Incidence of Illness Associated with Recreational Water Contact: Evaluating a Potential Public Health Problem

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PHASE Project Objective

To determine the likelihood that swimmers in Maryland are contracting illnesses from exposure to natural waters.
Background

• Disease Classification
  – Pathogenic agents: bacterial, viral, parasitic and fungal
  – Mode of infection: skin contact, ingestion of contaminated water
<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Disease</th>
<th>Symptoms</th>
<th>Reservoir</th>
<th>Method of Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salmonella</td>
<td>Typhoid, Paratyphoid fever, Salmonellosis</td>
<td>acute enterocolitis--fever, headache, nausea, vomiting</td>
<td>Domestic and wild animals--animals and birds=chronic carriers</td>
<td>Ingestion of contaminated food or water</td>
</tr>
<tr>
<td>Shigella (Plesiomonas shigelloides)</td>
<td>Bacillary Dissenter/Shigellosis; acute GI illness</td>
<td>diarrhea (bloody stool), fever, nausea, toxemia, vomiting</td>
<td>humans</td>
<td>Direct or Indirect Fecal oral transmission</td>
</tr>
<tr>
<td>E. Coli (O157:H7, O121)</td>
<td>gastroenteritis, HUS (hemolytic uremic syndrome)</td>
<td>Diarrhea, with or without bloody stool</td>
<td>cattle, humans, deer</td>
<td>Ingestion of contaminated food or injecting or swimming in contaminated water</td>
</tr>
<tr>
<td>Yersinia enterocolitica</td>
<td>Intestinal/Extraintestinal Yersiniosis</td>
<td>acute febrile diarrhea, enterocolitis, acute mesenteric lymphadenitis</td>
<td>pigs</td>
<td>fecal-oral transmission by ingestion of contaminated food or water; found in natural waters in absence of E. Coli</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>otitis externa</td>
<td>vomiting, diarrhea, abdominal cramps, nausea, prostration</td>
<td>humans, animals</td>
<td>dust, sewage, water</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>otitis externa</td>
<td>ear pain; may also be asymptomatic</td>
<td>humans, animals</td>
<td>water and soil especially when contaminated with human or animal waste</td>
</tr>
<tr>
<td>Clostridium perfringens (C. welchii)</td>
<td>Enteritis</td>
<td>sudden colic, diarrhea, nausea</td>
<td>soil; GI tract of humans and animals (cattle, poultry, fish)</td>
<td>usually associated with ingestion of food contaminated with soil or feces. Levels of organism detected in water quality studies.</td>
</tr>
<tr>
<td>Legionella</td>
<td>Legionellosis</td>
<td>muscle ache, headache, cough, fever, chills, diarrhea</td>
<td>Natural waters</td>
<td>Contact of skin or mucus membranes with water, moist soil or vegetation; swimming, direct contact with infected tissues, inhalation</td>
</tr>
<tr>
<td>Leptospira interrogans</td>
<td>Leptospirosis</td>
<td>Sudden fever, headache, chills, severe myalgia and conjunctival suffusion</td>
<td>Wild and domestic animals; rats, pigs, dogs, raccoons, cattle</td>
<td>Ingestion of contaminated food or water; US outbreaks involve eating seafood</td>
</tr>
<tr>
<td>Vibrio cholera</td>
<td>Cholera</td>
<td>sudden watery stools, nausea and vomiting</td>
<td>Humans, environmental (zooplankton, etc.)</td>
<td>Ingestion of contaminated food or water; US outbreaks involve eating seafood</td>
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<tr>
<td>Virus</td>
<td>Disease</td>
<td>Symptoms</td>
<td>Reservoir</td>
<td>Method of Transmission</td>
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<td>--------------------------------------------</td>
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<tr>
<td>Coxsackievirus A</td>
<td>Non-paralytic enterovirus</td>
<td>enteritis</td>
<td>variable</td>
<td>fecal-oral route; outbreaks related to swimming</td>
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<tr>
<td>Coxsackievirus B</td>
<td>Non-paralytic enterovirus</td>
<td>enteritis</td>
<td>variable</td>
<td>fecal-oral route; outbreaks related to swimming</td>
</tr>
<tr>
<td>Echoviruses</td>
<td>viral meningitis, mild respiratory disorders, diarrhea (infants)</td>
<td>respiratory symptoms, diarrhea</td>
<td>variable</td>
<td>fecal-oral route; outbreaks related to swimming</td>
</tr>
<tr>
<td>Adenoviruses</td>
<td>respiratory infection, conjunctivitis</td>
<td>respiratory symptoms, pinkeye</td>
<td>variable</td>
<td>fecal-oral route; outbreaks related to swimming</td>
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<tr>
<td>Reoviruses</td>
<td>Rotavirus, etc.</td>
<td>mild upper respiratory symptoms; diarrhea, vomiting, fever</td>
<td>variable; Rotavirus (mammals)</td>
