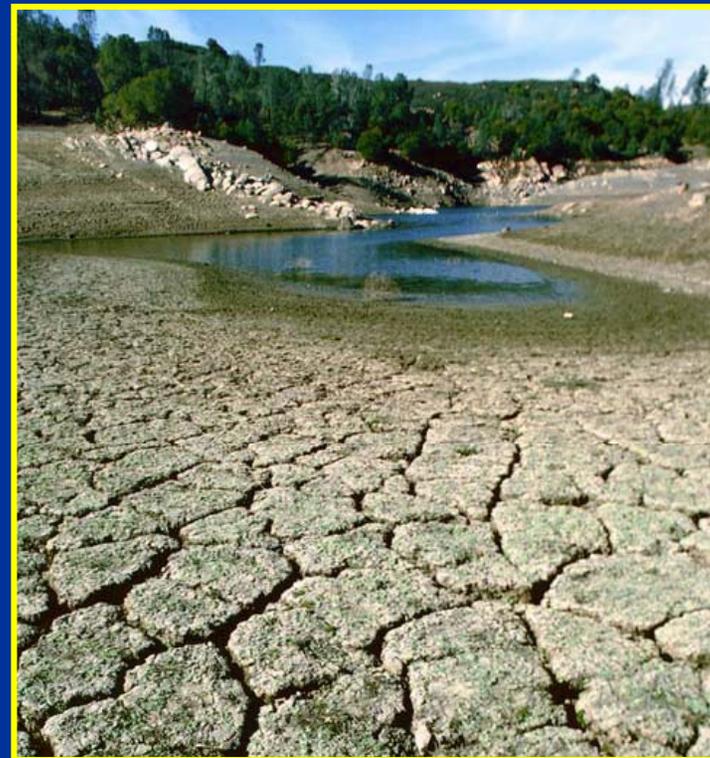


# Recreational Water: The Risks, the Effects, and Climate Change

Michael J. Beach, Ph. D.  
Centers for Disease Control and Prevention

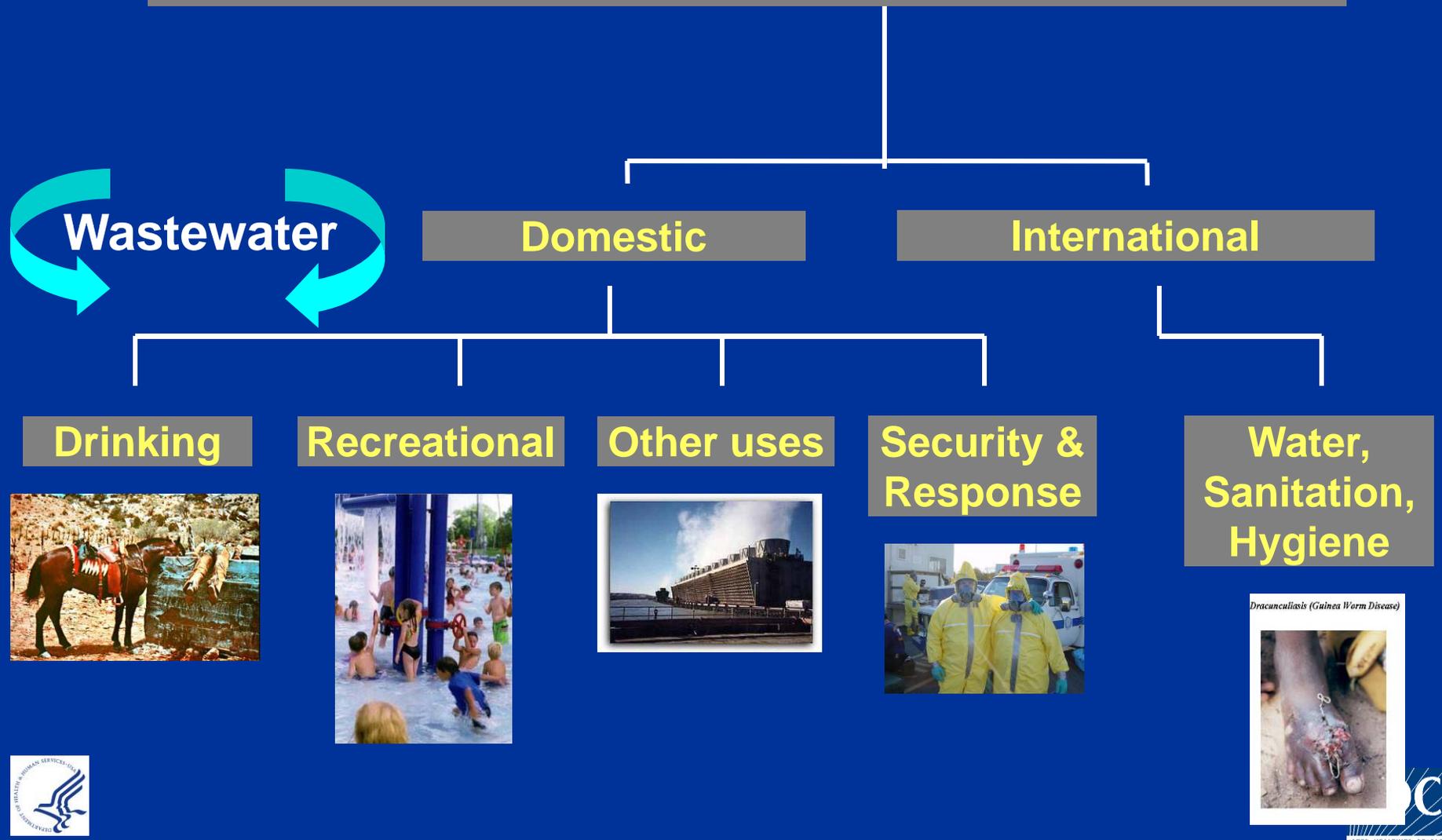


# Outline

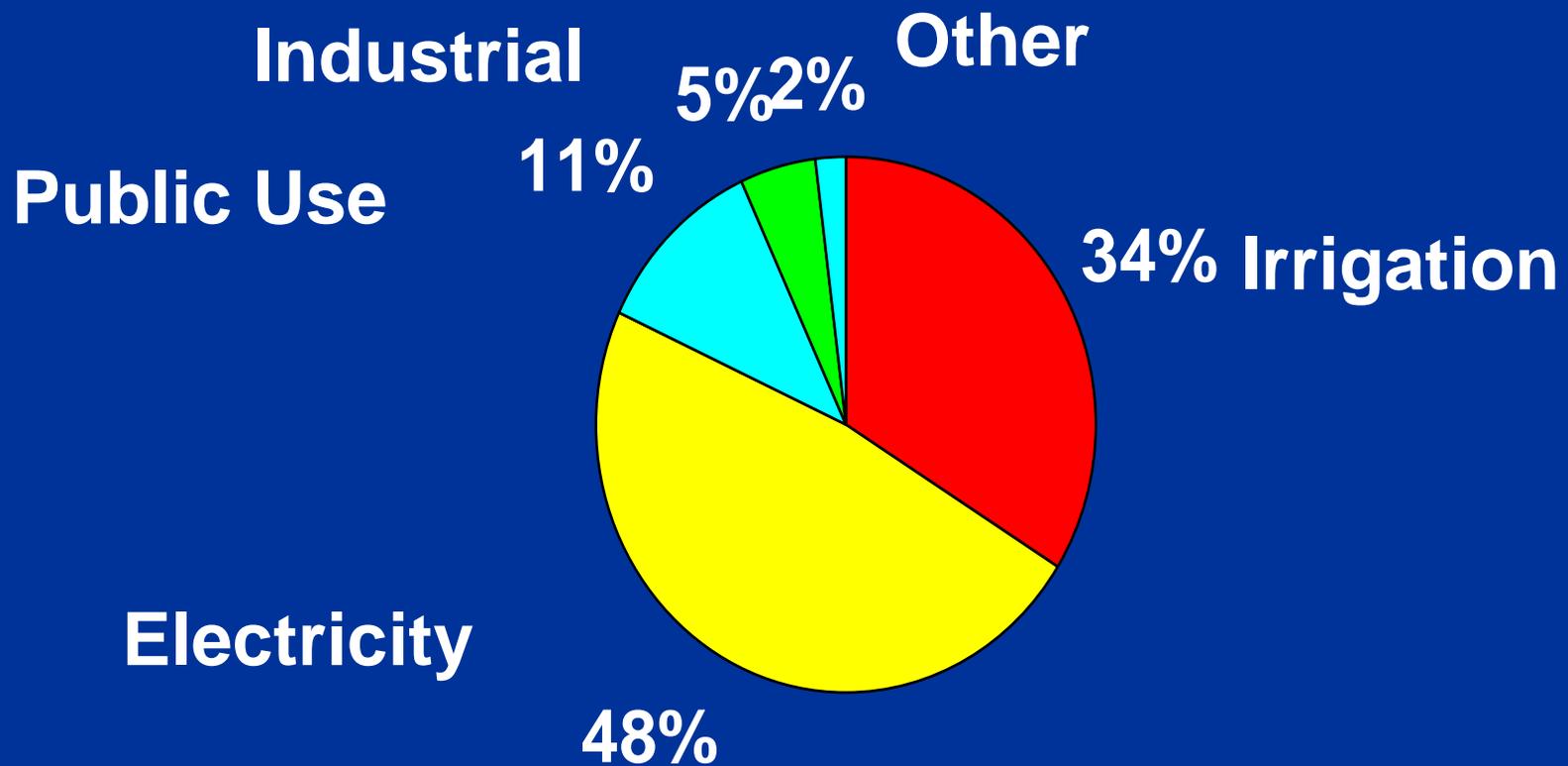
- Trends in recreational water-associated waterborne disease outbreaks in U.S.
- Potential climate change impact
  - Drought, floods, temperature
- Changes in reporting of *Cryptosporidium*
- Future thoughts



