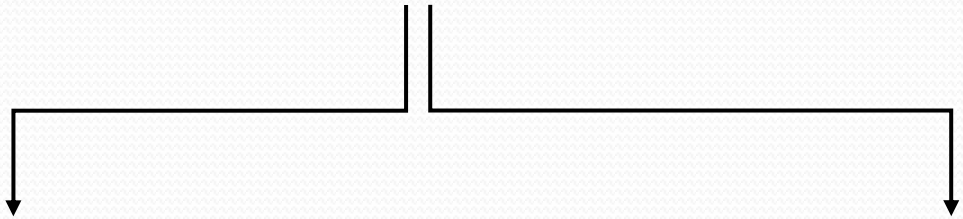
Ultimate goal: Prevention of waterborne disease



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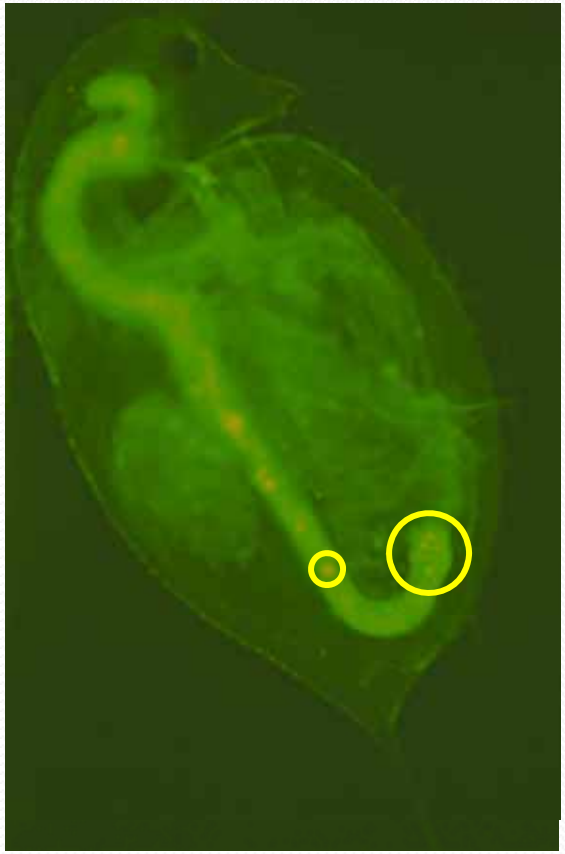
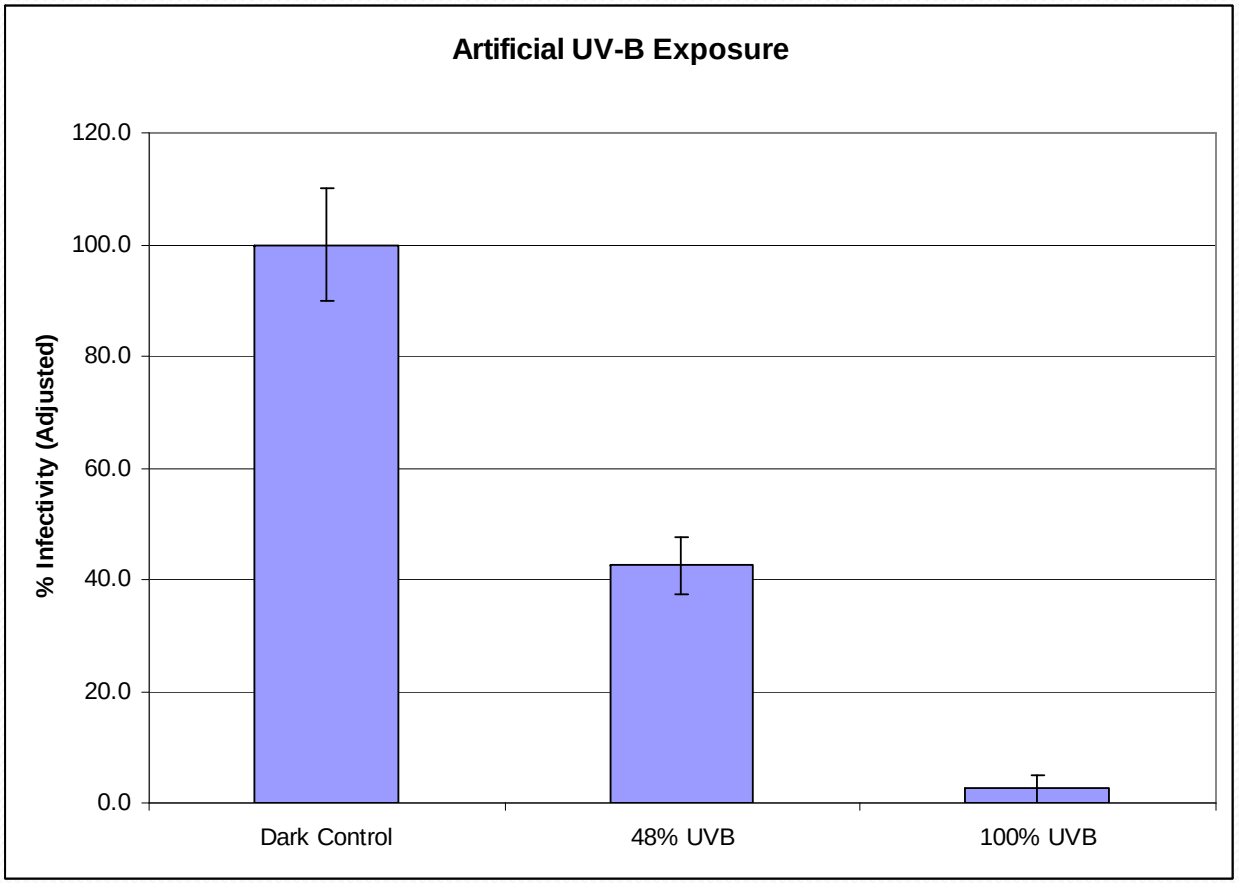
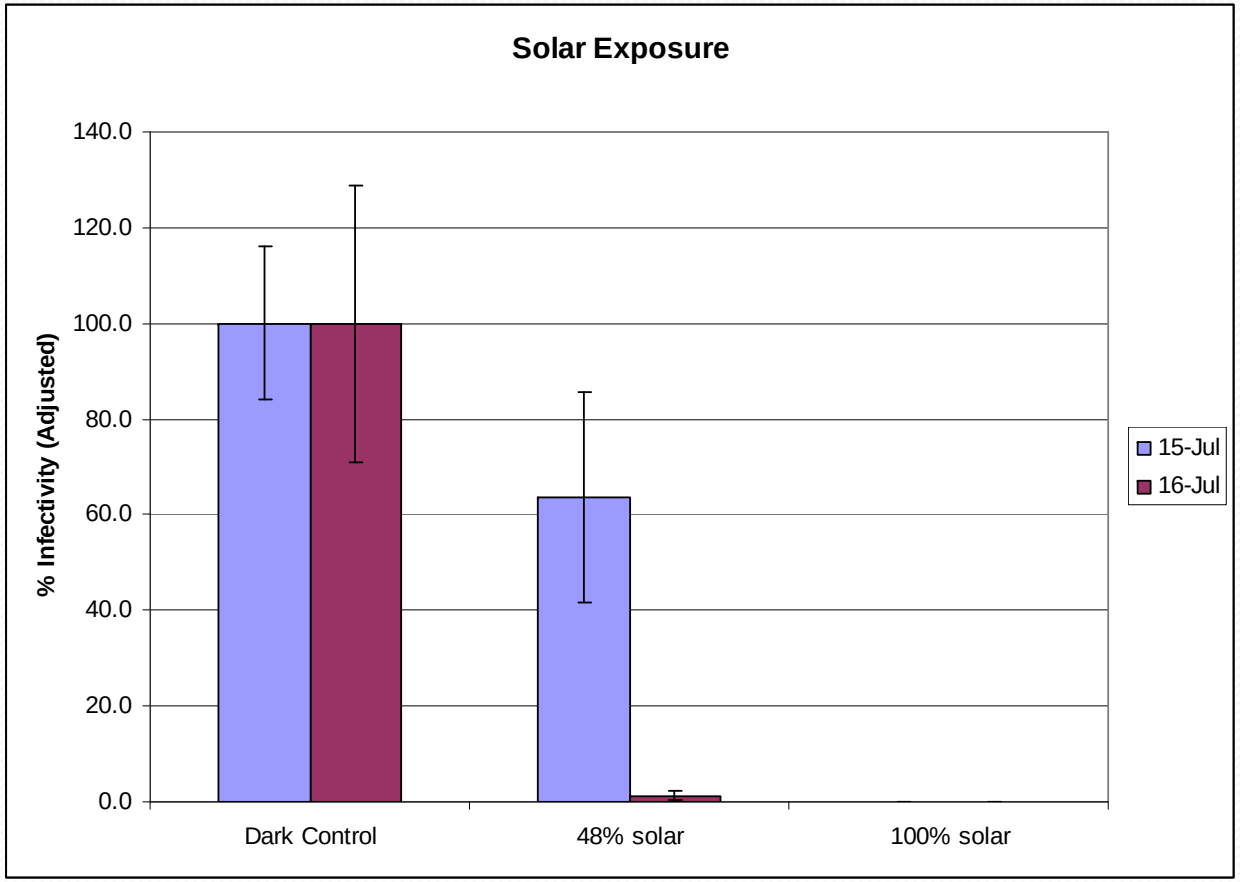
Grazing:



