Module 9: Water- & food-borne diseases

In this module, we will learn how the climate variability and change is related with waterborne and foodborne diseases.

Trainers note: Food-borne diseases aren't mentioned in the module content, so could possibly be cut from the module title in future?

Key messages in Module 9

- Water-borne diseases are mostly transmitted by faecal-orally transmitted diseases
- Climate can influence waterborne diseases in different ways depending on the local environment & population
- Mitigation & adaptation will be enhanced by understanding the ecology of pathogens

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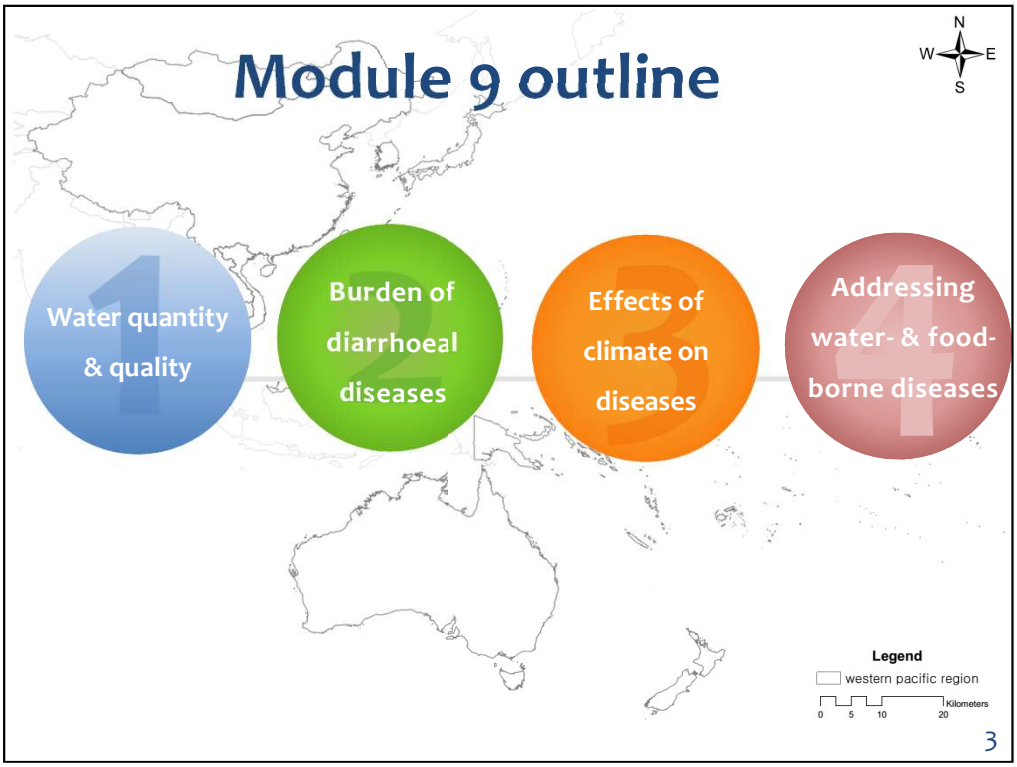
Key messages we'll cover in this module include: (**CLICK** for each)

- Water-borne diseases are mostly transmitted by faecal-orally transmitted diseases
- Climate can influence waterborne diseases in different ways depending on the local environment & population
- Mitigation & adaptation will be enhanced by understanding the ecology of pathogens

KT - Note that I have used thes key messages on the slide, supplied by Hae-Kwan as closing key message slides on 16/1/15, instead of those that were supplied from the first WHO training meeting:

- *Understand how water & food-borne diseases are impacted by climate change*
- *Know of priority diseases in WPR/SEAR & a range of examples*
- *Know what measures can be taken to prevent these diseases*

Key messages in all other modules are specific - "learn that X is the cause of Y under climate change", instead of the open"Understand", "know" above, which don't contain actual key messages.



