Connecting the Dots: Reducing Water, Sanitation, and Hygiene-related Diarrheal Illness

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Centers for Disease Control and Prevention

Water and Sanitation Innovations for the Arctic Workshop

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National Center for Emerging and Zoonotic Infectious Diseases

Division of Foodborne, Waterborne, and Environmental Diseases


106
CDC
Building 102
Building 101
Building 106

Background

- **Leading Causes of Death Globally, 2001**

1. Ischemic heart disease (7.2 million)
2. Cancer (7.1 million)
3. Cerebrovascular disease (5.5 million)
4. Lower respiratory infection (3.9 million)
5. Unintentional injuries (3.5 million)
6. HIV/AIDS (2.9 million)
7. COPD (2.7 million)
8. Diarrheal Diseases: Unsafe water, sanitation, hygiene (1.7 million)
9. TB (1.6 million)
10. Intentional injuries (suicide, homicide, war) (1.6 million)
11. Malaria (1.1 million)

WHO, 2002

Drinking Water and Disease Transmission

- Mills-Reincke Phenomenon (1893-94)
  - Filtration of the polluted public water-supplies of Lawrence , MA and of Hamburg, Germany produced a notable decline in the general death-rate of each of these cities above that of typhoid fever
- Hazen's Theorem (1904)
  - "Where one death from typhoid fever has been avoided by the use of better water, a certain number of deaths, probably two or three, from other causes have been avoided."

Drinking Water and Disease Transmission

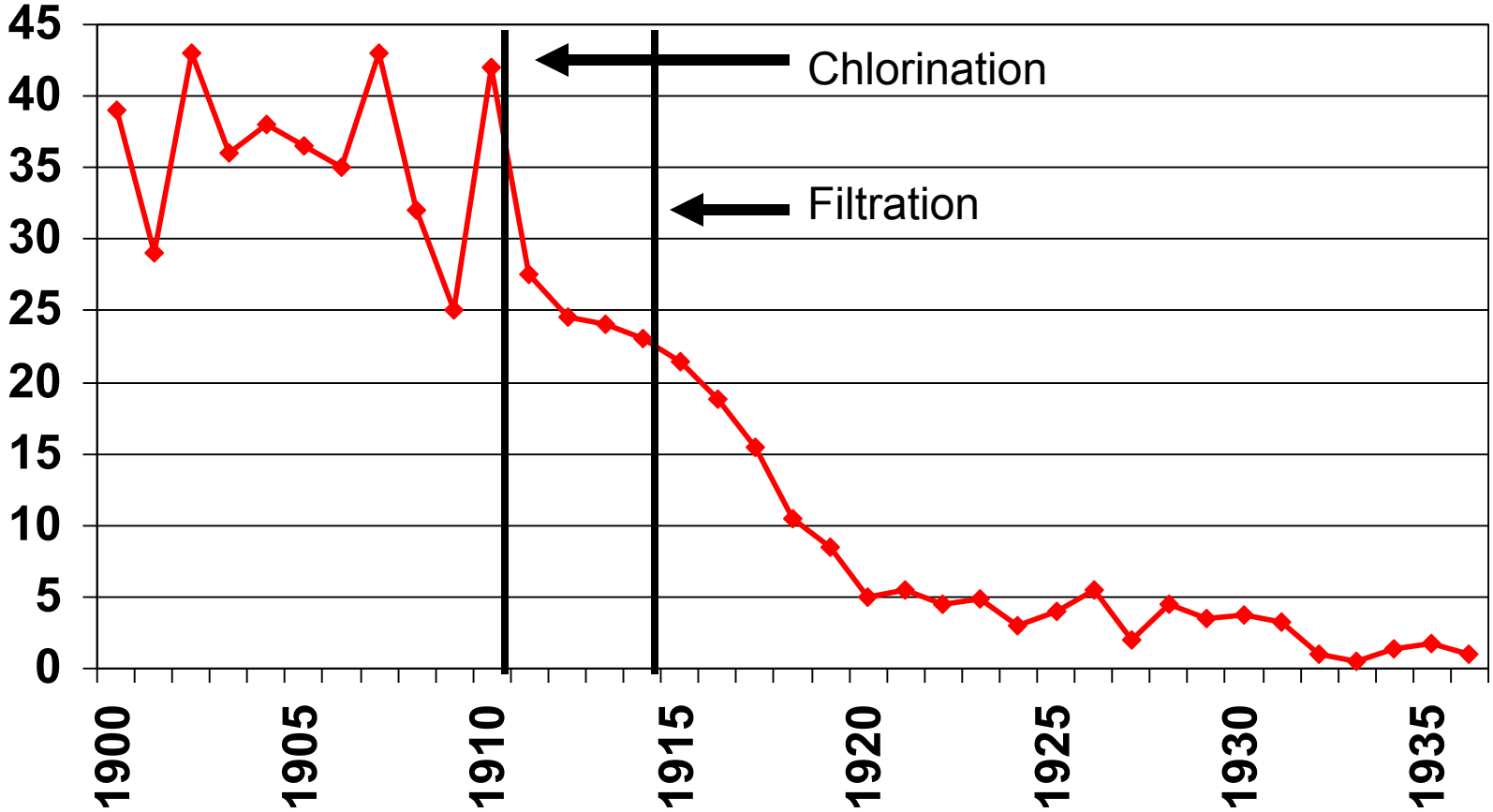
- 1900: Approximately 100 cases typhoid for every 100,000 Americans
- 1908: First disinfection of U.S. public water supply in NJ
- 1910-1920:
  - Thousands of U.S. cities begin disinfecting water
  - Dramatic decrease in cases of waterborne illness /death
- 2006
  - Approximately 0.1 cases of typhoid for every 100,000 Americans (most due to international travel)

One of the greatest public health achievements of the 20th Century

EPA. The History of Drinking Water Treatment: 2000.; CDC. Achievements in Public Health, 1900-1999: Safer and Healthier Foods. MMWR 1999; 48(40): 905.; CDC. Summary of Notifiable Diseases—United States, 2006. MMWR 2008; 55(53): 17

Baltimore, MD

Typhoid Fever Trend (Mortality per 100,000) and Sanitary Interventions, 1900–1936



Cutler D, Miller G. Demography. 2005;42(1):1-22.