<td>variable; Rotavirus (fecal-oral route)</td>
</tr>
<tr>
<td>Hepatitis A</td>
<td>Infectious Hepatitis</td>
<td>fever, abdominal cramps, anorexia, weakness, jaundice; may have vomiting or diarrhea</td>
<td>humans</td>
<td>fecal-oral transmission</td>
</tr>
<tr>
<td>Norovirus</td>
<td>Enteritis</td>
<td>nausea, vomiting, diarrhea, abdominal cramps, mild fever and headache</td>
<td>humans</td>
<td>Freshwater</td>
</tr>
<tr>
<td>Poliovirus</td>
<td>poliomyelitis</td>
<td>asymptomatic; abortive (fever, nausea, sore throat, abdominal pain); non-paralytic (severe headache, nausea, vomiting); paralytic (muscle weakness, wasting, difficulty breathing, paralysis)</td>
<td>humans</td>
<td>fecal-oral route</td>
</tr>
<tr>
<td>Parasite</td>
<td>Disease</td>
<td>Symptoms</td>
<td>Reservoir</td>
<td>Method of Transmission</td>
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<td>-----------------------------------------------</td>
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<td>----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Cryptosporidium parvum (coccidian protozoa)</td>
<td>cryptosporidiosis</td>
<td>watery diarrhea, anorexia, vomiting</td>
<td>humans, cattle, domestic animals</td>
<td>fecal-oral (person to person, animal to person, foodborne and waterborne); outbreaks associated with water ingestion and water recreation (pools and lakes)</td>
</tr>
<tr>
<td>Cyclospora cayetanensis (coccidian protozoa)</td>
<td>Cyclosporosis</td>
<td>watery diarrhea, anorexia, nausea, vomiting, cramping, fatigue, weight loss</td>
<td>humans</td>
<td>Drinking or swimming in contaminated water</td>
</tr>
<tr>
<td>Naegleria fowleri (free-living ameba)</td>
<td>Naegleriasis/Acanthamebiasis Primary amebic meningoencephalitis</td>
<td>sore throat, severe headache, fever, nuchal rigidity, somnolence, death</td>
<td>free living in aquatic and soil habitats</td>
<td>Exposure of nasal passages to contaminated water; diving or swimming in fresh water (stagnant ponds or lakes in summer, thermal springs, waters warmed by industrial effluents)</td>
</tr>
<tr>
<td>Entamoeba histolytica</td>
<td>Amoebic Dissentary; Amoebiasis</td>
<td>most asymptomatic; intestinal or extraintestinal disease</td>
<td>humans-chronically ill or asymptomatic cyst passer</td>
<td>Ingestion of fecally contaminated food or water</td>
</tr>
<tr>
<td>Giardia intestinalis</td>
<td>Giardiasis</td>
<td>GI distress</td>
<td>birds, flies, cockroaches; infects dogs, cats, humans, other animals</td>
<td>Ingestion of fecally contaminated food or water</td>
</tr>
<tr>
<td>Schistosoma (trematode); Cercaria (free-swimming trematode larva)</td>
<td>Schistosomiasis /Swimmers itch ; Cercarial Dermatitis</td>
<td>Eggs produce granulomata and scars in organs where they lodge; symptoms relate to number and location of eggs</td>
<td>Humans, wild and domestic animals</td>
<td>Water containing free swimming larval forms (cercariae); miracidia-stage organisms contained in urine and feces, reinfect new hose in cercariae stage after maturing in snails</td>
</tr>
<tr>
<td>Acanthamoeba</td>
<td>Granulomatous Amebic Encephalitis (GAE)</td>
<td>chronic skin lesions, conjunctivitis, keratoconjunctivitis</td>
<td>free living in aquatic and soil habitats</td>
<td>Infection through respiratory tract, breaks in the skin or water uptake in the nostrils with spread to nervous system</td>
</tr>
<tr>
<td>Ascaris lumbricoides</td>
<td>Ascariasis</td>
<td>asymptomatic; mild (worms in stool, loss of appetite, fever, wheezing); severe (vomiting, abdominal distension, intestinal or biliary tract blockage)</td>
<td>soil; human feces</td>
<td>Ingestion of fecally contaminated food, water or soil</td>
</tr>
<tr>
<td>Fungus</td>
<td>Disease</td>
<td>Symptoms</td>
<td>Reservoir</td>
<td>Method of Transmission</td>
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<tr>
<td>Blastomyces dermatitidis</td>
<td>Blastomycosis</td>
<td>granulomatous mycosis of lungs and skin; sudden fever, cough and pulmonary infiltrate on x-ray; skin lesions may become crusted, ulcerated and spread</td>
<td>moist soil in wooded areas and along water ways</td>
<td>Inhaled spores</td>
</tr>
<tr>
<td>Candida albicans</td>
<td>Candidiasis (Thrush)</td>
<td>infects skin and mucosal surfaces; pneumonia, septicemia, endocarditis</td>
<td>humans</td>
<td>Resident in human mouth and gut; infection determined by host factors</td>
</tr>
<tr>
<td>Aspergillus niger</td>
<td>Otomycosis</td>
<td>external ear infection; scaling, itching, pain</td>
<td>decaying vegetation in nature; all seasons</td>
<td>Inhaled spores</td>
</tr>
</tbody>
</table>
Background (2)