# One Water: The Universe of Water-Related Disease



# Water Use in the U.S.



USGS, 2000



# Diarrhea is Common



- ~8% of general public had diarrhea in past month<sup>1</sup>
- 0.1–3.5 cases of diarrhea/person/year (higher for young children)<sup>2</sup>
- > 2% fecal incontinence (FI) in Wisconsin Family Health survey<sup>3</sup>
  - 70% with FI <65 years old

1. Roy SL et al. 2006. *J Water Health* 4(Suppl 2):31–69.
2. Jones TF et al. 2007. *Epidemiol Infect* 135(2):293–301.
3. Nelson R et al. 1995. *JAMA* 274(7):559–61.



# Fecal Contamination of Recreational Water is Common



- Heavy use by diapered and toddler-aged children: swimmer to swimmer
- Fecal accidents common
  - 293 formed stools, 47 pools<sup>1</sup>
- ~ 0.14g of feces on peri-anal surface/person
  - range: 0.01g (adults)–10g (children)<sup>2</sup>

1. CDC. 2001. MMWR 50(20):410–2.

2. Gerba CP. 2000. Quant Microbiol 2(1):55–68



# Fecal Contamination of Fresh Water/Recreational Water is Common

- Environmental contamination
  - animal--urban/pastureland/forestland runoff
- Wastewater effluent
  - CSO, SSO
- Untreated dumping -- pleasure craft, houseboats, failing septic systems
- Most surface water in U.S. contaminated with pathogens



# Exposure to Recreational Water is Common: Americans swim...a lot



- Swimming is the 2<sup>nd</sup> most popular exercise activity in the United States
  - ~ 350 million swimming visits each year<sup>1</sup>
    - Underestimate
      - $\geq 7$  years of age
      - Swim  $\geq 6$  times in last year

1. US Bureau of the Census. 2005. Statistical Abstract of the United States. Arts, Recreation, & Travel: Recreation and Leisure Activities.

[www.census.gov/compendia/statab/cats/arts\\_recreation\\_travel/recreation\\_and\\_leisure\\_activities.html](http://www.census.gov/compendia/statab/cats/arts_recreation_travel/recreation_and_leisure_activities.html)



# Spectrum of Waterborne Disease in the U.S.

- **Acute gastroenteritis**
  - *Cryptosporidium*, toxigenic *E. coli*, *Giardia*, *Shigella*, norovirus, chemicals
- **Skin infections and irritation**
  - *Pseudomonas* dermatitis/folliculitis, fungal infections, chloramines
- **Ear infections** – *Pseudomonas*
- **Eye infections and irritation**
  - Adenoviruses, chloramines
- **Respiratory infections**
  - *Legionella*, *Mycobacterium*, chloramines, chemicals
- **Neurologic infections** – Echovirus, *Naegleria*
- **Wound infections** – *Vibrio*
- **Hepatitis** – HAV
- **Urinary tract infections** – *Pseudomonas*
- **Other** – *Leptospira*, HAB's