PROVIDING SAFE AND HEALTHY WATER

Does Safe Water Reduce the Risk of Diarrhea Globally?

- 1991[1]
  - 15-17% reduction for improved water quality in 16 studies
  - 20-27% reduction for water quantity in 15 studies
- 2009[2]
  - 55% reduction for all ages in 7 studies
  - 46% reduction in children <5 y.o. in 5 trials

Why the difference?

1. Esrey et al., 1991. Bull WHO 69:609-621.
2. Clasen et al., 2009. Cochrane Library 2009(1);1-115.

Does Site or Type of Water Treatment Reduce Diarrheal Illness?

- **Treat at Source or at Home**
  27% Reduction
  - **Treat at Source**
    13% Reduction
  - **Treat in Home**
    44% Reduction
    - **Chlorination**
      39% Reduction
      

    - **Filtration**
      63% Reduction
      
    - **Storage**
      39% Reduction
      

Clasen et al., 2010. Cochrane Library 2009(1);1-115.

The Converse: What Happens When We Lose Water Service?

- Alabama, Winter 2010
  - Extended freeze left ~18,000 residents without water service for up to 12 days
- Comparing diarrhea in residents w/o water service to those with service
  - Lost water for $\geq$ 7 days
    - odds 2.4x more
  - Lost water pressure for $\geq$ 7 days
    - odds 3.5x more
    - Dose dependence correlated to length of time with water or pressure loss
  - Drank non-recommended water:
    - odds 3.7x more

Gargano J, Freeland A, Miller M, Brunkard J. et al., CDC Epi-Aid Report 2010-039.

PROVIDING IMPROVED AND ACCESSIBLE SANITATION

Does Improved Sanitation Reduce Diarrheal Illness?

- 22% reduction in 10 studies[1]
- 36% reduction in 11 studies[2]
- 32% reduction in 2 studies[3]
- 37% reduction using 6 studies[4]
- Difficult to assess due to multiple differences between studies using 13 studies[5]

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4. Waddington et al., 2009. J Develop Effect 1;295-335.
5. Clasen et al., 2010. Cochrane Reviews 2010(6): 1-30..

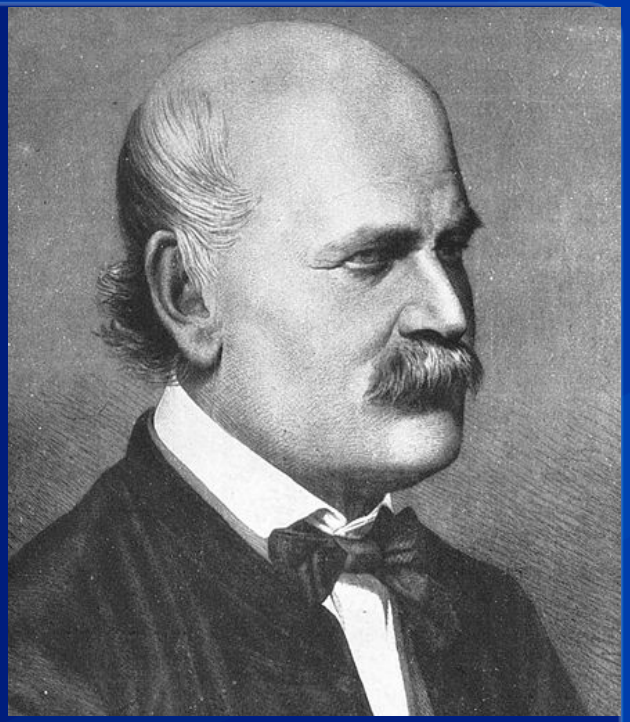
What is the Economic Impact of Inadequate Sanitation?

- New report from World Bank documents losses to the Indian economy related to inadequate sanitation[1]
- US $53 billion or 6.4% of GNP (2006)
  - US $38.5 billion from premature deaths, health effects
  - US $10.7 from time lost seeking access to sanitation
  - US $4.2 billion for drinking water-related impacts

1. Water and Sanitation Program, World Bank 2010. Available at http://www.wsp.org/wsp/sites/wsp.org/files/publications/wsp-esi-india.pdf

ENHANCED HANDWASHING AND HYGIENE

Ignaz Semmelweis
1818- 1865



- Puerperal fever at Vienna Lying-In Hospital
  - Midwife ward mortality 2%
  - Medical student ward mortality 13%
- Intervention 1847
  - Medical students required to wash hands thoroughly with chlorinated lime after autopsies
  - Proportion of puerperal fever in student ward dropped to 2.4%
- Conclusion
  - Handwashing saves lives

Comparing Handwashing Studies from Around the Globe

- Institution-based (schools, child care centers)
  - 39% reduction in diarrheal episodes
- Community-based (still all children)
  - 32% reduction in diarrheal episodes
- Immunosuppressed
  - 58% reduction in diarrheal episodes (2.9-1.2 episodes)
- High income
  - 39% reduction in diarrheal episodes in children in institutions
- Middle to low income
  - 32% reduction in diarrheal episodes in children living in communities

Ejemot et. al. 2008. Cochrane Library 2009(3) (14 studies)