• Contamination Measures
  – Total Coliforms (TC): total number of microscopic agents in a sample of water
  – Fecal Coliforms (FC): includes fecal contaminants from humans and other warm-blooded animals
  – Enterococci (ENT): human enterococci; associated with diarrhea in swimmers
  – E. coli
  – Streptococci
Background (3)

• Federal Guidelines for water safety
  – Guidelines implemented at state level
  – Maryland marine waters:
    • Monthly geometric mean: ≤35 enterococci/100ml
    • Single samples: ≤104 enterococci/100ml
  – Maryland fresh water:
    • Monthly geometric mean: ≤ 126 E. coli/100 ml
    • Single sample: ≤ 235 E. coli/100ml
Background (4)

• Potential contamination Sources
  – Sewage effluents: sewer overflows
  – Recreational population (shedding or defecation)
  – Industrial processes
  – Live stock
  – Farming activities
  – Domestic animals
  – Wildlife
Data Sources and Accessibility

• Potential Data Sources
  – Drug (prescription, OTC) sales
  – Ambulatory care databases
  – Hospital discharge data
  – Patient diagnostic (ICD-9) codes
  – Outbreak data
  – Weather data
  – Reportable disease data
  – Water quality data
  – Beach surveys
Data Sources and Accessibility

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  – Hospital discharge data
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  – Outbreak data
  – Weather data
  – Reportable disease data
  – Water quality data
  – Beach surveys
Data Analysis: Weather