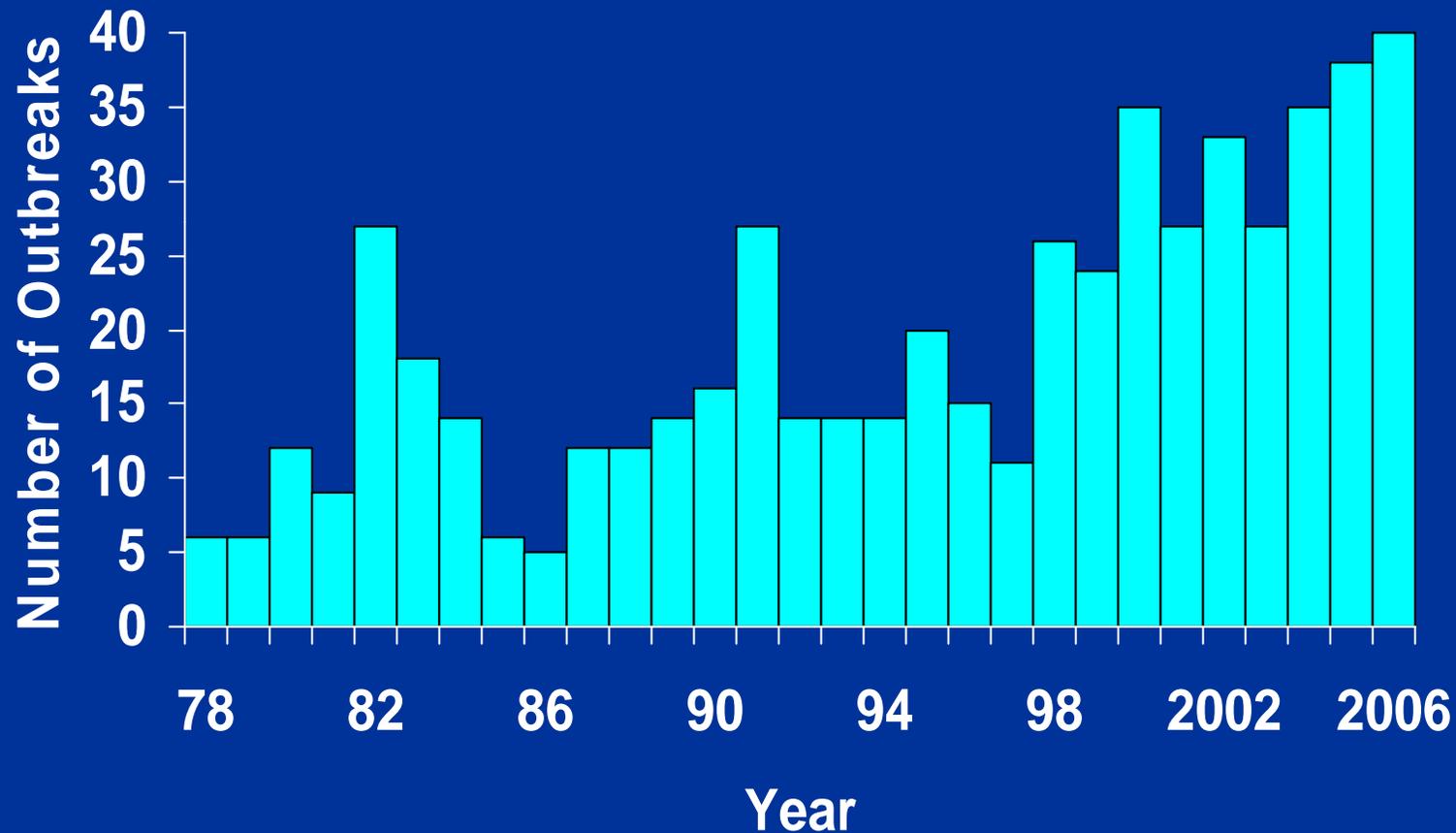


# Tracking RWIs/Surveillance Data



## What Do We Know About Outbreaks?

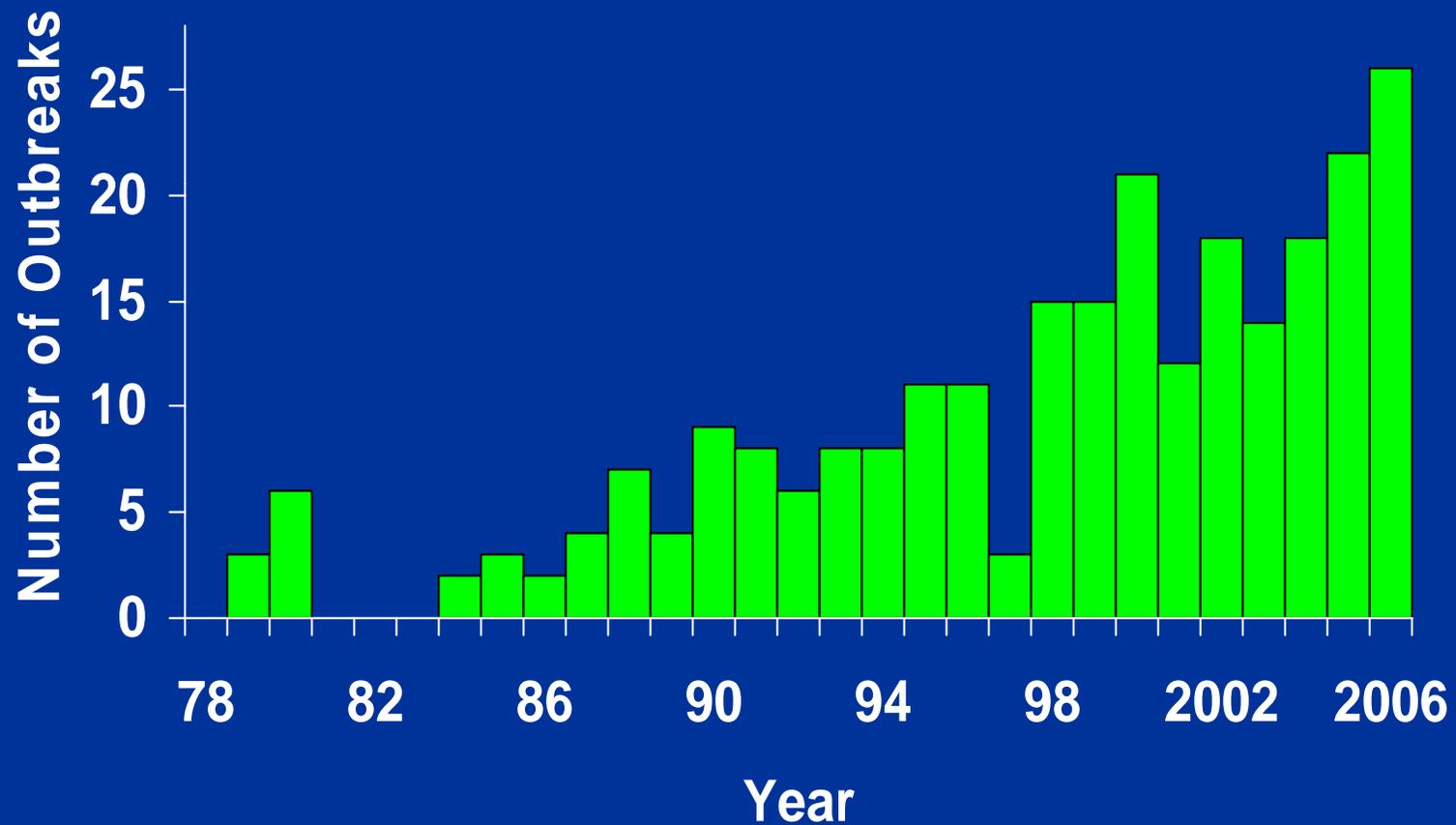
# RWI Outbreaks, United States, 1978–2006\*



\* N=557, Yoder JS *et al.* 2008. MMWR 57(SS-9):1-38.



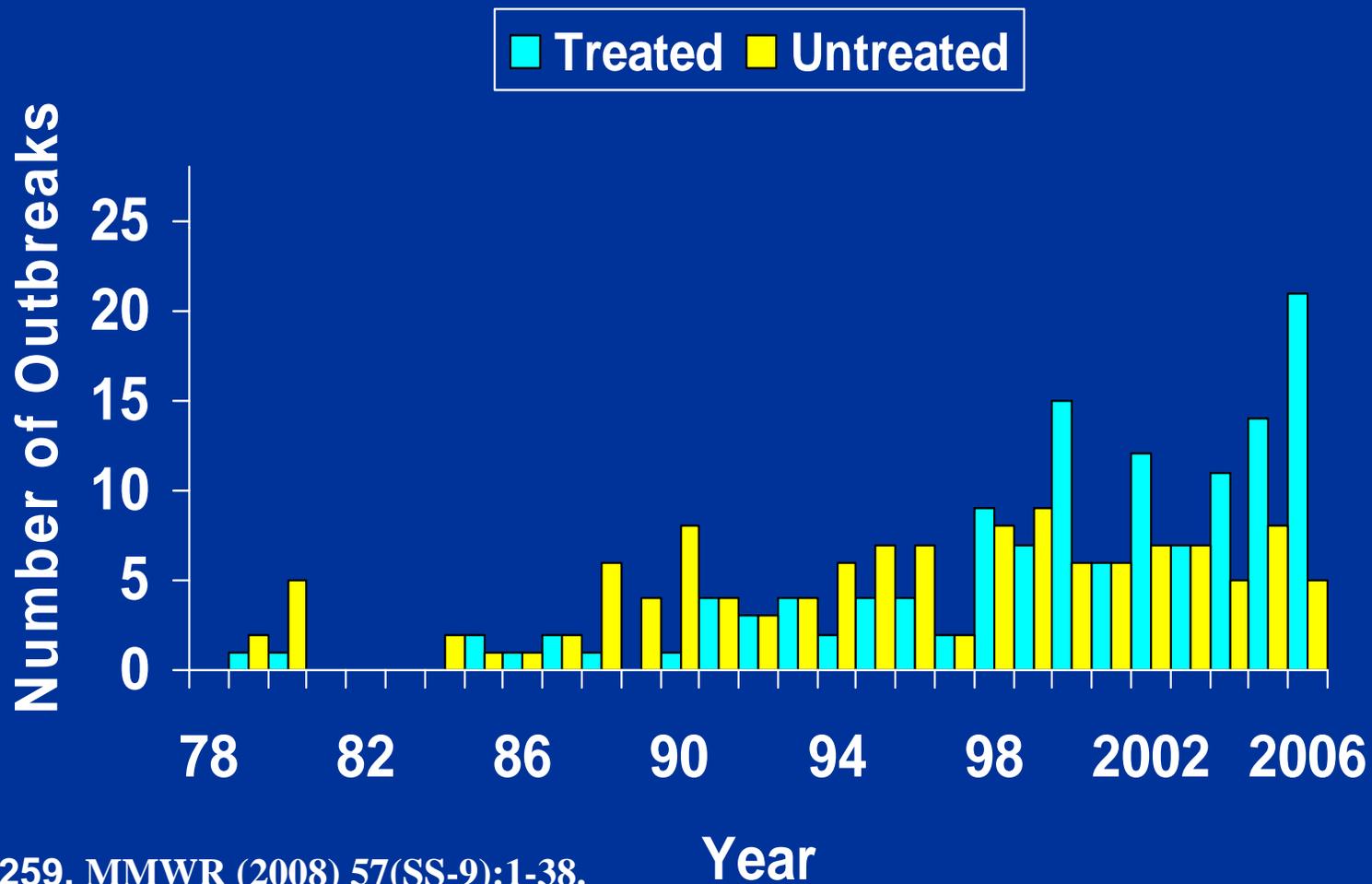
# Gastroenteritis Outbreaks, United States, 1978-2006



N=259, MMWR (2008) 57(SS-9):1-38.



# Gastroenteritis Outbreaks, United States, 1978-2006

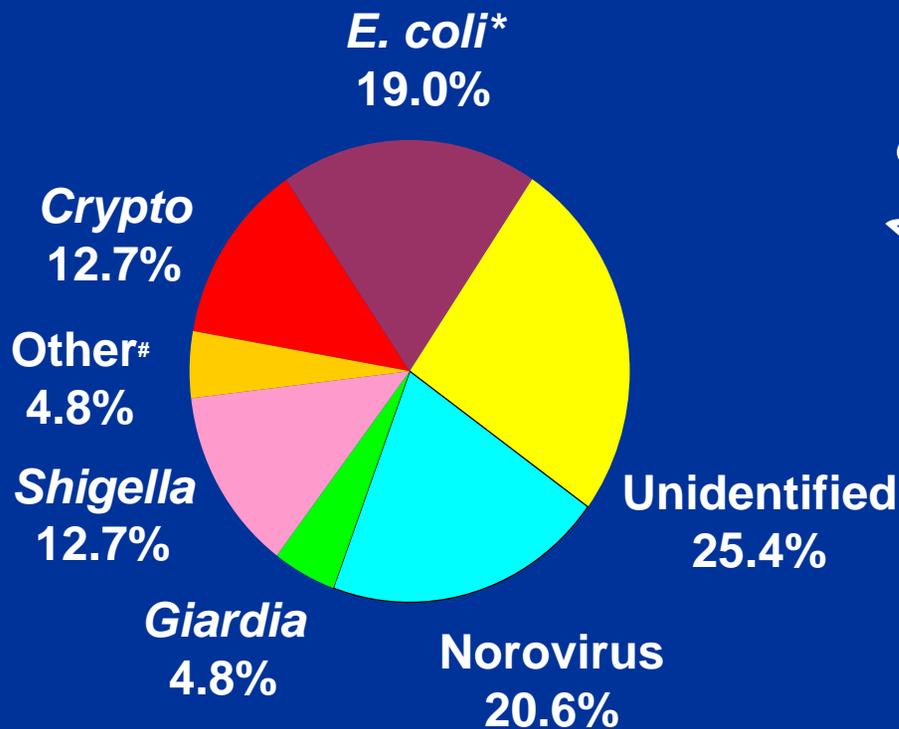


N=259, MMWR (2008) 57(SS-9):1-38.