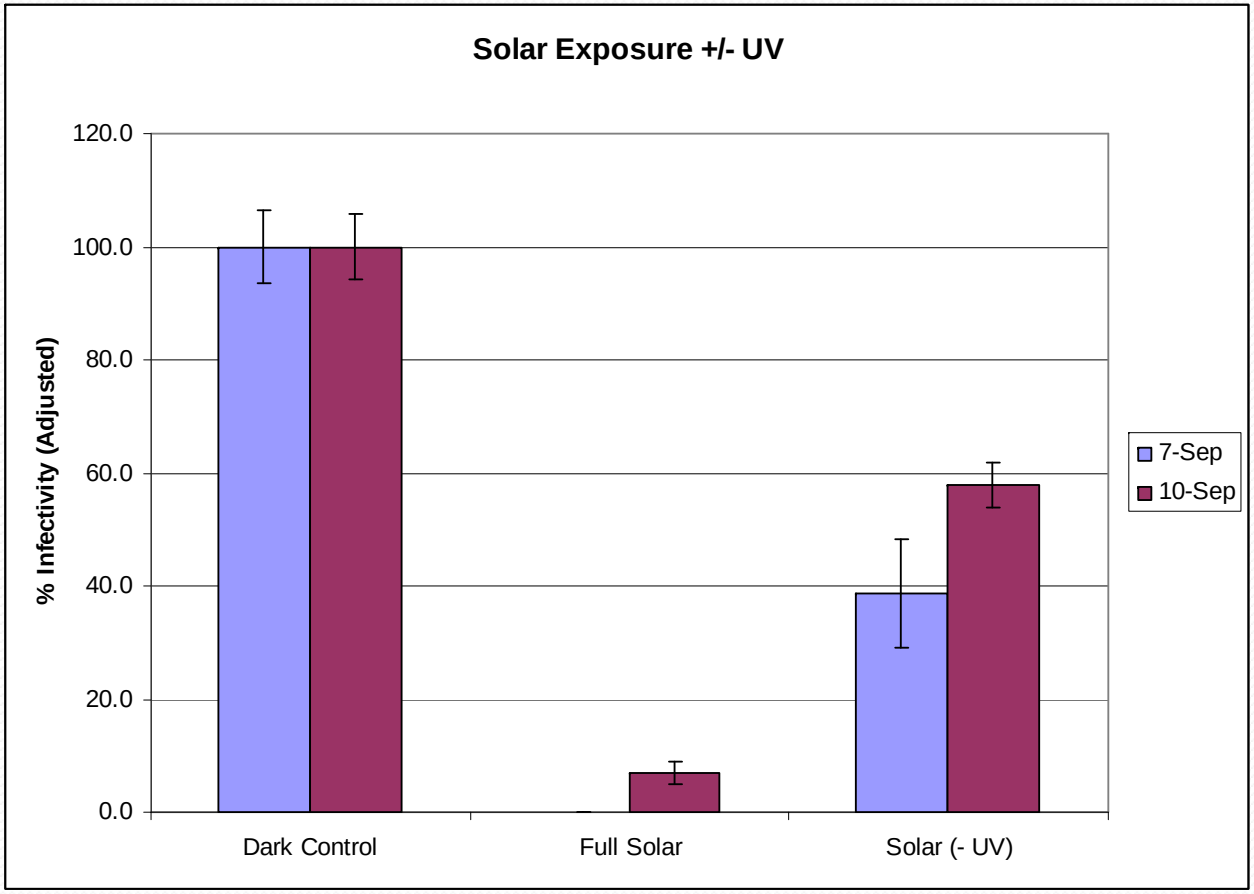
UV Exposure


Artificial UV-B Exposure
% Infectivity (Adjusted)
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Dark Control
48% UVB
100% UVB