Here's what we'll cover in Module 9:

1. Water quantity and quality
2. Burden of diarrhoeal diseases
3. How climate and weather affects diarrhoeal diseases and food- and water-borne pathogens
   - Season
   - Temperature
   - Precipitation (flooding and drought)
   - Sea level rise
4. Measures to address water & food-borne diseases

Water quantity & quality

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Water is an essential component of human body and life. Both quality and quantity are important, but without enough quantity, quality cannot be assured.

Water-related diseases

Category	Transmission	Disease examples
Water-borne	Ingestion of water contaminated by human or animal faeces or urine containing pathogenic bacteria, viruses or parasites	Gastroenteritis, enteric hepatitis, amoebic & bacillary dysentery, cholera, leptospirosis, poliomyelitis, typhoid/paratyphoid fever
Water-washed	Skin, ear or eye contact with contaminated water & poor personal hygiene	Conjunctivitis, trachoma, intestinal helminth infections, leprosy, scabies
Water-aerosol disease	Inhalation of water aerosol containing pathogen	Legionellosis, phiesteria
Water-based	Parasitical worm infections (parasites found in intermediate organisms living in water)	Dracunculiasis, schistosomiasis, (tricho)bilharziasis
Water-related arthropod vector	Insect vectors breeding in water or biting near water	Dengue, lymphatic filariasis, malaria, onchocerciacis, trypanosomiasis, yellow fever

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Water is related with development of diseases in various ways.

The most common mode of transmission is waterborne diseases. It is transmission of fecal-orally transmitted infectious diseases through ingestion of water contaminated by human or animal faeces or urine containing pathogenic bacteria, viruses or parasites.

However, transmission of fecal-orally transmitted diseases can develop from shortage of water, in case of long-term shortage of water, lowered hygiene level may provide more opportunity for the pathogens by direct person-to-person route. Those waterborne diseases with winter or dry season peak may be related with this type of transmission.

In some infectious disease such as legionellosis, microbe proliferates in water and infects human who inhaled the aerosol.

In some parasitic infestations in which the intermediate vectors are water-living organism, water can be a media of transmission of disease.

In many mosquito-borne infectious diseases, presence of stationary water mass is an essential condition for the survival of the larva. In this group of diseases, rainfall is very important determinant of the disease transmission.

Which of these water-related diseases do you experience in your country?

Category	Disease examples
Water-borne	Gastroenteritis, enteric hepatitis, amoebic & bacillary dysentery, cholera, leptospirosis, poliomyelitis, typhoid/paratyphoid fever
Water-washed	Conjunctivitis, trachoma, intestinal helminth infections, leprosy, scabies
Water-aerosol disease	Legionellosis, phiesteria
Water-based	Dracunculiasis, schistosomiasis, (tricho)bilharziasis
Water-related arthropod vector	Dengue, lymphatic filariasis, malaria, onchocerciacis, trypanosomiasis, yellow fever

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"I'm curious which of these water-related diseases you deal with in health practice in your country. Have a look over the list and then we'll do a hand raise to see which types of disease are likely to be most common, based on your knowledge.

So I'll read each out and if you know that this disease is present in your country, please raise your hand.

Read slowly and raise your own hand for each (at least at the start) to model the behaviour you're looking for:

- Gastroenteritis
- enteric hepatitis
- amoebic & bacillary dysentery
- Cholera
- Leptospirosis
- Poliomyelitis