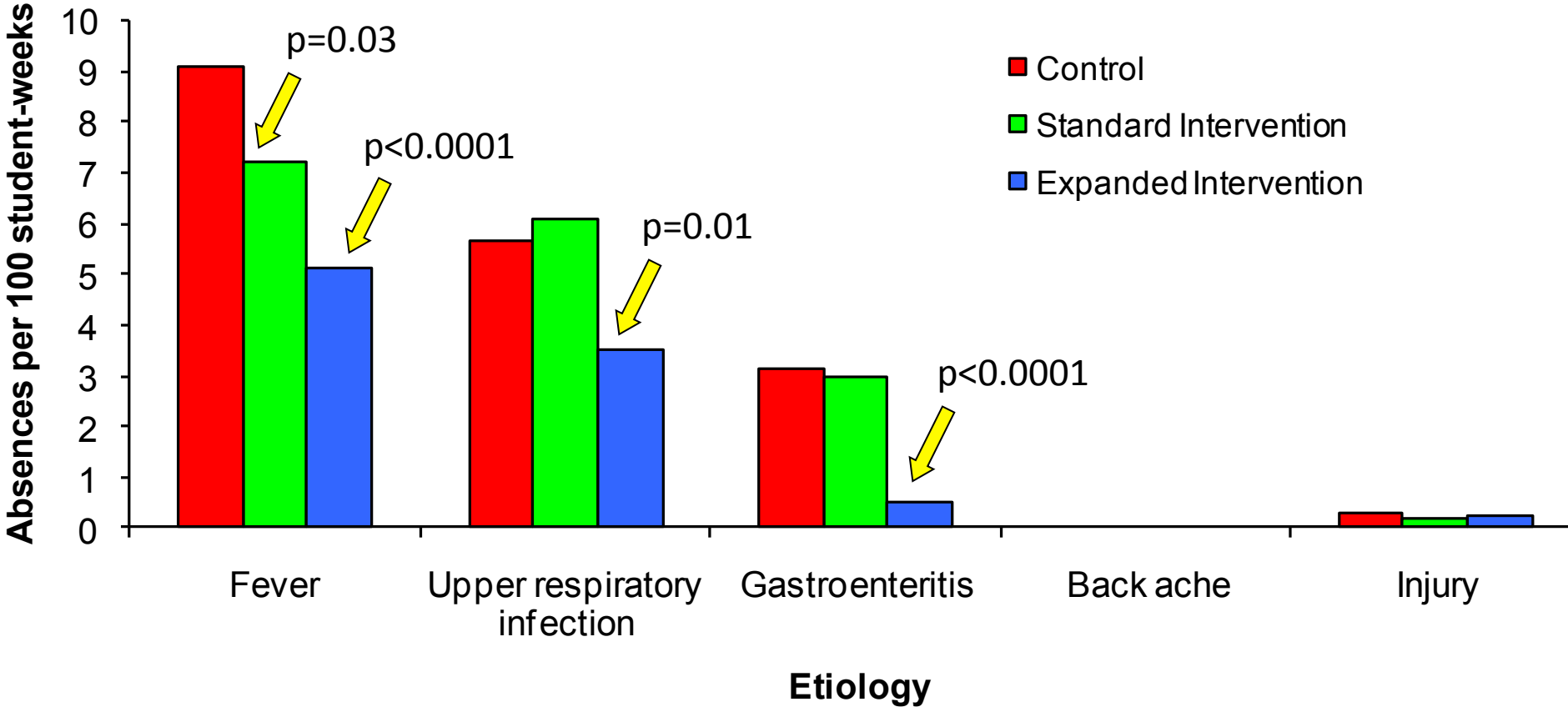
Impact of a School-Based Handwashing Promotion Program on Students and Their Households

- Randomized 154 elementary schools in Pakistan
  - Control: standard practices
  - Standard: an existing school handwashing promotion program (one 90-min lesson plus student hand-outs)
  - Expanded: standard school handwashing program, on-going supply of soap for school, and a student hygiene champion assigned in each class

- Followed absenteeism among 1st graders and illnesses among students' household members for 5 months

Bowen et al., 2010. Unpublished data.

Absence Rates by Etiology and Study Group



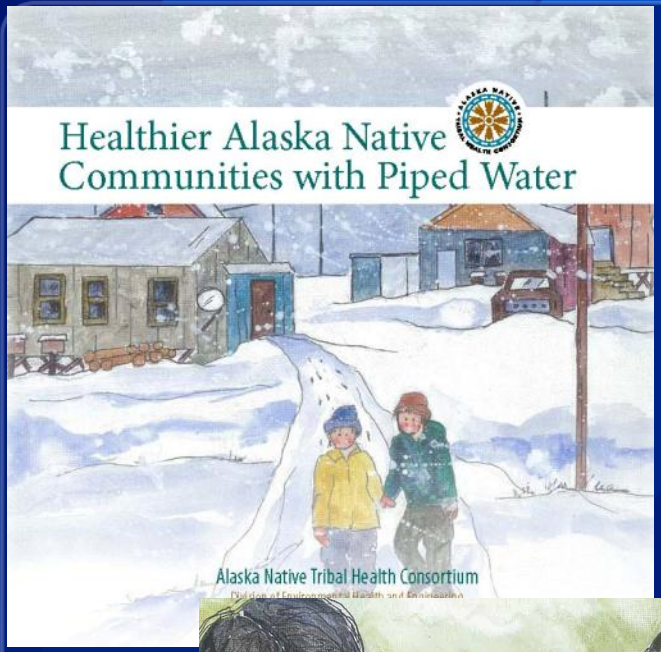
Bowen et al., 2010. Unpublished data.