UV Exposure

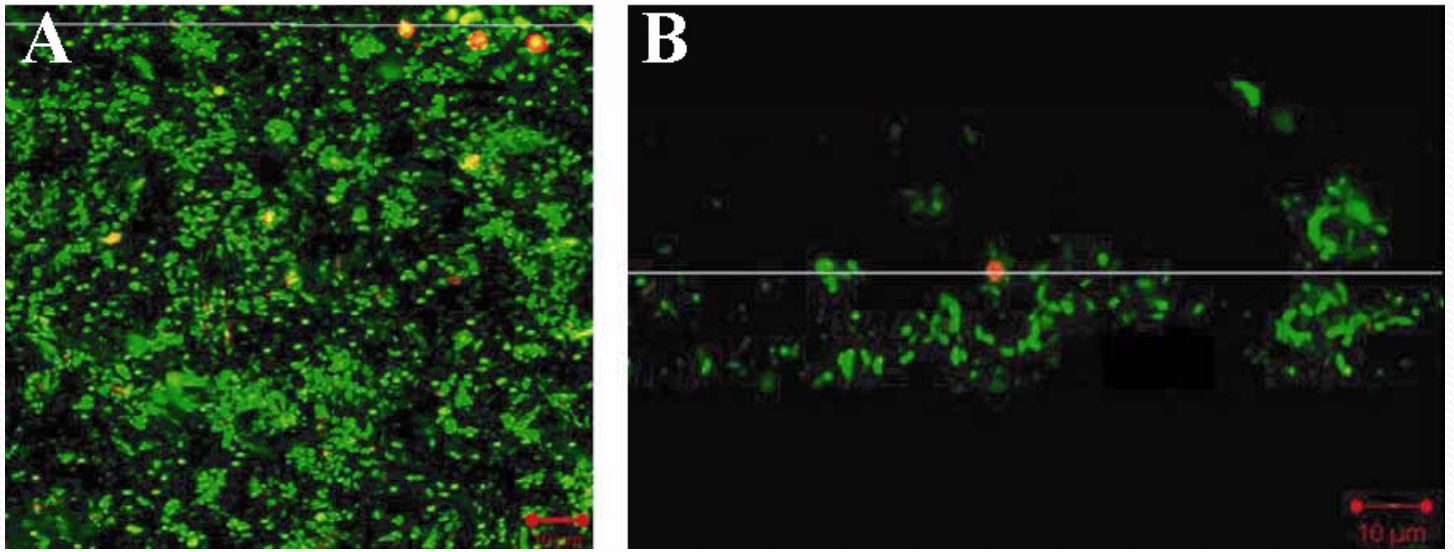

Solar Exposure
% Infectivity (Adjusted)
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Dark Control
48% solar
100% solar
15-Jul
16-Jul