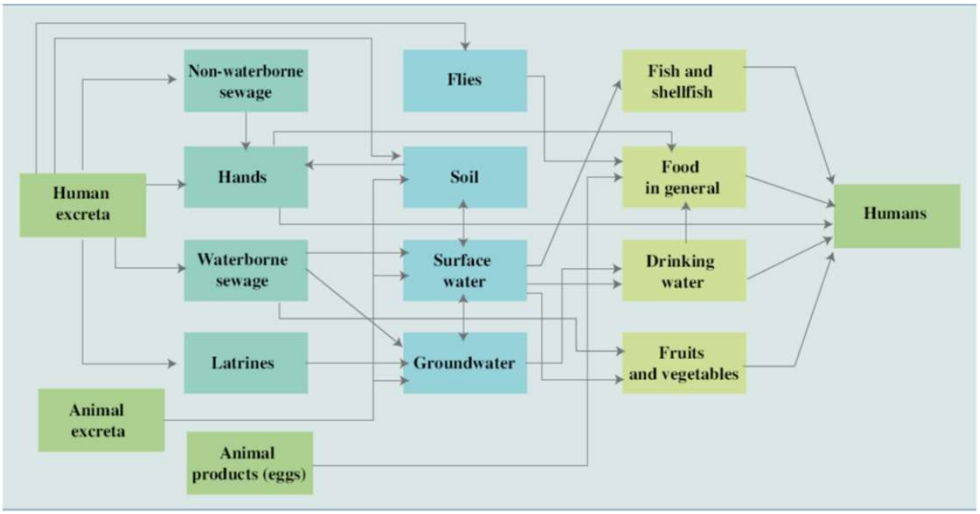
- typhoid/paratyphoid fever
- Conjunctivitis
- Trachoma
- intestinal helminth infections
- Leprosy
- Scabies
- Legionellosis
- Phiesteria
- Dracunculiasis
- Schistosomiasis
- (tricho)bilharziasis
- Dengue
- lymphatic filariasis
- Malaria
- Onchocerciacis

- Trypanosomiasis
- yellow fever

Thanks. That gives us a sense of some of the most common water-related diseases in the Asia Pacific, and that water-borne diseases are definitely a key area of public health practice.

Let's now look at some of the ways that climate change is likely to affect water-borne disease."