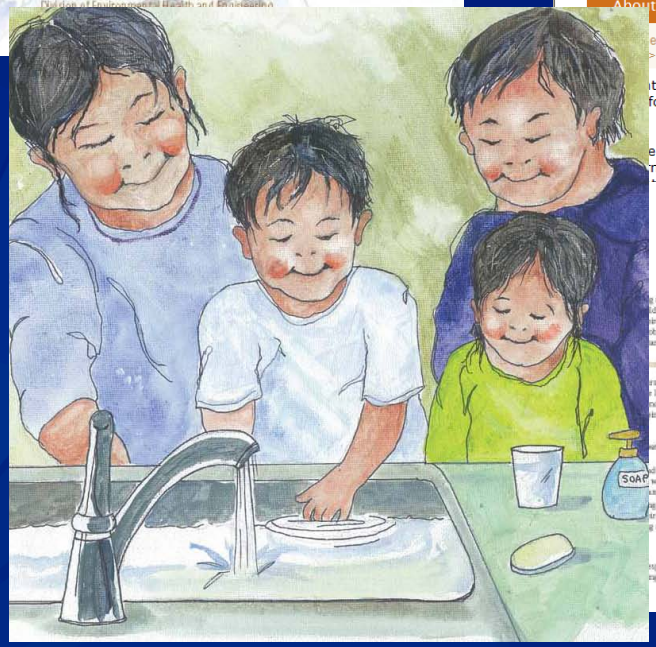
Do the Handwashing Interventions Make a Difference?

- Substantial health impact
- Health impact extended to student household contacts
  - Novel finding
- Among households, the Expanded Intervention group had a significant economic impact
  - Lower rates of health care visits for illness
  - Lower rates of work absenteeism among parents due to illness
- Worldwide access to hand soap and peer hygiene education in schools could have broad public health and economic implications

Bowen et al., 2010. Unpublished data.

Promoting and Monitoring Behavior Change to Reduce Diarrheal Illness

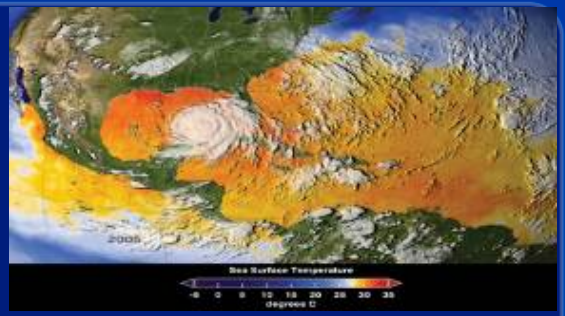




http://www.anthc.org/cs/dehe/envhlth/research/water-use-promotion.cfm

EFFECTS OF CLIMATE VARIABILITY ON WATER QUALITY AND QUANTITY: FUTURE CHALLENGES

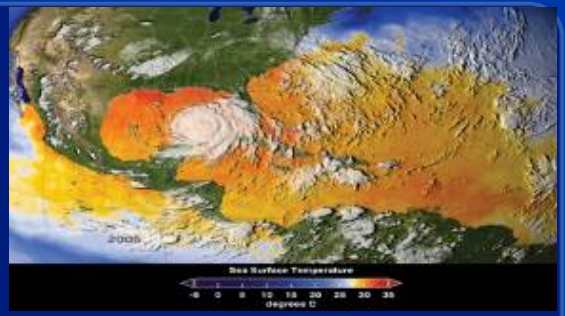
Climate Change and Water Impacts: General



- Air and water temperature increases
- Sea level changes
- Portion of precipitation falling as snow declines
- Increased or decreased water availability by region
- Extreme weather events increase
  - Droughts, floods, increased temperatures
- Water quantity as well as water quality becomes issue

Sources: IPCC, 2007; USGCRP, 2009

Climate Change and Water Impacts: Arctic



- Melting permafrost
  - Stress to water and wastewater infrastructure
- Storm surge
  - Saline intrusion of water sources
  - Flooding damage to water/wastewater systems
  - Coastal erosion
- Increased particulate and nutrient loads
  - Surface and groundwater sources affected
  - Operational issues with high turbidity and organic load; decreased efficacy of disinfection
- Changes in climate sensitive pathogens such as *Giardia*

Climate Change, Water, and Public Health: Building Adaptive Management Models

- CDC collaboration with AWWA
- Identify current and future water and public health impacts of climate change on water utilities
- Collect lessons learned from water utilities dealing with the effects of climate change
- 16 participating utilities including three in Alaska
  - Sitka, Anchorage, Barrow
- Analysis of ongoing issues and anticipated issues completed for 13 utilities (Alaska not included yet)

Climate-related Impacts on Water Utilities

Water Quantity	Current (N)	Future (N)
More intense precipitation events	7	7
Increased drought	6	7
Climate variability	5	5
Increased flooding	3	6
Changes in precipitation patterns/ runoff	2	7
Decreased snowpack, earlier snowmelt	2	3
Sea level rise	2	6

N= 13 utilities; Brunkard, 2011. Unpublished data .