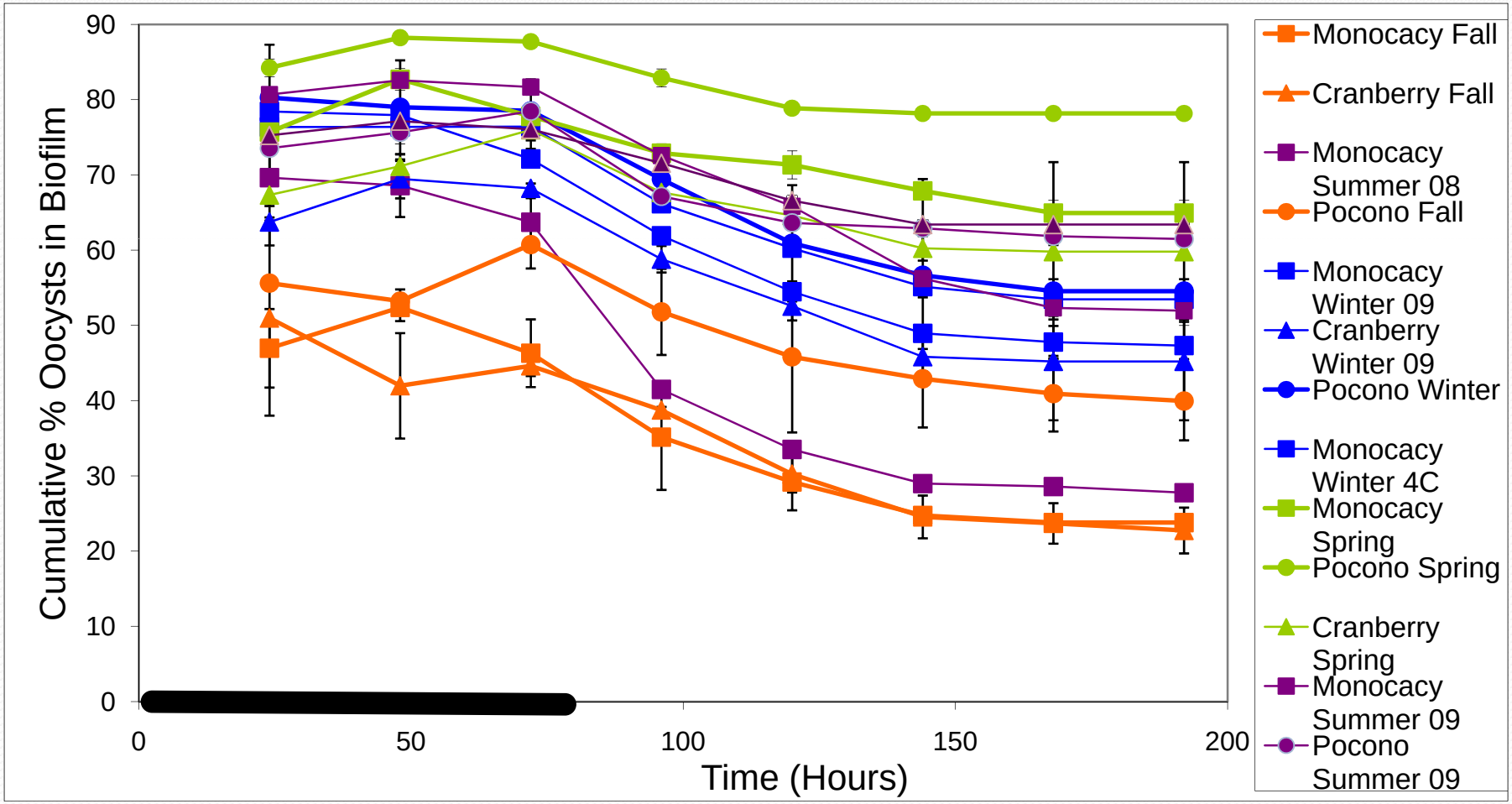
UV Exposure


Solar Exposure +/- UV
% Infectivity (Adjusted)
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Dark Control
Full Solar
Solar (- UV)
7-Sep
10-Sep