Diarrhoeal disease pathways: Fecal-oral transmission

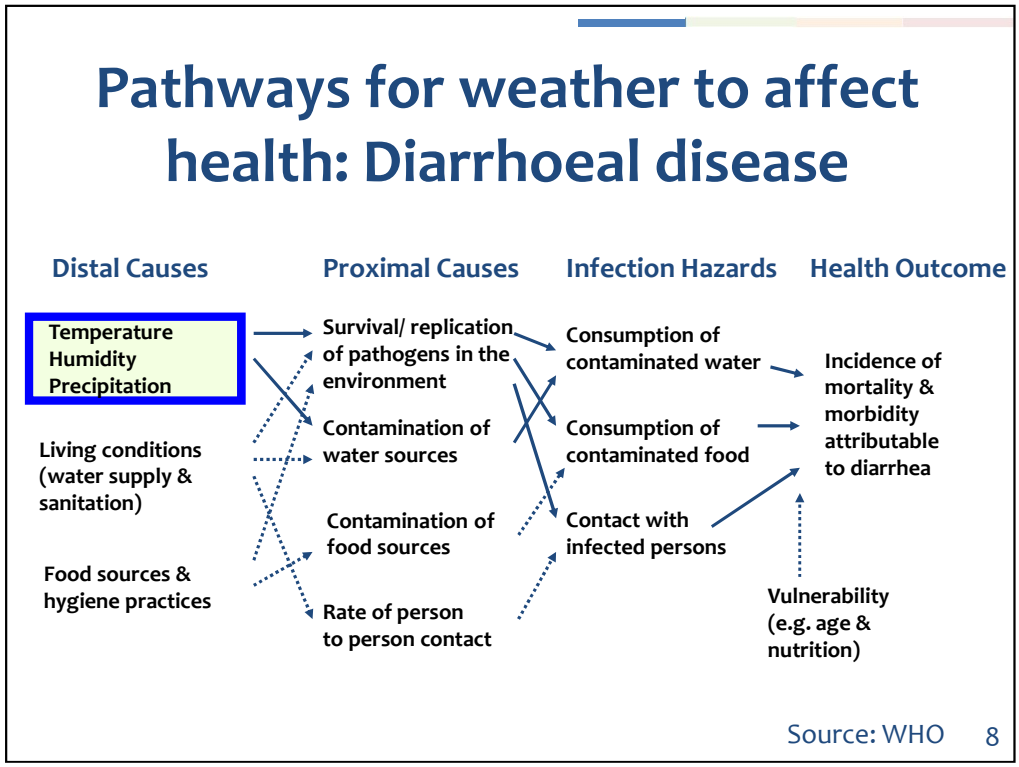


Source: Prüss-Üstün et al. (2008) 7

While the first goal, as stated in the previous slide, of determining human health end points (morbidity) in relation to climate change parameters can be measured in the absence of information about specific factors in transmission, an understanding of the specific mechanisms that link the climate parameter to the pathogen and transmission route, require an understanding of how a climate parameter acts on specific pathways.

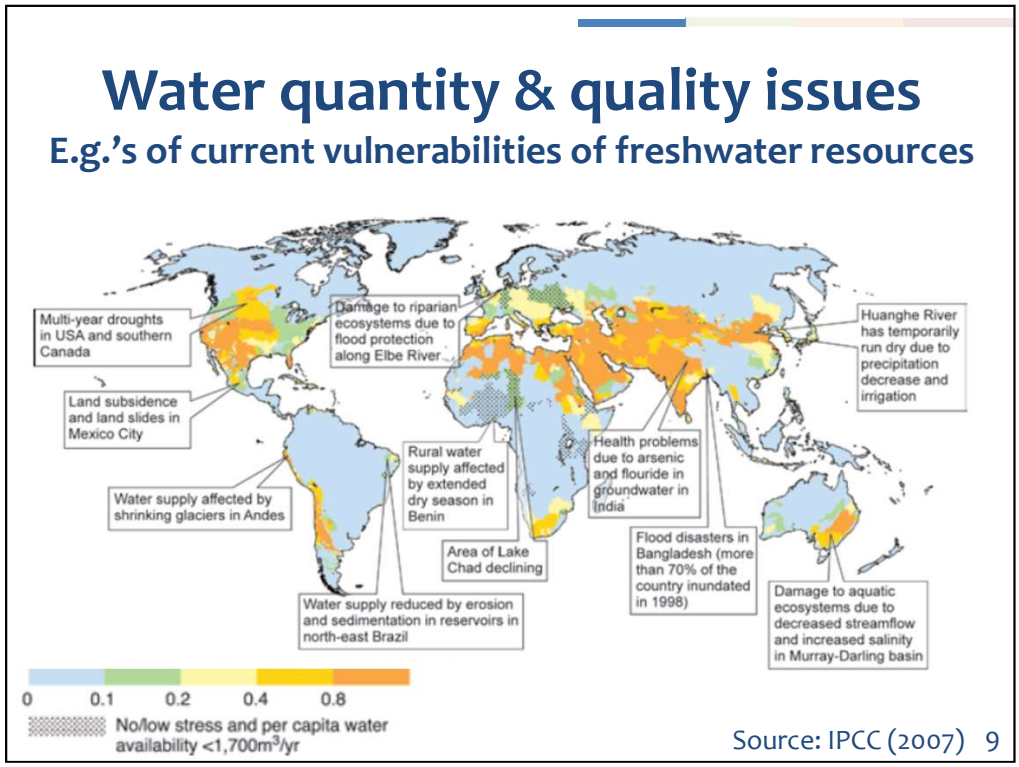
This flow chart illustrates the points at which we might start to investigate the mechanisms that provide the link between a climate signal and a disease.

It is evident even in this relatively simple chart that the pathways from source to exposure can be complex. While we are interested in the human health end points (at the far right of the chart), many of these diarrheal diseases are zoonotic and, therefore, transmission pathways must include both human and animal contamination. The pathogens can be transmitted from person to person (in some cases), or indirectly through contamination of food products, groundwater, and surface water.