- Temperature patterns: May-September
- Wind speed patterns: May-September
- Precipitation patterns: variable
Average Temperature by Beach Location

- Cumberland (Allegany Co.)
- Sharptown (Wicomico Co.)
- Snowhill (Worcester Co.)
- Ocean City (Worcester Co.)
- Grasonville (Queen Anne's Co.)
- Boonesboro (Frederick Co.)
- Thurmont (Frederick Co.)
- Hampstead (Carroll Co.)
- Essex (Baltimore Co.)
- Crisfield (Somerset Co.)
Data Analysis: Water Quality Indicators

• Variation in Measurements
  – Area and depth of water
  – day/time of day measurements taken
  – variations in weather conditions

• ENT/E. coli counts peaks in June/July
  – Coincident with peak swim season

• Counts sometimes exceed EPA standards
  – Beaches closed 7 times in 2003 and 12 times in 2004 for exceeding safety standards
Queen Anne's County Average Enterococci Measurements by Station (2003-2004)
Analysis: Seasonal Trends

• Methods: Number of cases tabulated and plotted by month and year (1999-2003).

• 12 diseases matched both the disease matrix and the list of Reportable Diseases.
  – Amebiasis, Cryptosporidiosis, Cyclospora, E. coli, Giardiasis, Hepatitis A, Legionellosis, Leptospirosis, Meningococcal Bacteremia, Salmonella, Shigella and Yersinia enterocolitica
Results:
- Salmonella showed the strongest correlation with swimming season.
Analysis: Seasonal Trends (3)

• Results:
  – Numbers of reported E. coli, Shigella and Legionella cases also showed promising correlations with warm temperature trends
  – Remaining eight reportable diseases, showed no significant seasonal trends
    • Underreporting, physician misdiagnosis, mild or self-resolving treated with OTC drugs, home remedies or gone untreated.
    • Endemic disease levels also create “noisy” data making it more difficult to see seasonal trends
Analysis: Seasonal Trends (4)

- Methodology:
  - Difficulty with plotting cases against time
- Cannot calculate risk estimates (Incidence rates, relative risk, odds ratios)
- Cannot see increase or decrease in risk over time (rate of change)
  - Difficult to correlate disease rate fluctuations with similar changes in weather or dramatic events
- The result is a weak statistical argument for a “likely” association between swimming and disease
Recommendations

• Further research
  – Observational studies (cohort, case-control designs), randomized trial

• Focus research
  – most probable pathogens
  – broad scope of diseases
    • GI
    • non-enteric illnesses

• Fill-in existing data “gaps”
Recommendations (2)

• Filling in the “gaps” and more:
  – Demographics
    • parameters of population at risk for illness from swimming
  – Improve reporting
    • Underreporting is a potentially large problem (self-resolving, self-treated infections)
      – Cases not being reported to medical or PH services
      – Many potential diseases not “reportable”
  – Improve data access
    • Look for project coordination and information sharing opportunities
      – Lack of financial and time resources limit data accessibility
      – Legal agreements protect against third-party use
Recommendations (3)

• Filling in the “gaps” and more (con’t):
  – More research
    • Non-swimming risk factors for disease higher in swimmers (Fleisher et al. study)
    • Collaborate to reduce costs
  – Potential interventions
    • Physician Education Program
      – Partner with the Health Dept. to alert physicians to dangers of water recreation
      – Help physicians ask ALL the right questions of their patients to determine disease etiology
      – May improve reporting and help more accurately assess association between swimming and illness
    • Public Education Program
      – Make swimmers aware of specific potential dangers (disease symptoms, etc.)
      – Public awareness greatest reporting tool
Lessons Learned

• Need more information:
  – Demographic and other data needed to determine correlation between illness and proximity to swimming areas

• Poor water quality is a likely threat to swimmer health:
  – Seasonal correlation between swimming and four (4) potential swimmer illnesses (E. Coli, Salmonella, Shigella and Legionella).
    • Factor in determining resource allocation
    • Launching point for further research, study or continued observation (fill-in “gaps”)
  – Mathematical Modeling?
    • Weather data, water quality info and cases of illness in swimmers
    • Better method of predicting beach closures? (Turbow et al.)