Cryptosporidium and Biofilms

www.pall.com


A
B
10 µm



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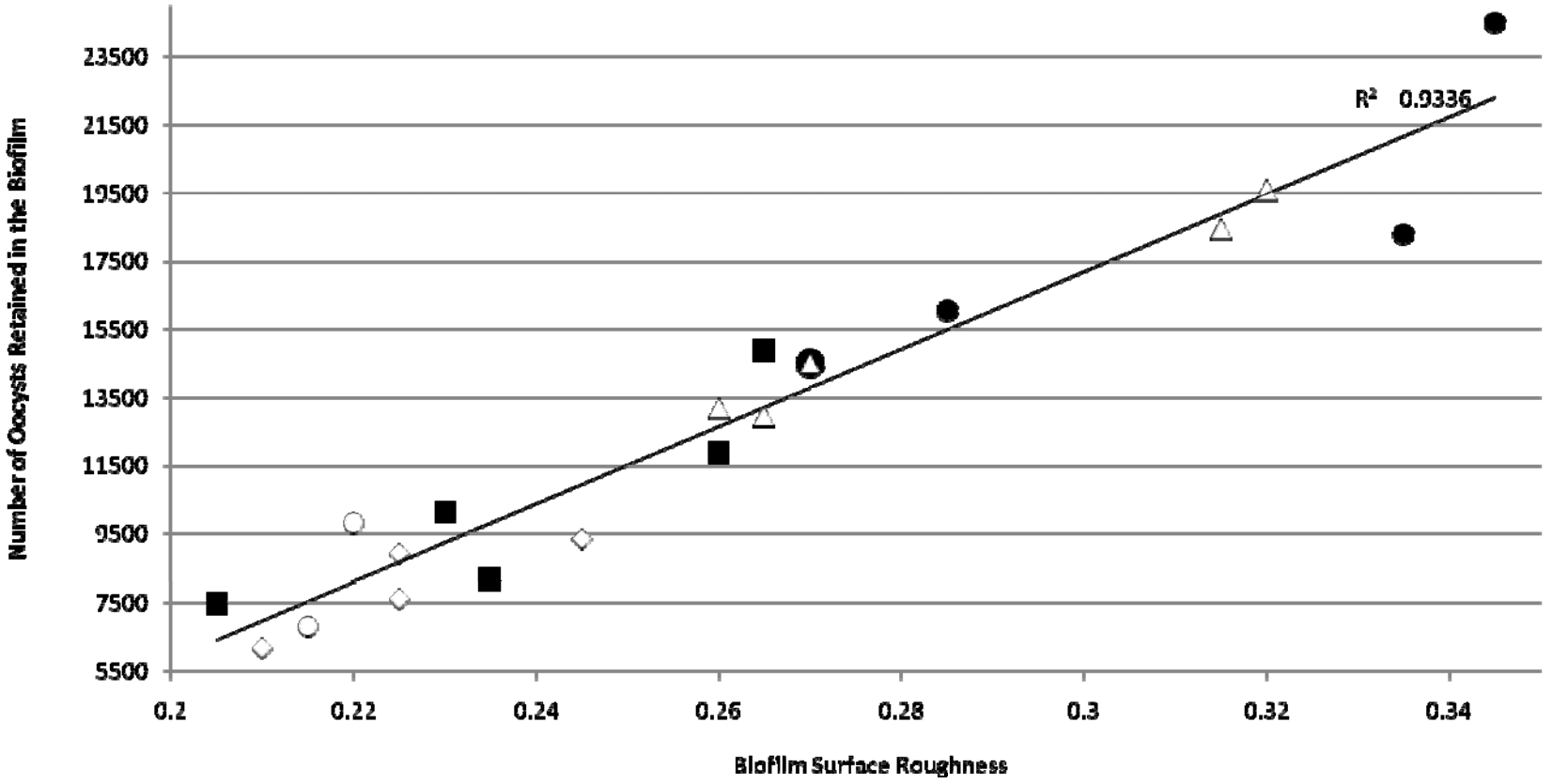