This is an example of the pathways by which weather affects health. Temperature, humidity, and precipitation can interact with living conditions, food sources, and hygiene practices to create conditions favorable for the survival and replication of pathogens in food, water, and the environment. These proximal causes of diarrheal disease can then lead to infection hazards and, in some circumstances, to cases of disease. There are multiple interacting factors at each step in the causal pathway.

YEAR for WHO source?



As preface to any discussion of water and foodborne disease trends, it is important to point out current and predicted changes in the water cycle.

Both water quality and water quantity are significant issues.

Across large areas of the globe, many of which are in lesser developed nations, freshwater sources are already vulnerable due to a combination of contamination and inadequate supply.

Many of the predicted trends are for increased areas of drought leading to desertification, decreased crop production and food scarcity, along with increasing water sanitation problems associated with increasing demand placed on a diminishing supply of water.

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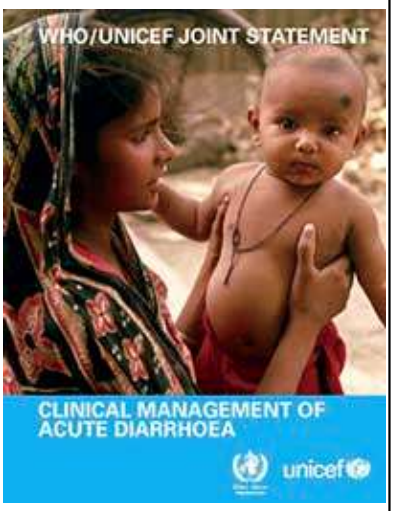
Burden of diarrhoeal diseases



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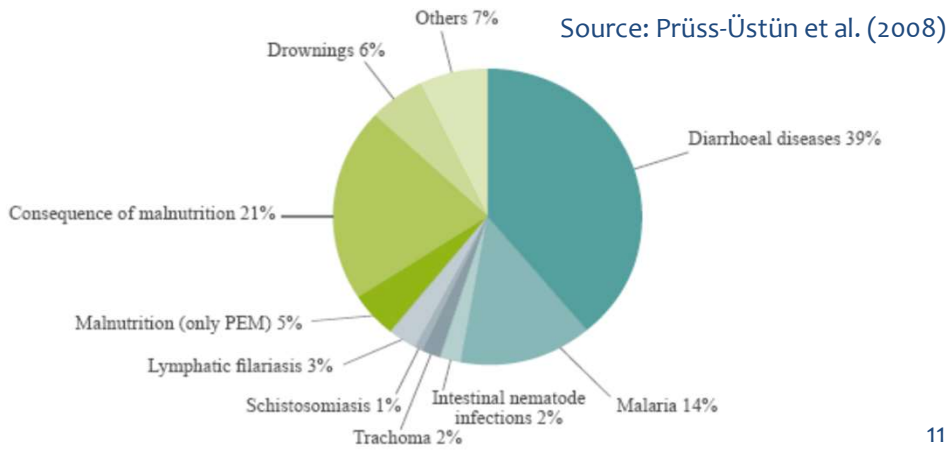
Burden of diarrhoeal diseases

Burden of water-borne disease

- 1.8 million deaths - 4 million cases- in 2004 due to gastroenteritis (WHO)
- 88% due to unsafe water & poor sanitation