Year

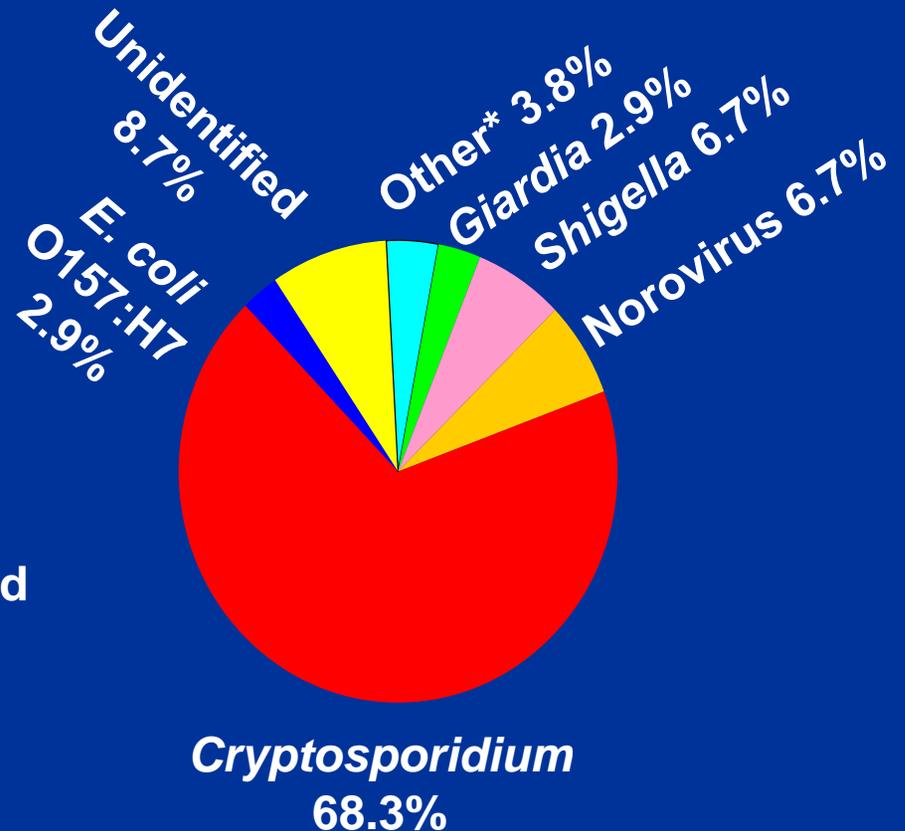


# RWI Outbreaks, United States, 1997-2006; Gastroenteritis



**Fresh Water**

**N=63**



**Chlorinated Water**

**N=104**



\* Includes *E. coli* O157:H7, O26:NM, O121:H19  
# includes *Salmonella*, *Campylobacter*, *Plesiomonas*,  
*mixed pathogens*

\* Includes *Campylobacter*, *Salmonella*



# Recreational Water: Natural Waters



- Only one reported Great Lakes-associated outbreak since 1978
- No ocean-related outbreaks reported in US since 1978
- If you do prospective health effects studies you generally find GI illness associated with swimming



# Illness Incidence and Adjusted Cumulative Incidence Ratios (aCIR) Comparing Swimmers With Nonswimmers

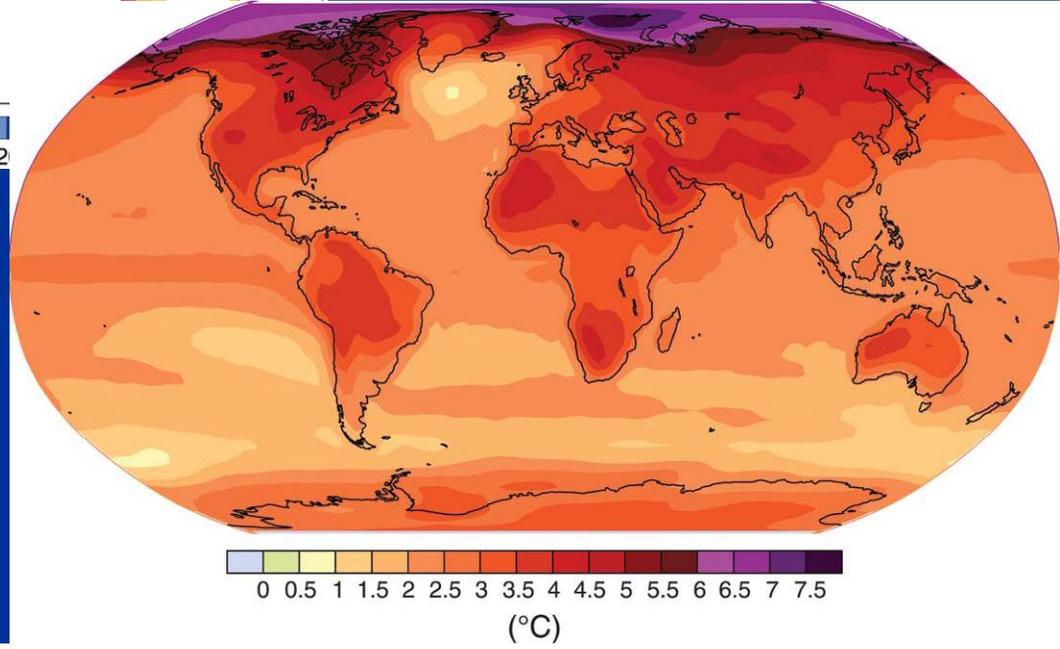
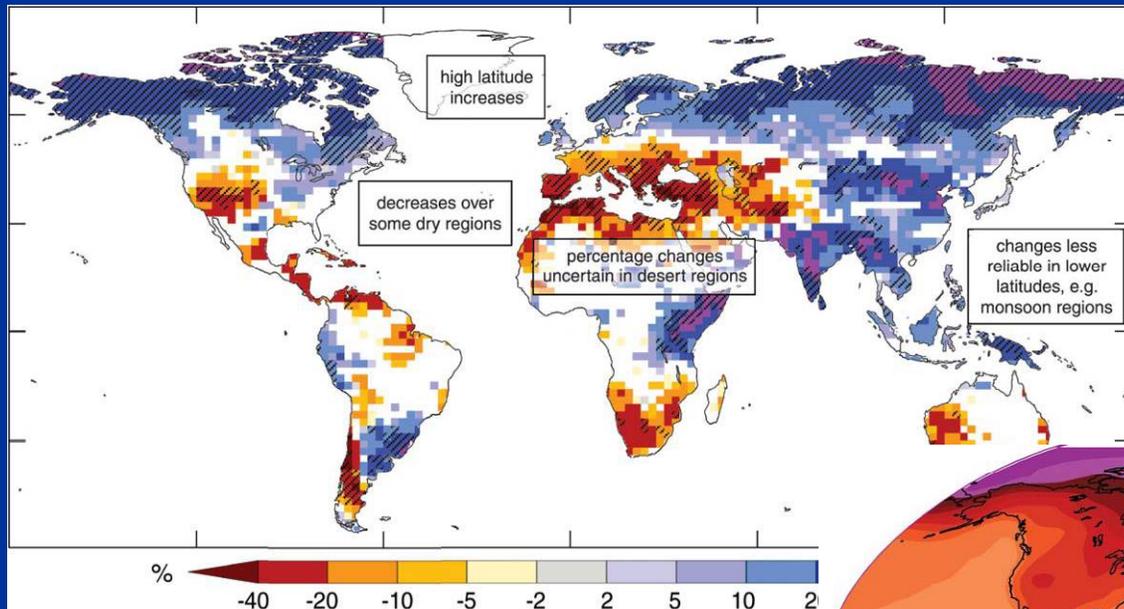


Illness	aCIR (95% CI)
GI	1.4 (1.3-1.6)
Rash	1.4 (1.1-1.7)
Earache	1.6 (1.2-2.2)

Four Great Lakes Beaches. 21,015 interviews  
Wade et al., Epidemiol 2008;19: 375–383