Climate-related Impacts on Water Utilities

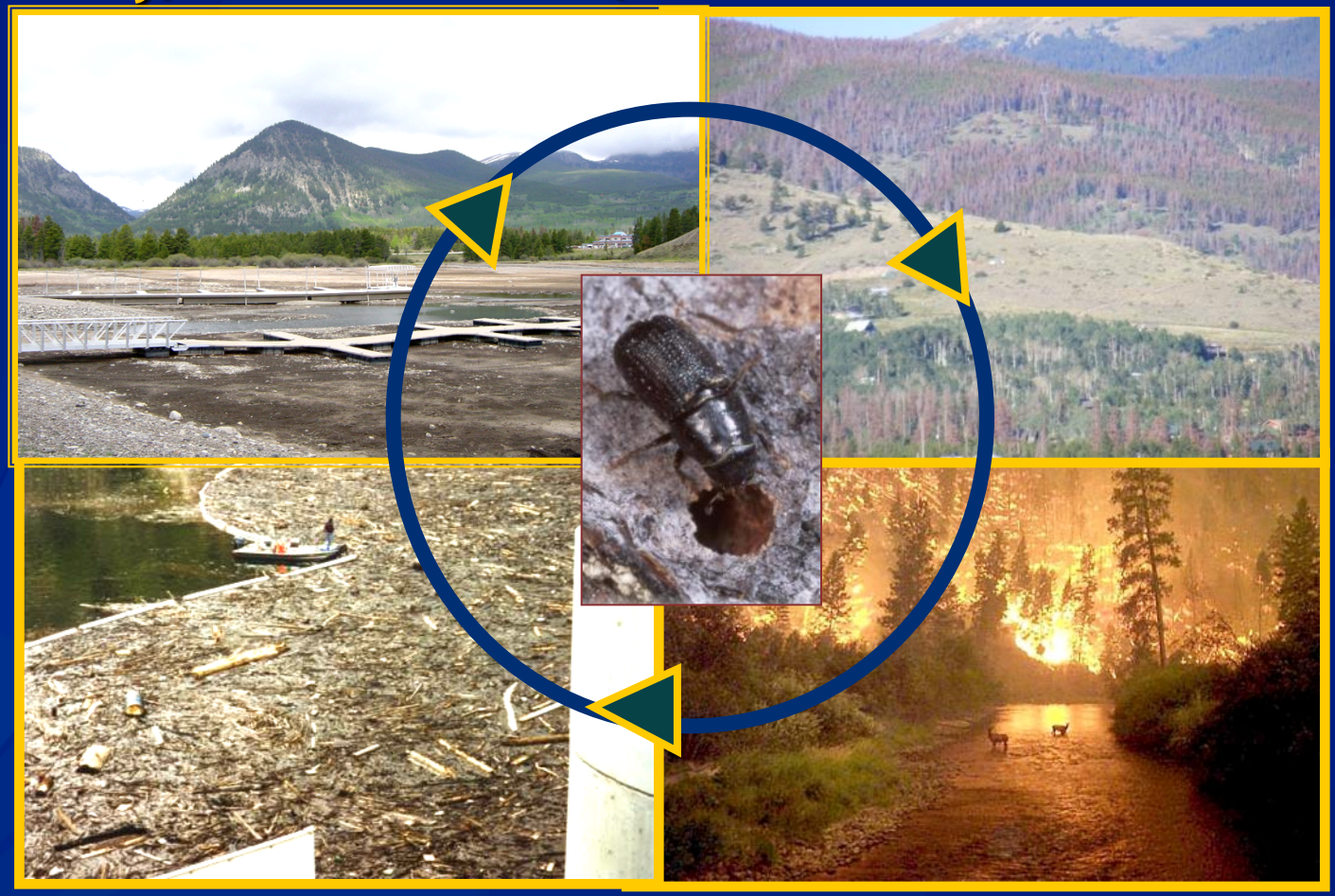
Water Quality	Current (N)	Future (N)
Algal blooms	3	8
Ecological changes	2	10
Water quality changes	2	10
Turbidity and treatment challenges	2	5
Water age/economic downturn	2	5
Increase in more extreme weather events	1	6
Infrastructure challenges	0	5

N= 13 utilities; Brunkard, 2011. Unpublished data .




ECOLOGIC CHANGES: UNINTENDED CONSEQUENCES

The Ecological Cascade Effect: ↑ Minimum Temp, Pine Beetle Exceeds Carrying Capacity, ↑ Forest Fires, ↑ Sediment Load in Water



Source: Marc Wagge, Denver Water

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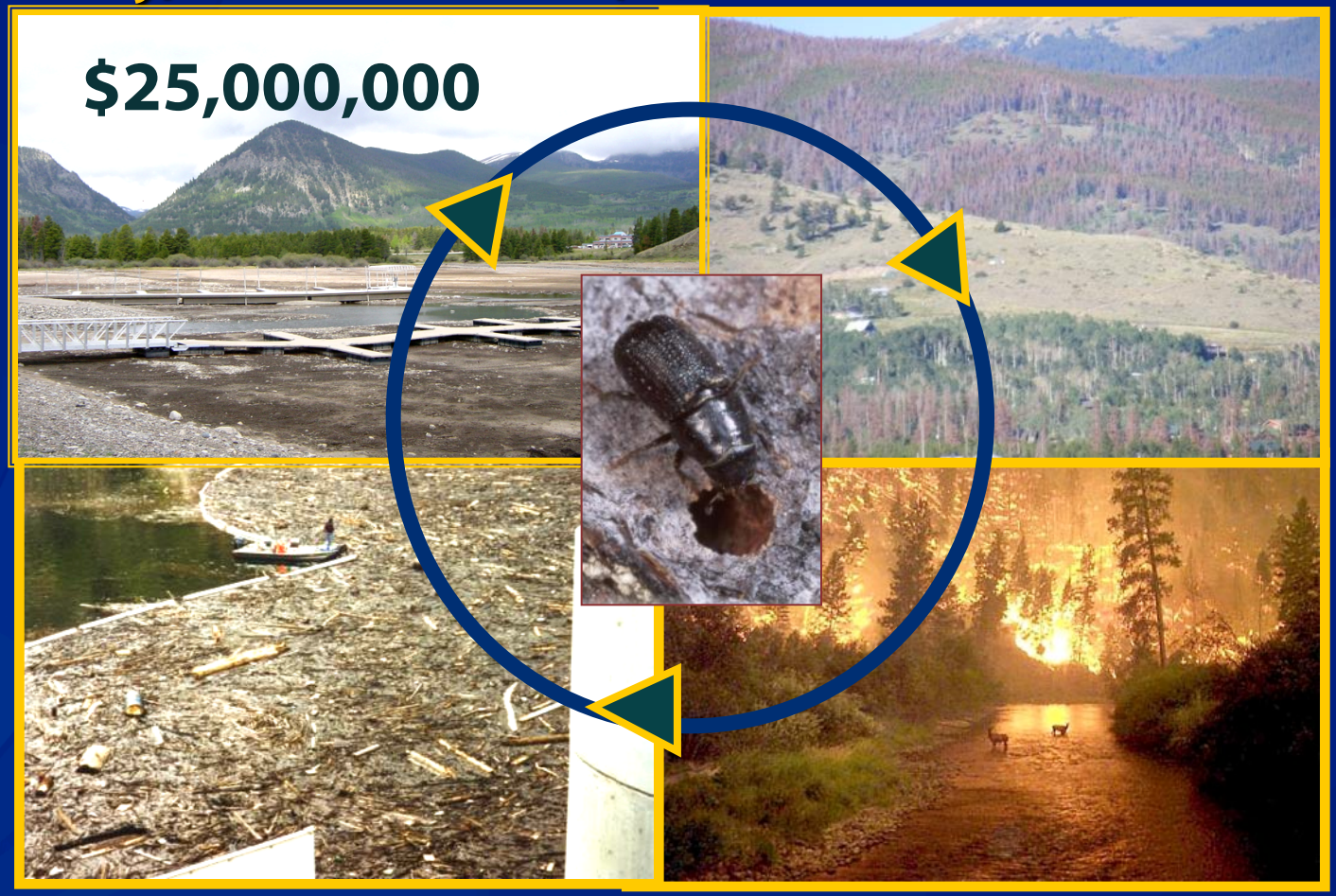