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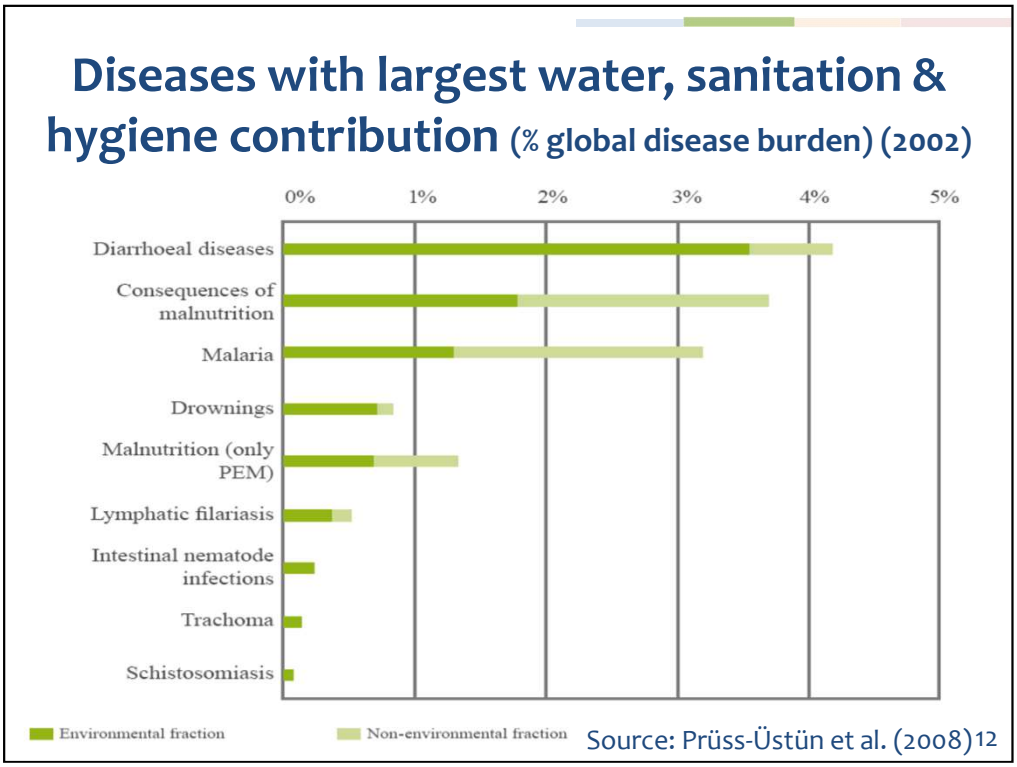
Overlaying the issues of water stress both from flooding and drought is the fact that water-borne and foodborne diseases continue to be significant causes of morbidity and mortality world-wide.

Among the wide spectrum of diseases that are associated with food and especially water, gastroenteritis is the most commonly identified illness. These diarrheal diseases contribute to as many as 4 million cases annually and 1.8 million deaths. Of these cases, 88% can be linked to poor water quality (World Health Organization, 2009).

DALYs = Disability Adjusted Life Years.



Diarrheal diseases are a significant global health problem and, as this chart shows, they are the largest contributor to water-borne disease burden world-wide.

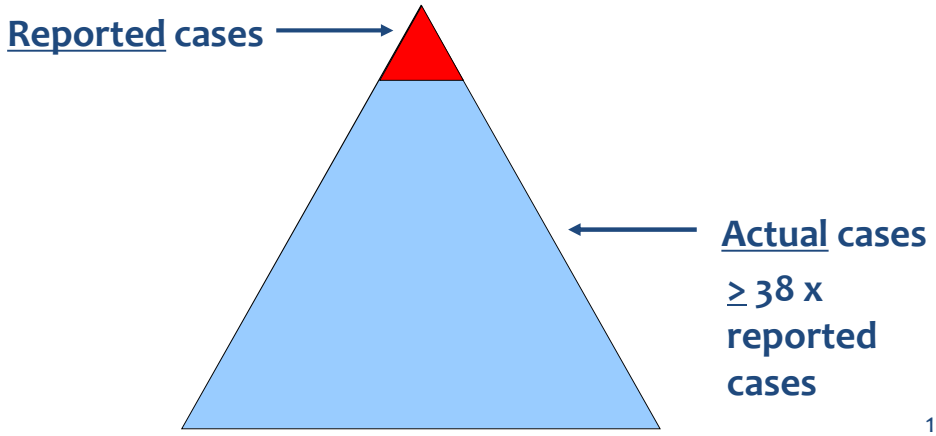
Given the global problem associated with diarrheal diseases and its common association with water, our discussion of climate and water-borne disease will focus primarily on enteric pathogens and gastroenteritis.