# Extreme Weather Events, Climate Change, and Water Availability/Quality



Source: IPCC Climate Change 2007 Synthesis Report

# Climate Change Water Impacts



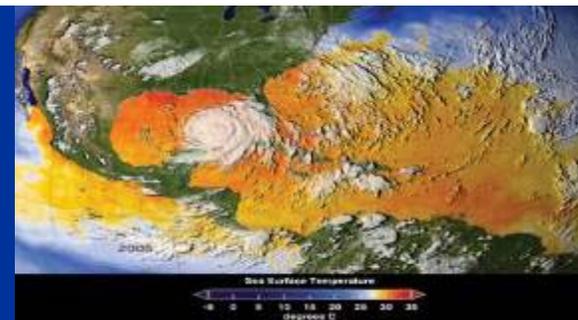
- Increased water availability in moist tropics and high latitudes
- Decreased water availability and increasing drought in mid-latitudes and semi-arid low latitudes
- Water stress for hundreds of millions
- Extreme weather events
  - Droughts
  - Floods
  - Increased temperatures



Source: IPCC

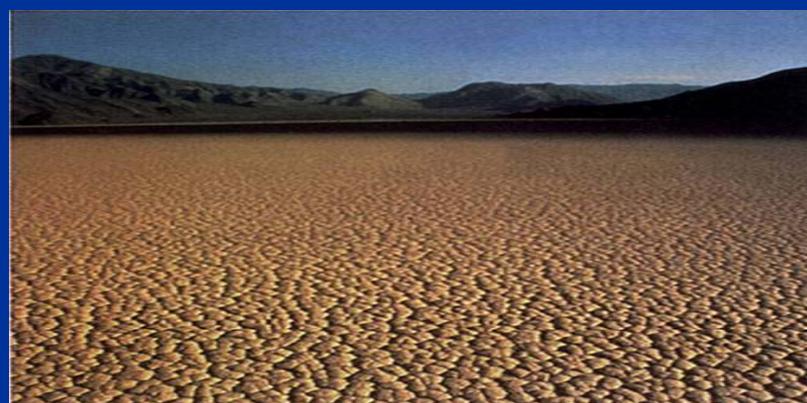


# Water and Climate Change: Challenges



## Water quality

Cholera, cryptosporidiosis, campylobacter, shigellosis, giardiasis, *Naegleria*, leptospirosis, vibriosis, HABs, chemicals

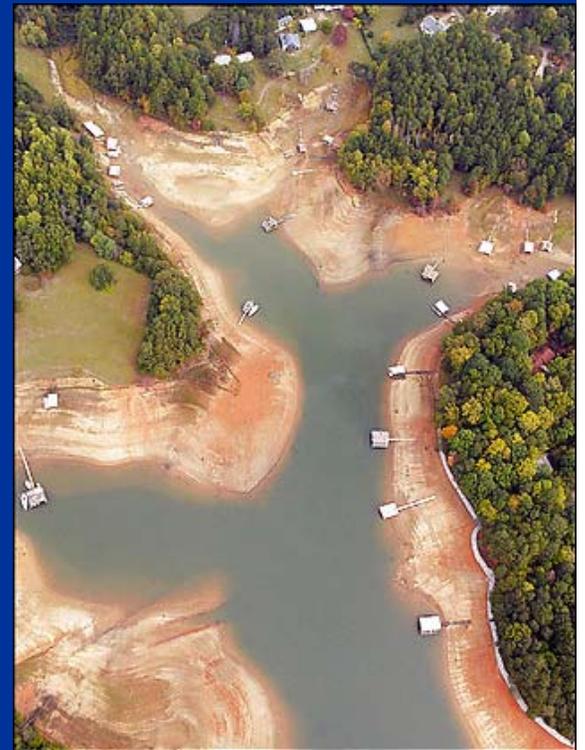
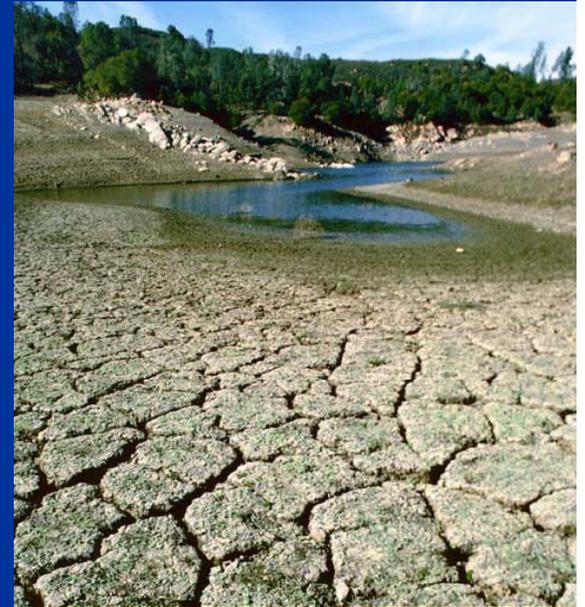


## Water quantity



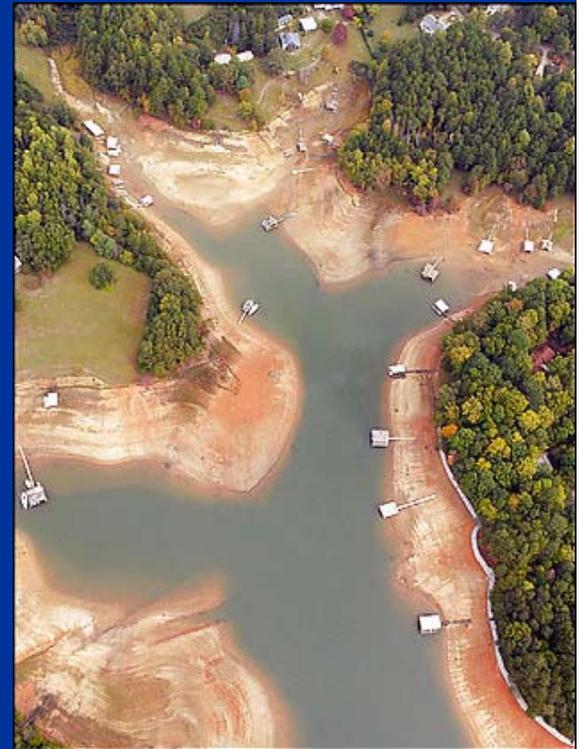
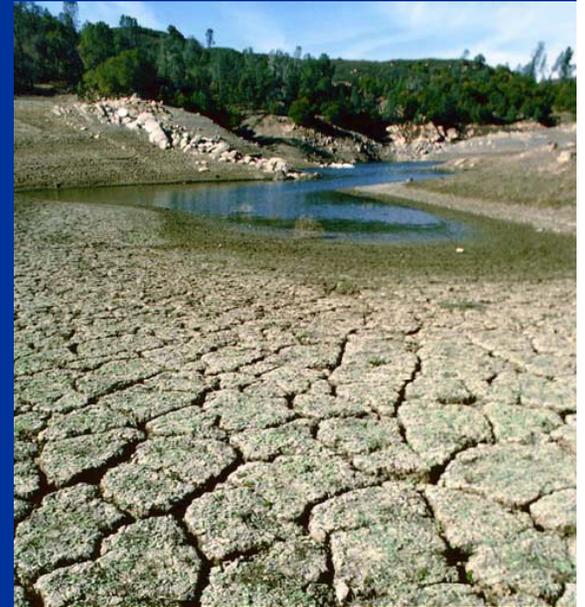
# Drought

- **Current problems**
  - Colorado basin
  - Tucson, AZ
  - Atlanta, GA
- **Drinking and recreational water quality and quantity decreasing**
- **Surface water**
  - Concentration of contaminants
  - Decreased dilution factor in outflows
  - Increased risk for swimmers?