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Summary and Future Outlook

- Strong body of data demonstrating reductions in diarrheal illness with improved WASH
  - Both water quality and quantity important
  - Role for point-of-use treatment and improved storage?
- Data also demonstrates collateral benefits with reduced respiratory illness and skin infections
- Water provision & infrastructure issues require complementary hygiene-related behavioral changes
- Climate change is wild card due to increasing stress on source water quality and infrastructure
- Need improved monitoring and evaluation of changes
  - What does water testing in Alaska show now?

Acknowledgements

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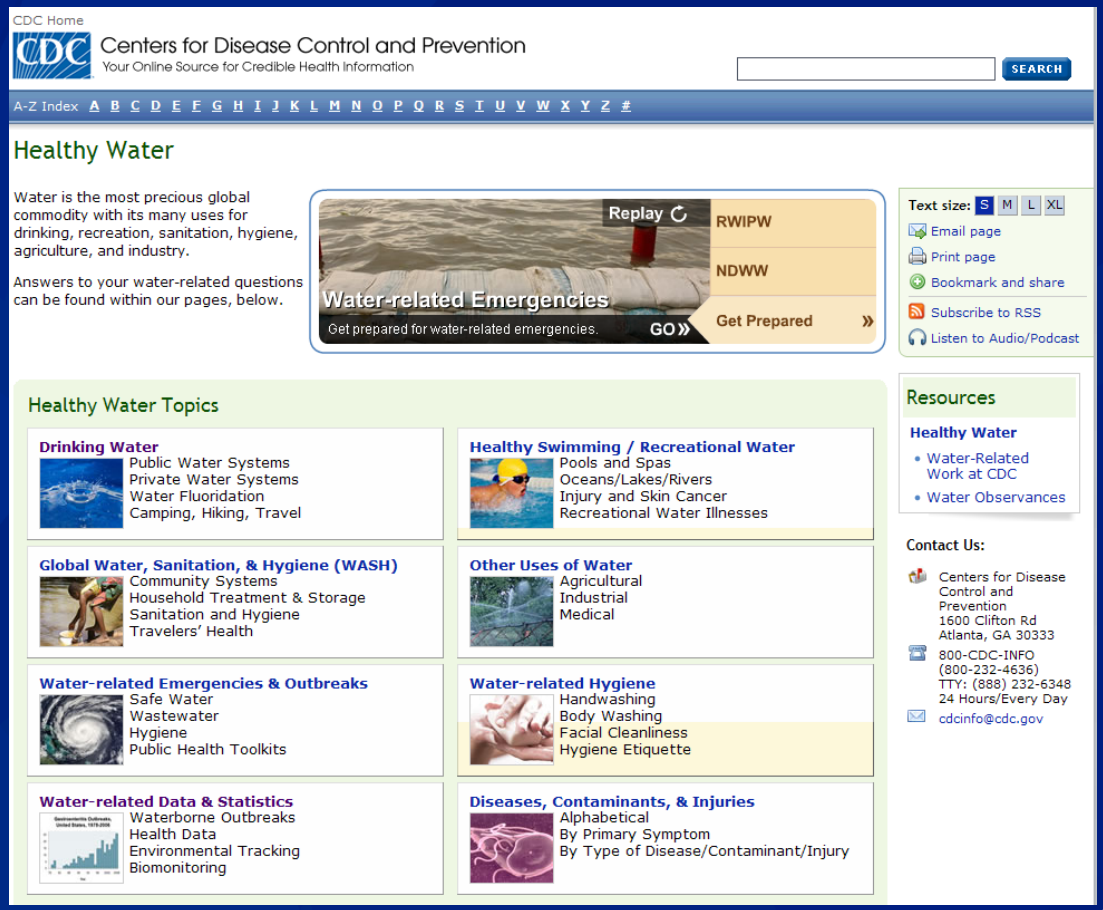
- Anna Bowen
- Joan Brunkard
- Julia Gargano
- Amy Freeland

NCEH/EHSB

- Mark Miller
- Charles Otto

"The findings and conclusions in this presentation have not been formally disseminated by CDC and should not be construed to represent any agency determination or policy"

Questions?
More Information: Healthy Water Website
www.cdc.gov/healthywater



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Does Site or Type of Water Treatment Reduce Diarrheal Illness?