In the figure also note the relative significance of *Drownings* as a source of DALYs.

Burden of diarrhoeal diseases

Diarrhoeal diseases are vastly underestimated

- 211 million cases *estimated* in the US annually (Mead et al. (1999)



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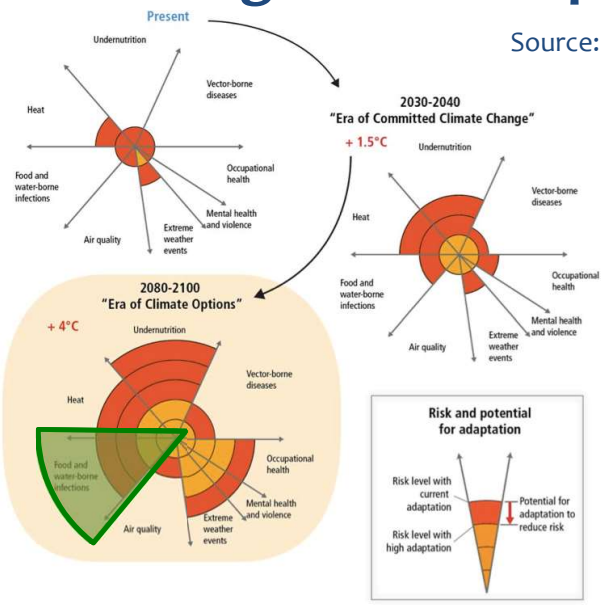
Despite the global burden of diarrheal diseases, they remain vastly under-reported even in nations with highly developed surveillance systems. This is related to multiple factors including lack of diagnosis, lack of specimen collection, lack of reporting, and lack of treatment sought. This translates into what is known as the "tip of the iceberg" scenario where very few of the actual number of cases of gastroenteritis are ever reported and etiology determined. For something like salmonellosis, among the most common bacterial sources of gastroenteritis world-wide, the actual number of cases is estimated to be 38-fold greater than the numbers that are reported.

The lack of good health data for diarrheal diseases is a common problem for investigating food and water-borne disease, especially when attempting to find associations with environmental and climate drivers.

Direction & magnitude of climate change health impacts

Source: IPCC AR5 (2014)



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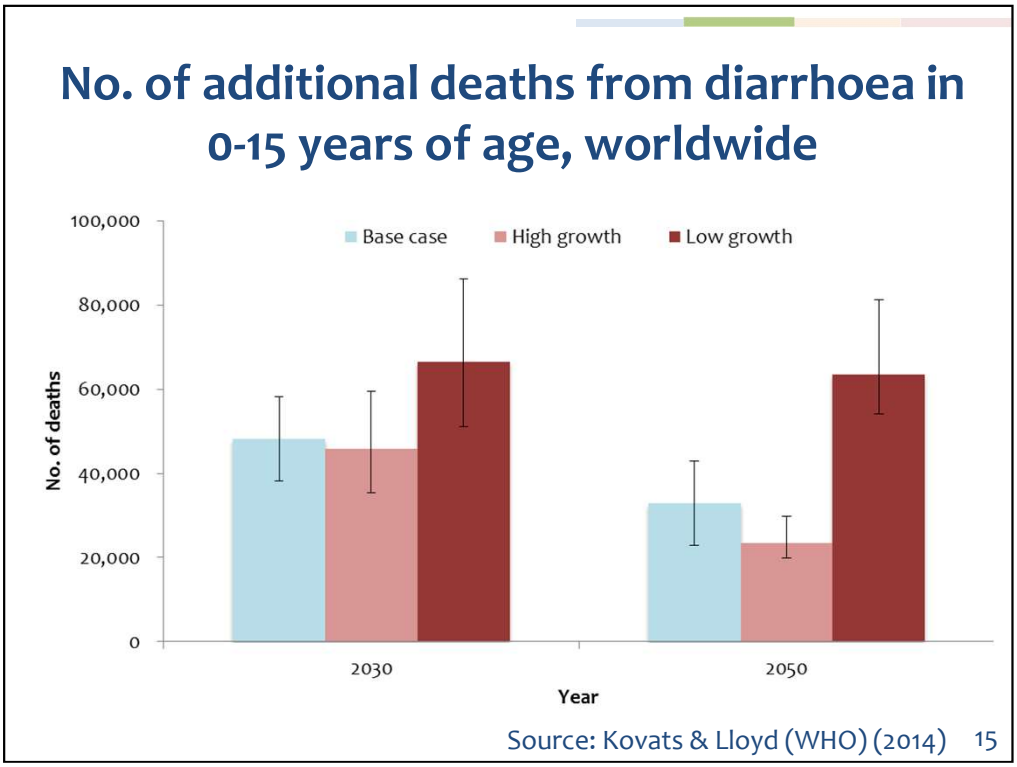
In fact the IPCC 5th Assessment Report (Working Group II) indicates that the burden of diarrheal disease will increase as climate changes over the next century. The magnitude of food and waterborne infections are expected to be increased very high by the end of 21st century, next to the undernutrition. Moreover, proportion of the risk that is preventable with high adaptation is smaller.