# Drought

- **Groundwater**
  - Increasing need for groundwater recharge
  - Surface water sources used
  - Saltwater intrusion into groundwater
- **Collateral damage**
  - Air quality, mental health, poor hygiene, fires, crop loss
- **Water quantity**
  - First act in GA was to try and shut all pools
  - Need to replace water more often



# Other Uses of Water: Challenges

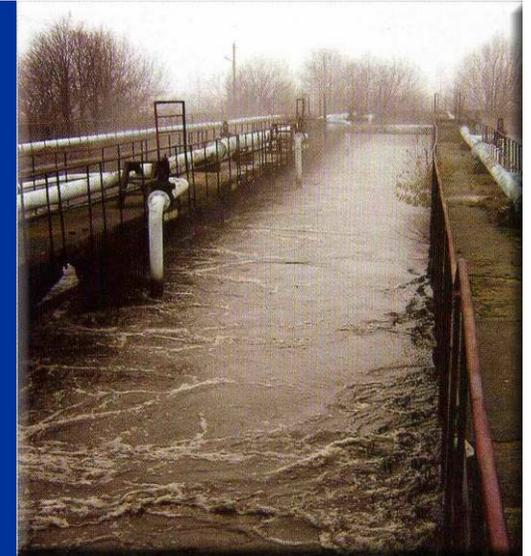


- **Food production**
  - **Agriculture: production and processing is one of the major uses of water in the world**
    - **Eat the food and drink the water from around the world**
    - **Water suspected in Cyclospora outbreaks 1995+**
    - **Spinach and E coli O157:H7, 2007**
  - **Drawing from decreasing water resource that may be more prone to contamination**
- **Increasing re-use of wastewater & grey water**



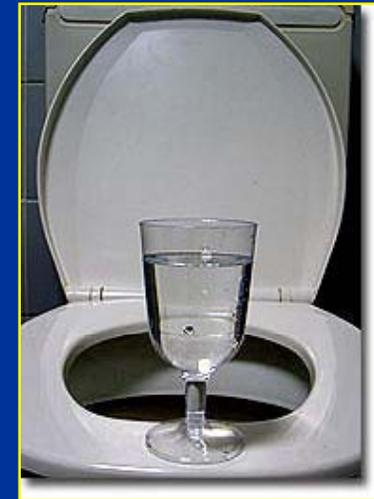
# U.S. Wastewater Issues

- On-site waste water system failures
- Reuse/recycle inevitabilities
  - Focus on wastewater/greywater
  - Sludge disposal
    - Farmers encouraged to use as fertilizer
      - Pathogens, chemicals, drugs, hormones, heavy metals
  - Use/management of animal waste
- GA 2007: Farmer got “free” fertilizer from city which contained industrial sewage
  - Grass and > 100 cows killed---contained heavy metals, PCB's, rat poison



# Water Reuse

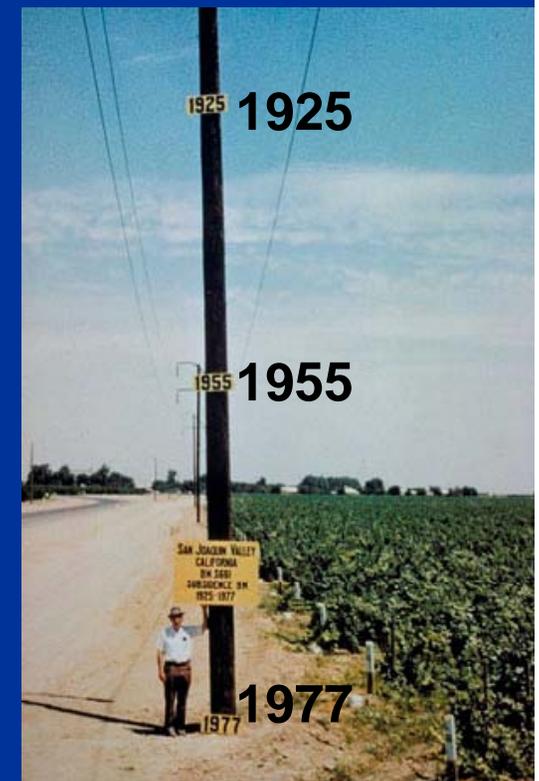
- Indirect Potable Reuse  
aka “Toilet-to-Tap”---indirect potable water re-use
  - Orange County, CA: 70 mgd
    - Salt water intrusion
  - Gwinnett County, GA: 60 mgd
    - Drought affecting reservoir



- Grey Water
  - Tucson, AZ
  - Australia



- Aquifer depletion
  - Land subsidence (San Joaquin Valley, CA)
  - Direct pumping of water back into aquifers (Tucson, AZ)



# Floods

- Midwest 2007/8, post-hurricane, tsunami
  - extreme precipitation
- Collateral damage
  - Injuries, mental health, crop loss
- Mold growth
- Potential infrastructure failures for drinking/ wastewater treatment
- Drinking and recreational water quality issues



# Floods

- Sewer overflows (combined and sanitary)
  - >1 trillion gal of sewage & storm water discharged annually during CSO's
- Agricultural and livestock areas rinsed into surface water---"first flush"
- Water quality
  - Surface & ground water contamination w/ pathogens, chemicals



# Extreme Precipitation and Waterborne Disease Outbreaks in the United States, 1948 -1994

- 67% of WBDO preceded by precipitation above the 80th percentile,  $p < 0.001$
- 51% of WBDO's preceded by precipitation above the 90th percentile,  $p < 0.002$ 
  - Surface water-related outbreaks 1 month after extreme precipitation
  - Groundwater-related outbreaks 2 months after extreme precipitation.

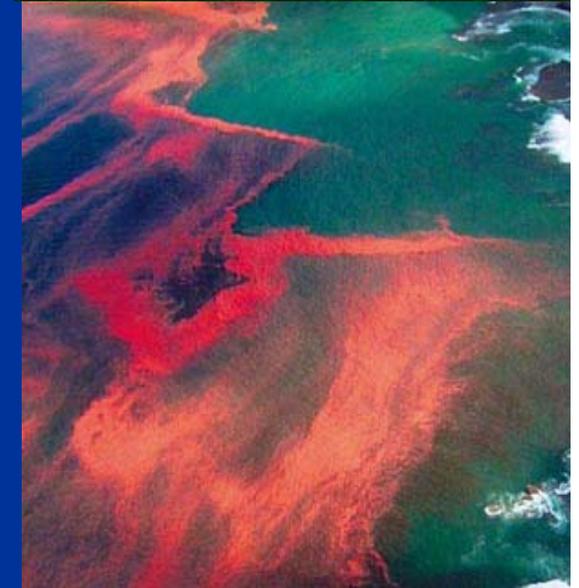
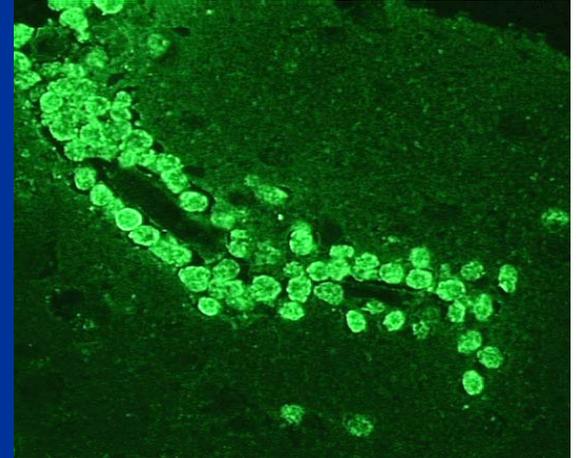


Curriero et al AJPH 2001;91;1194-1199.



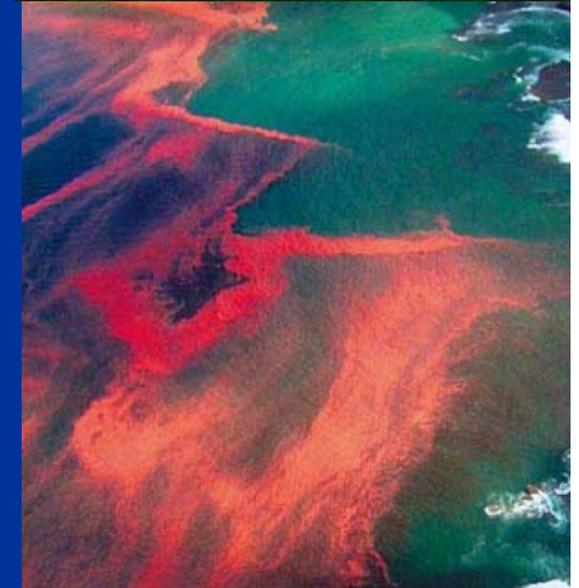
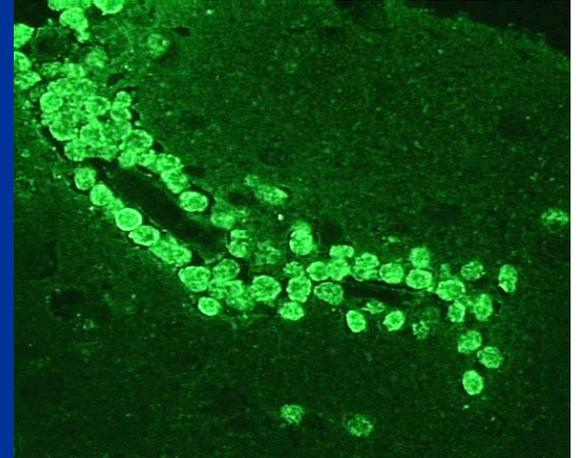
# Higher Temperatures

- Increasing water temperatures and/or nutrients
  - Movement of pathogens to more northern regions
    - *Vibrio parahaemolyticus* in Alaska
  - Enhanced growth of pathogens
    - *Naegleria*, *Vibrio*, harmful algal blooms, *Pseudomonas*
    - Recreational water climate change indicators
    - Increased infections, health effects