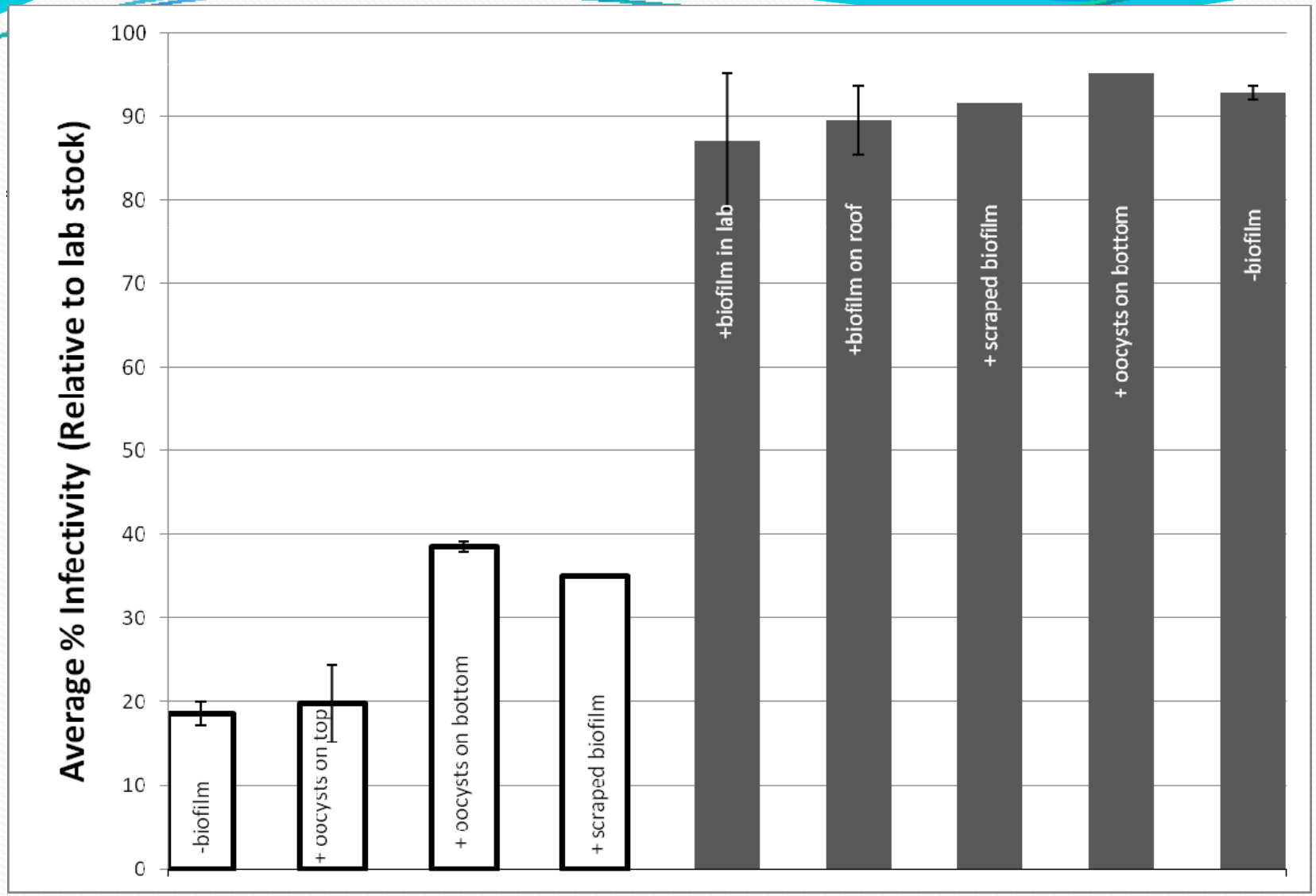
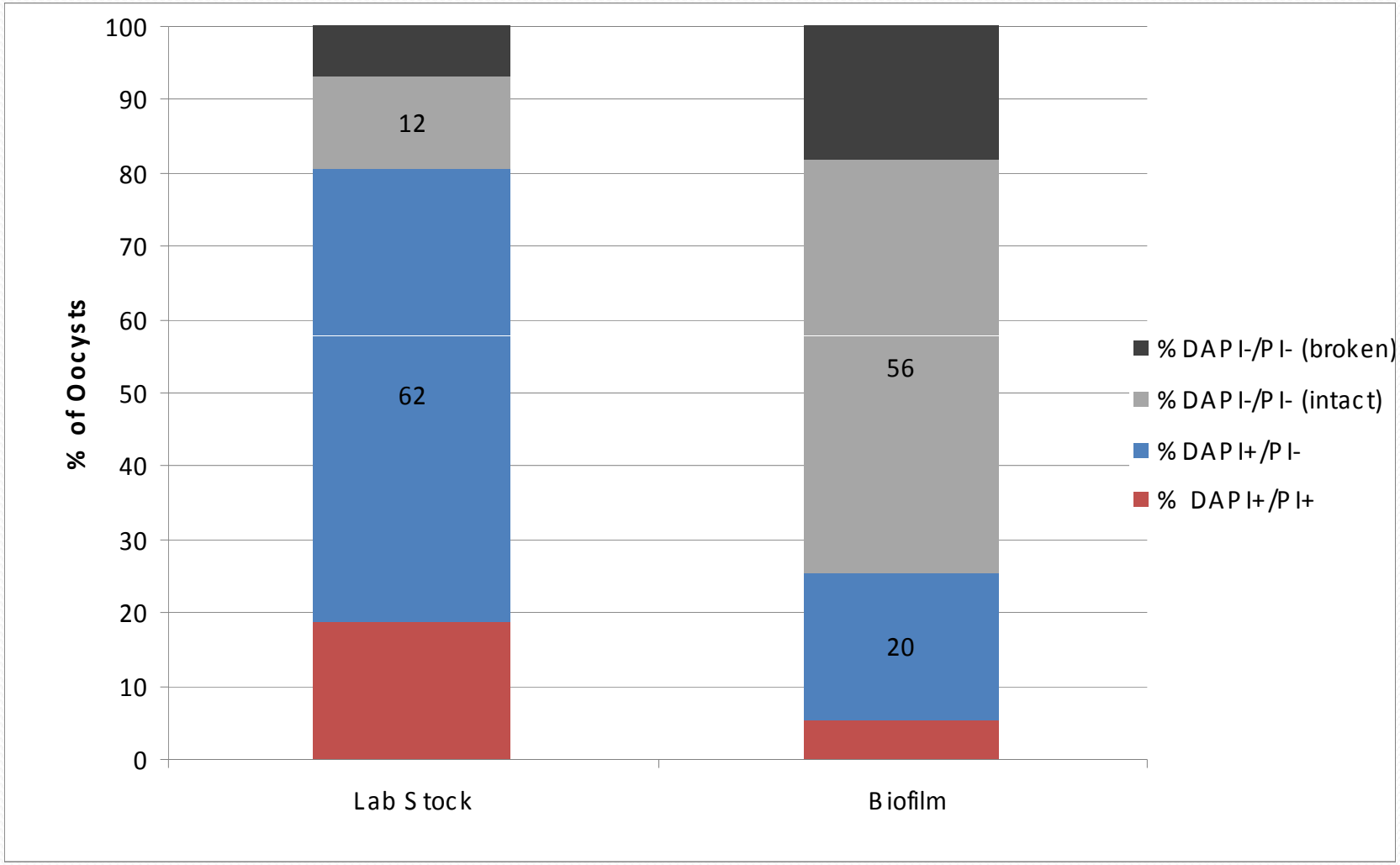
$$R = \frac{1}{N}\sum_{i=1}^{N}\frac{|L_{fi} - \overline{L}_f|}{\overline{L}_f}$$