- 27% reduction: source or household treatment:
  - RR 0.73 [0.63, 0.85]
- 13% reduction: source treatment
  - RR 0.87 [0.74, 1.02]
- 44% reduction: household treatment
  - RR 0.56 [0.42, 0.74]
- 39% reduction: household chlorination
  - RR 0.61 [0.46, 0.81]
- 63% reduction: household filtration
  - RR 0.37 [0.15, 0.92]
- 39% reduction: household storage
  - RR 0.79 [0.61, 1.03]

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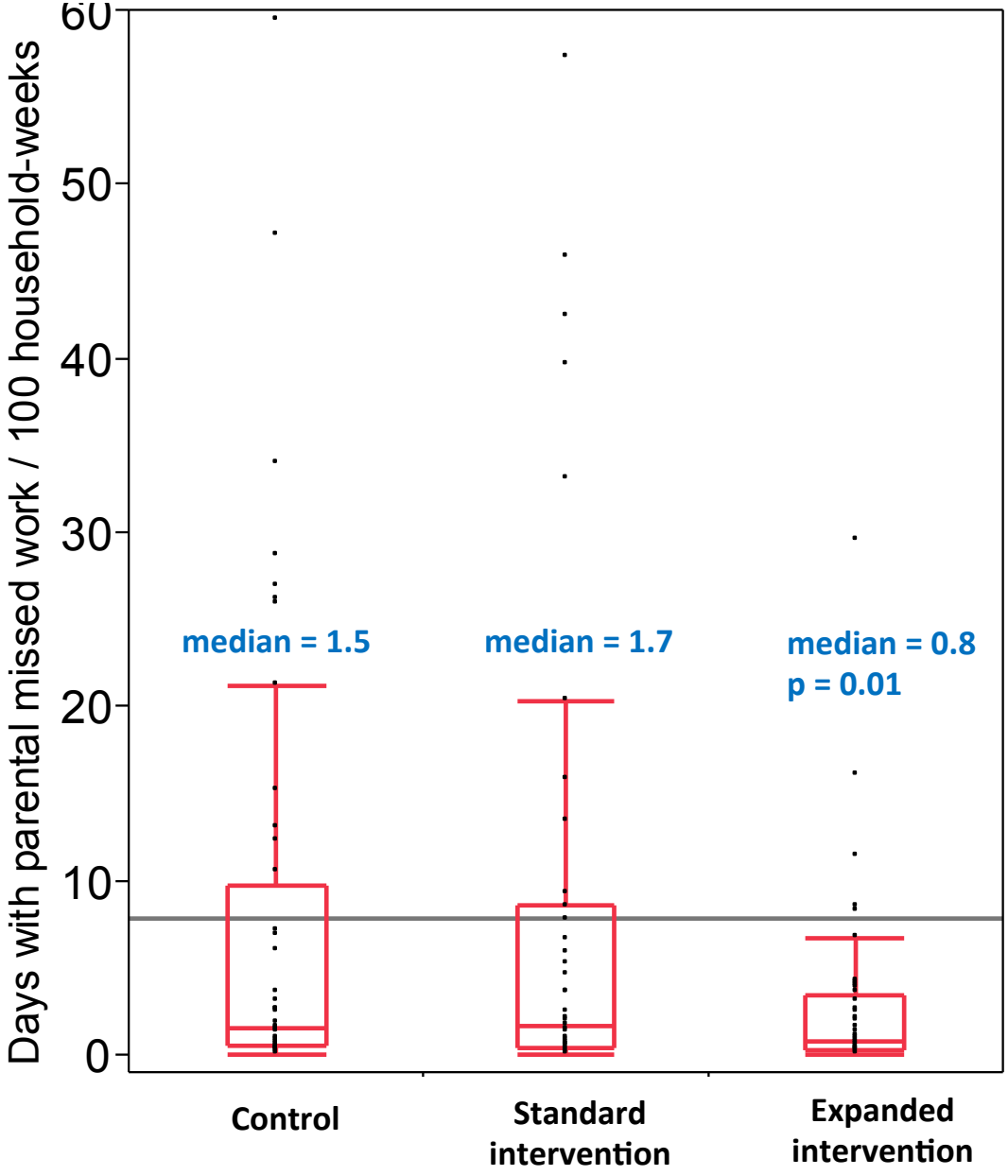
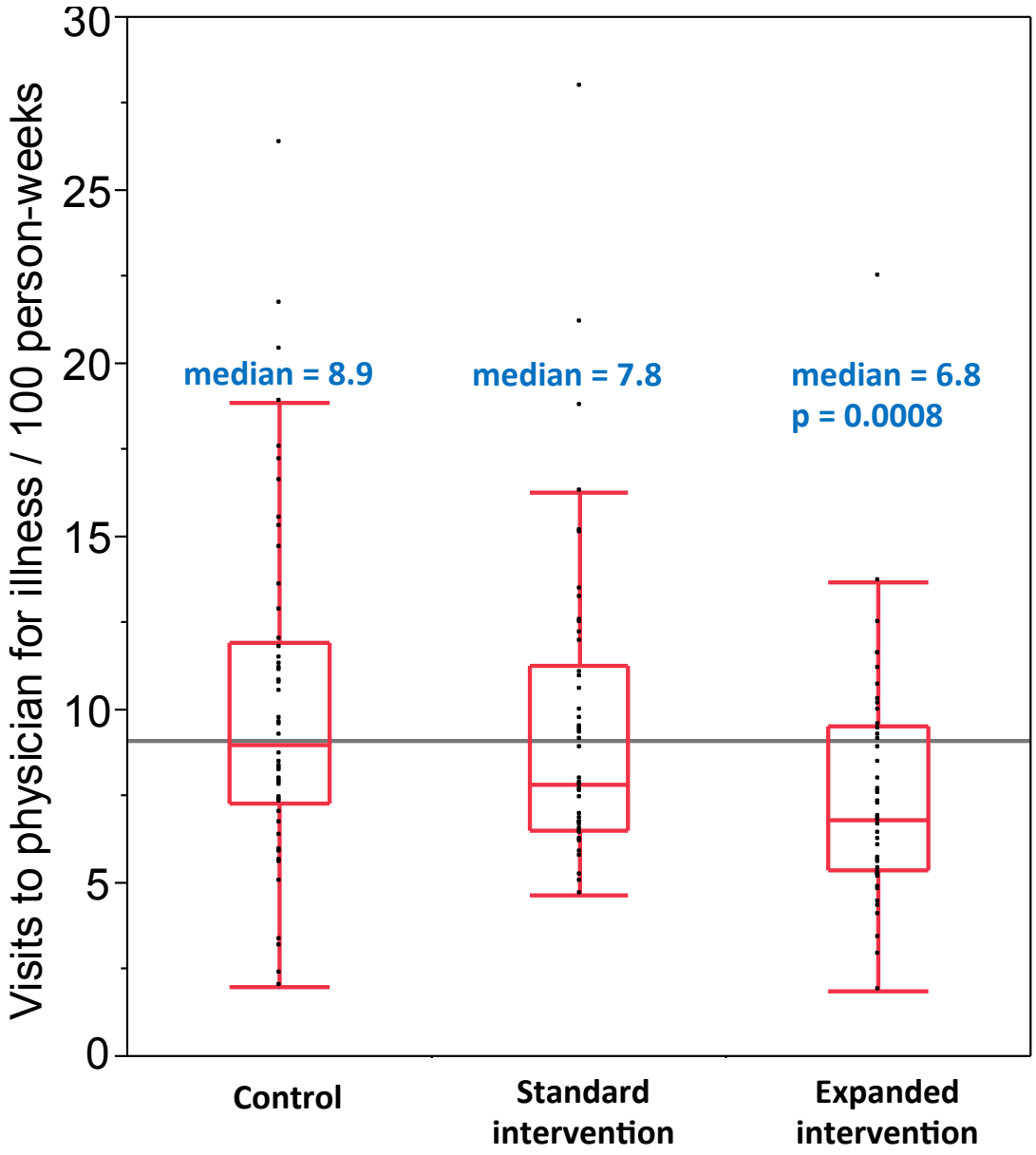
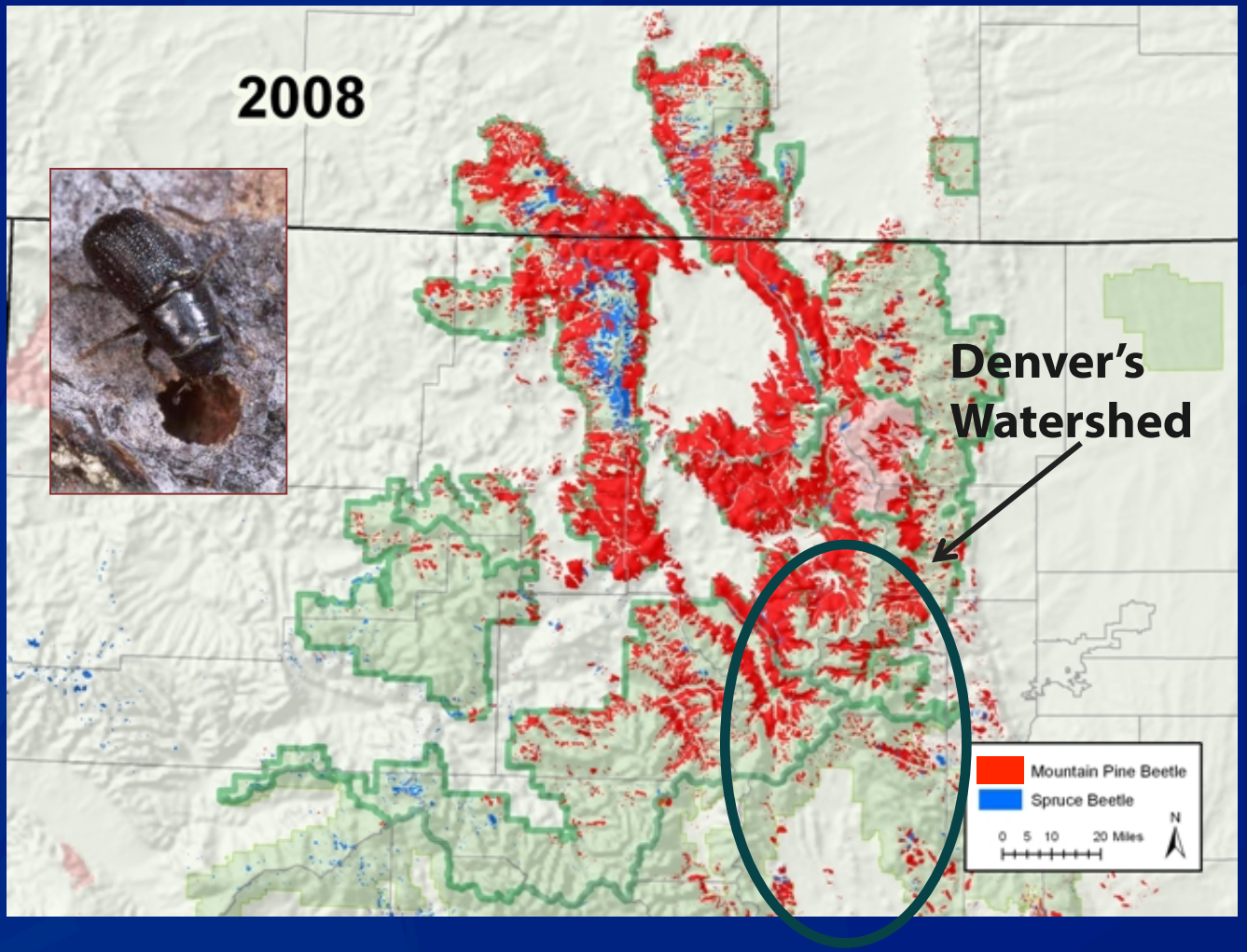
Parental Missed Work due to Illness



Health Care Visits due to Illness



Trees Killed By Pine Beetles



Source: Marc Wagge, Denver Water