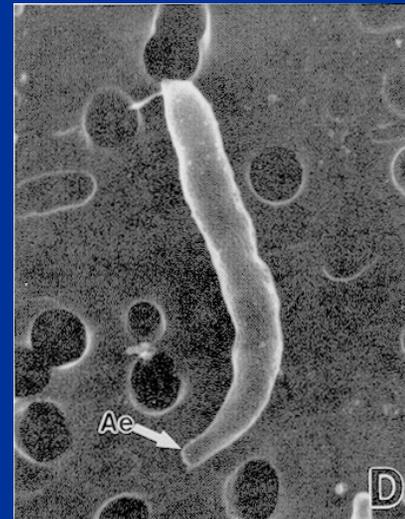
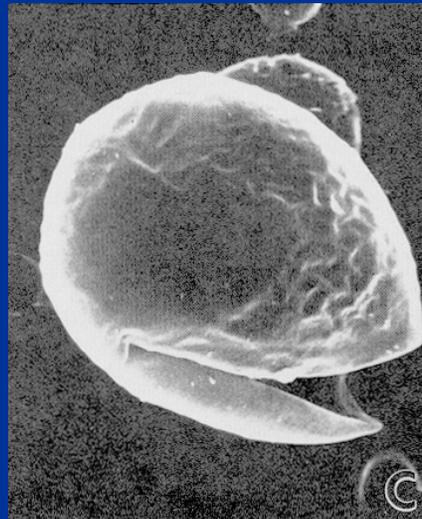
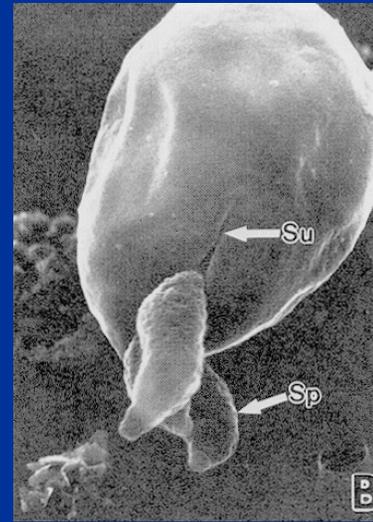
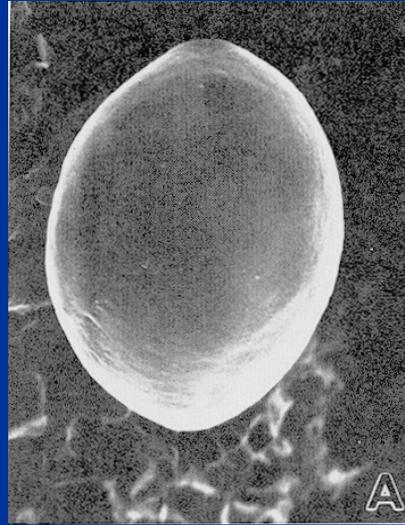


# Higher Temperatures

- **Increasing recreational water activities**
  - Ambient waters
  - Swimming pools
- **Increased pathogen transmission**
  - Already seeing now at pools