where $\overline{L}_f$ is the mean thickness, L_{fi} is the ith individual thickness, and N is the number of thickness measurements.




Average % Infectivity (Relative to lab stock)
100
90
80
70
60
50
40
30
20
10
0
-biofilm
+ oocysts on top
+ oocysts on bottom
+ scraped biofilm
+biofilm in lab
+biofilm on roof
+ scraped biofilm
+ oocysts on bottom
-biofilm


100
90
80
70
60
50
40
30
20
10
0
% of Oocysts
12
62
56
20
Lab Stock
Biofilm
% DAPI-/PI- (broken)
% DAPI-/PI- (intact)
% DAPI+/PI-
% DAPI+/PI+

Biofilms as Biomonitors

Sample Date	Biofilm FISH	Water Sample FISH	Water Sample PCR
11-Aug-09	Positive	N/A	N/A
18-Aug-09	Positive	N/A	N/A
31-Aug-09	Positive	N/A	N/A
29-Sep-09	Positive	N/A	Negative
13-Oct-09	Positive	N/A	Negative
3-Nov-09	Positive	N/A	N/A
10-Nov-09	Positive	N/A	Positive
9-Dec-09	Positive	N/A	N/A
26-Jan-10	Positive	N/A	Negative
9-Feb-10	Positive	N/A	Negative
17-Feb-10	Positive	N/A	N/A
23-Feb-10	Positive	N/A	Negative
9-Mar-10	Positive	N/A	Positive
13-Apr-10	Positive	N/A	Negative
27-Apr-10	Positive	Positive	Negative
11-May-10	Positive	Negative	Negative
25-May-10	Positive	Positive	Negative
1-Jun-10	Positive	N/A	N/A
8-Jun-10	Positive	Negative	Negative
10-Jun-10	Positive	N/A	N/A
29-Jun-10	Positive	Positive	Negative
20-Jul-10	Positive	Positive	Negative
27-Jul-10	Positive	Positive	Positive (Pending)
10-Aug-10	Positive	Negative	Inconclusive

Summary

Ultimate goal: reduce prevalence of waterborne disease

- Understand parasite fate and transport in the environment
- Identify public health risk associated with parasites in drinking water supplies
- Improve methods for watershed monitoring of parasites
- Optimize household water treatment options in developing countries and develop standard operating procedures for their use

Acknowledgements

Graduate Students

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Sara Zientarski
Margo Wilson
Nadine Kotlarz
Kelsey Preston
Ally Mayer
Kevin Myers

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Collaborators

Philadelphia Water Department
U.S. Centers for Disease Control
Centre for Affordable Water and Sanitation Technology (CAWST)

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Questions?

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