• Invest in clean-up activities:
  – Water quality measures are improving but unreliable
  – Safeguard swimmer health by improving water conditions
Any Questions?

DANGER
Polluted Water
NO SWIMMING
By Order Of
Hammond Board of Health.
Back-Up Slides
Data Accessibility Issues

- Drug sales and patient diagnostic codes are guarded by HMOs
- Military-owned patient data
  - Contractor controlled
  - Legally protected from third-party access
- Ambulatory care databases, hospital discharge data and ICD-9 diagnostic code databases
  - Designed to track services for billing purposes, not detect illnesses associated with swimming
- Data “Gaps”
  - Lack of appropriate data points makes thorough analysis difficult
    - Demographic data
    - Precise geographic “matching” of cases to population
- Note: Data owners are looking at how to integrate disease incidence due to swimming into their surveillance systems
<table>
<thead>
<tr>
<th>Beach Closed 2003</th>
<th>County</th>
<th>Date Start</th>
<th>Date Stop</th>
<th>Activity</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Beach</td>
<td></td>
<td>6/12/2003</td>
<td>6/26/2003</td>
<td>Closure/advisory start</td>
<td>Sewage spill</td>
</tr>
<tr>
<td>North Beach</td>
<td></td>
<td>8/25/2003</td>
<td>9/30/2003</td>
<td>Closure/advisory start</td>
<td>Sewage spill</td>
</tr>
<tr>
<td>Brownie’s Beach</td>
<td></td>
<td>8/25/2003</td>
<td>9/30/2003</td>
<td>Closure/advisory start</td>
<td>Sewage spill</td>
</tr>
<tr>
<td>Oyster Harbor</td>
<td></td>
<td>7/21/2003</td>
<td>7/25/2003</td>
<td>Closure/advisory start</td>
<td>Sewage spill</td>
</tr>
<tr>
<td>Greenbrier SP</td>
<td></td>
<td>N/A</td>
<td>8/8/2003</td>
<td></td>
<td>end of season</td>
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<tr>
<td>Hunting Creek Lake CFSP</td>
<td></td>
<td>N/A</td>
<td>8/14/2003</td>
<td></td>
<td>illness outbreak</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Beach Closed 2004</th>
<th>County</th>
<th>Date Start</th>
<th>Date Stop</th>
<th>Activity</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carpenters Point Beach</td>
<td>CE</td>
<td>6/9/04 12:00 AM</td>
<td>6/11/04 12:00 AM</td>
<td>closure</td>
<td>WQ Criteria exceeded</td>
</tr>
<tr>
<td>Holloway Beach</td>
<td>CE</td>
<td>6/9/04 12:00 AM</td>
<td>6/11/04 12:00 AM</td>
<td>closure</td>
<td>WQ Criteria exceeded</td>
</tr>
<tr>
<td>Red Point Beach</td>
<td>CE</td>
<td>6/9/04 12:00 AM</td>
<td>6/11/04 12:00 AM</td>
<td>closure</td>
<td>WQ Criteria exceeded</td>
</tr>
<tr>
<td>Elk Neck State Park North East River</td>
<td>CE</td>
<td>6/9/04 12:00 AM</td>
<td>6/11/04 12:00 AM</td>
<td>closure</td>
<td>WQ Criteria exceeded</td>
</tr>
<tr>
<td>Charlestown Manor</td>
<td>CE</td>
<td>6/9/04 12:00 AM</td>
<td>6/11/04 12:00 AM</td>
<td>closure</td>
<td>WQ Criteria exceeded</td>
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<tr>
<td>Elk Neck State Park North East River</td>
<td>CE</td>
<td>6/16/04 12:00 AM</td>
<td>6/23/04 12:00 AM</td>
<td>closure</td>
<td>WQ Criteria exceeded</td>
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<td>Carpenters Point Beach</td>
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<td>6/16/04 12:00 AM</td>
<td>6/23/04 12:00 AM</td>
<td>closure</td>
<td>WQ Criteria exceeded</td>
</tr>
<tr>
<td>Red Point Beach</td>
<td>CE</td>
<td>6/16/04 12:00 AM</td>
<td>6/23/04 12:00 AM</td>
<td>closure</td>
<td>WQ Criteria exceeded</td>
</tr>
<tr>
<td>Hacks Point</td>
<td>CE</td>
<td>6/17/04 12:00 AM</td>
<td>6/24/04 12:00 AM</td>
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<td>WQ Criteria exceeded</td>
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<tr>
<td>Elkview Shores</td>
<td>CE</td>
<td>6/24/04 12:00 AM</td>
<td>7/1/04 12:00 AM</td>
<td>closure</td>
<td>WQ Criteria exceeded</td>
</tr>
<tr>
<td>Elk Neck State Park North East River</td>
<td>CE</td>
<td>8/4/04 12:00 AM</td>
<td>8/11/04 12:00 AM</td>
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<td>WQ Criteria exceeded</td>
</tr>
<tr>
<td>Betterton Beach</td>
<td>KE</td>
<td>8/12/04 12:00 AM</td>
<td>8/29/04 12:00 AM</td>
<td>closure</td>
<td>WQ Criteria exceeded</td>
</tr>
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</table>
Cryptosporidium Cases (1999-2003)
### Giardiasis Cases (1999-2003)