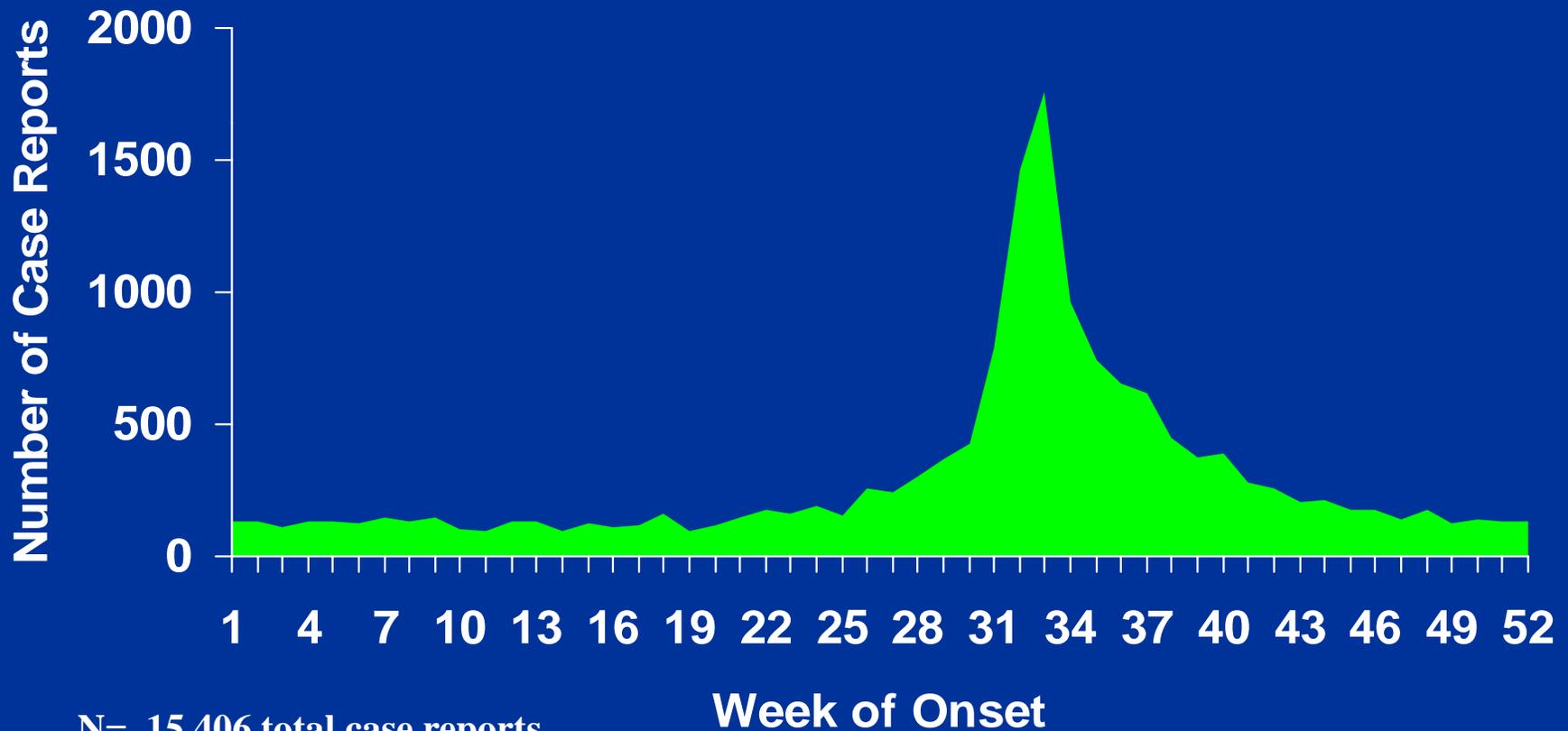


# What is Happening with Cryptosporidiosis Reporting?



# Cryptosporidium Seasonality: United States, 2003-2005

Chlorine resistant, largest cause of rec. water outbreaks

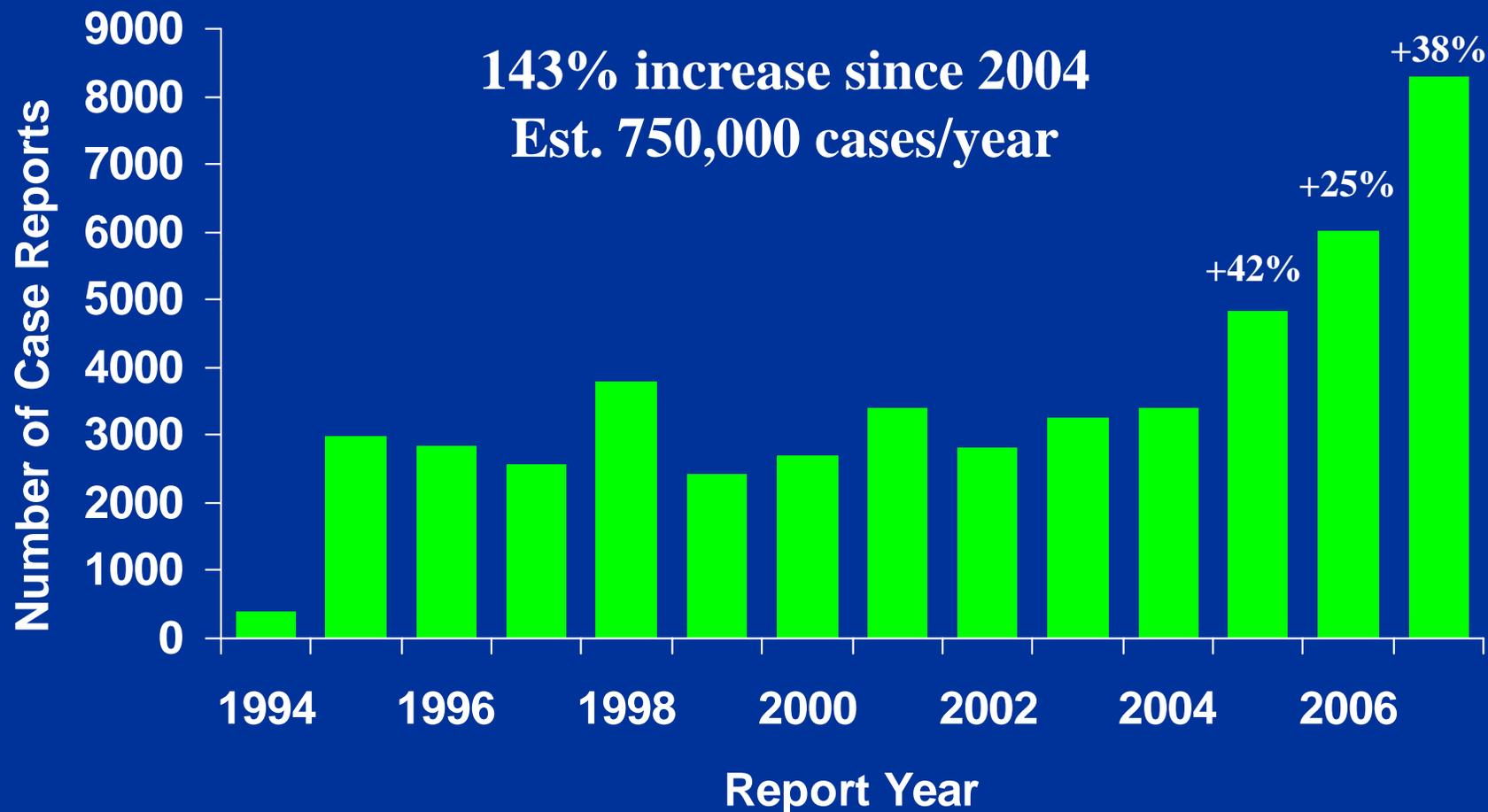


N= 15,406 total case reports  
N=15,276 have onset dates

\*Yoder JS, Beach MJ. MMWR (2007) 57(SS-7):1-10.



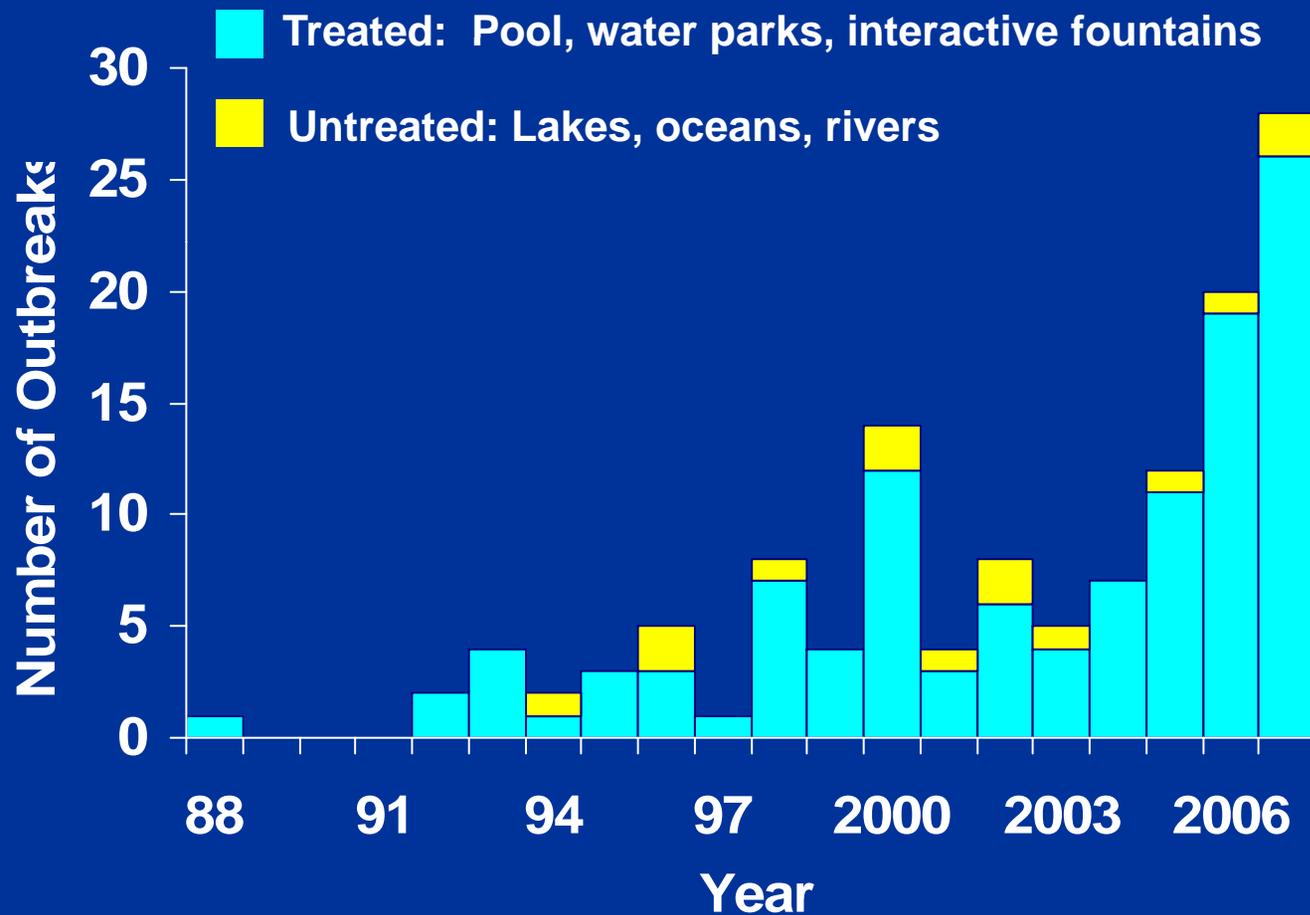
# Cryptosporidiosis Non-Outbreak Case Reports: United States, 1994-2007\*



\*Yoder JS, Beach MJ. MMWR (2007) 57(SS-7):1-10.



# Recreational Water–Associated Outbreaks of Cryptosporidiosis, by Water Treatment United States, 1988–2007\*



•N=128, Yoder JS *et al.* 2008. MMWR 57(SS-9):1–38.  
2007 data preliminarily based on CDC Logs, not verified by states



# Crypto is in Our Community. Is it in Our Pools? Yes.

Country	Crypto Positive % (n)	<i>Giardia</i> Positive % (n)
United States <sup>1</sup>	1.9% (3/160)	6.9% (11/160)
Netherlands <sup>2*</sup>	5.9% (9/153)	7.2% (9/153)
France <sup>3*</sup>	2.1% (1/48)	0.0% (0/48)
Italy <sup>4*</sup>	38.1% (8/21)	28.6% (6/21)

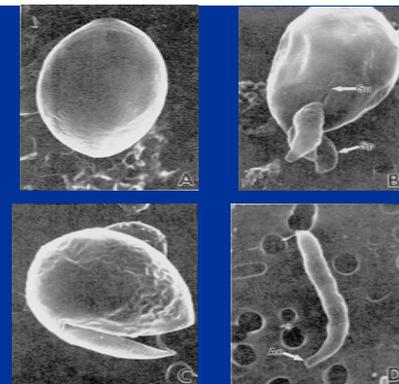
Yellow font in table indicates backwash samples.

\* Indicates serial samples for given pools.

1. Shields JM *et al.* 2008. *Emer Infect Dis* 14(6):948–950.
2. Schets FM *et al.* *J Water Health* 2(3):191–200.
3. Fournier S *et al.* 2002. *FEMS Immunol Med Microbiol* 33(2002):209–13.
4. Olivieri R *et al.* 2006. *Ann Ig* 18(5):367–74.



# Hypotheses



- Real increase in transmission
- Improved surveillance
- Improved awareness about cryptosporidiosis and pool exposures
- Changing healthcare testing practices
  - 2002: New children's formulation of drug approved (only drug ever approved)
  - 2004: adult formulation approved
- Combination of all of the above

# Future Needs

- Increased stressors on freshwater quality
- Health effects resulting from adaptive strategies to water scarcity and quality
  - Water conservation and reuse (waste & grey water)
  - Different types of water use (agriculture, municipal, environmental, and industry)
  - More swimming
- Intervention includes:
  - Conservation (re-use, cutting use)
  - Technological (improved treatment)
  - Behavioral/education (reduce contamination)
  - Regulatory (collect & use data to enforce compliance with what system can bear)
  - Partnerships and resources/commitment



# Acknowledgements

## CDC Partners

- Michele Hlavsa
- Jonathan Yoder
- Virginia Roberts
- Sharon Roy
- Lihua Xiao



# Newly Required Disclaimer From the Department of Health and Human Services (Please Interpret as You See Fit)



- "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