<table>
<thead>
<tr>
<th>Months</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>Average (01-03)</th>
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<tbody>
<tr>
<td>Jan</td>
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<td>Nov</td>
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<tr>
<td>Dec</td>
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</tr>
</tbody>
</table>
Analysis: Geographic Trends

- Reportable disease, water quality, beach surveys and weather data all “matched” by county
- Plotted total number of disease cases per year per county
- Graphs subdivided into counties with beaches within the borders and counties without beaches
- Results varied
Analysis: Geographic Trends (2)

• Results:
  – Amebiasis in both beach and non-beach counties showed a range of 0-9 cases from 1999-2003
  – E. coli beach county cases ranged from 0-13, while the range for non-beach counties was 0-8 over the same time period

• supports data analysis for seasonal trends and may suggest swimming is a risk factor of disease
Amebiasis Cases by Beach Counties (1999-2003)

Year | Number of Cases
--- | ---
1999 | 9
2000 | 8
2001 | 7
2002 | 6
2003 | 5
Average (99-03) | 7

- Baltimore Co.
- Anne Arundel Col
- Worcester Co.
- Wicomico Co.
- Carroll
- Somerset
- Cecil
- Montgomery
Amebiasis Cases by Non-Beach County (1999-2003)

Number of Cases

Prince George's
Howard
Charles
Harford
Caroline
Baltimore City

Years
1999 2000 2001 2002 2003 Average (99-03)
Analysis: Geographic Trends (2)

• Results:
  – Amebiasis in both beach and non-beach counties showed a range of 0-9 cases from 1999-2003
  – E. coli beach county cases ranged from 0-13, while the range for non-beach counties was 0-8 over the same time period
    • supports data analysis for seasonal trends and may suggest swimming is a risk factor of disease
Analysis: Geographic Trends (3)

• Results:
  – Cannot draw conclusions about whether or not geographic proximity to natural water sources is a risk factor of any of the reportable diseases
  • Some counties have consistently higher reporting than others. But higher reporting occurs in both beach and non-beach counties (Baltimore Co, Montgomery, PG).
  • Likely that non-water related risk factors are approximately the same for each county
  – Risk of illness from swimming in natural waters may be greater for those with greatest ease of access