While projections include increasing diarrheal disease as the global climate changes, at local levels we are already witnessing disease events that can be linked to climate. This map and descriptions (figure from Hall et al., 2002) indicate some of these weather or climate linked water-borne disease events from around the world. We will touch upon some of these in more detail.

According to updated estimation of burden of diarrhoeal disease by WHO, overall premature deaths will increase up to 66,403 (51,032-86275) in 2030 and 63442 (54,110–81,330) in 2050. Economic growth is closely related to the deaths from diarrhoeal disease, resulting in decreasing tendency of deaths in the future expectations.

How climate & weather affects food- & water-borne disease

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Let's now look at how climate & weather affects diarrhoeal diseases & food- & water-borne pathogens.

Of the critical issues in studying the specific impacts of climate on health, and specifically the impacts on water-borne disease, are the need to (1) identify broad trends in disease outcome, and (2) identify mechanisms that lead to these trends, especially in terms of the biology and physiology of specific pathogens.

How climate influences waterborne disease trends

Local temperature	• Replication in the environment or associated with food products • Persistence
Local rainfall	• Loading into the environment (contamination) • Increased concentration of contaminants (drought)
Changes in hydrologic cycle	• Increased drought • Increased storm intensity
Change in frequency of 'extreme events'	• Hurricanes • Ocean-atmosphere oscillations: ENSO, IOD, others
Sea level rise	• Influx of marine pathogens • Flooding (storm surge), contamination, loss of infrastructure

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As we begin to shift to a discussion of how water-borne diseases may be impacted by climate variability and change, we need to focus a bit on climate change scenarios and which climate parameters are expected to have the greatest impact on water-borne pathogens and diseases.

We will go through each of these mechanisms in detail next, and provide some specific examples of research that is addressing these issues. Where possible, examples of the two ways of examining climate change impacts will be addressed - that is, studies that look at specific health end points and studies that address mechanisms or pathways.

So, as shown in this table, climate change scenarios predict:
• Rising temperatures,
• Changes in the hydrological cycles (especially frequency of high intensity storms and drought),
• Other extreme events, including tropical cyclones and interannual variability associated with pressure shifts over large areas of oceans, which result in far reaching changes in precipitation and temperature patterns (e.g., El Niño Southern Oscillation, Pacific Decadal Oscillation, North Atlantic Oscillation, among others)
• Sea level rise.

These expected changes will certainly impact many sectors, but these parameters are expected to impact water-borne pathogens both directly (i.e., temperature) indirectly (i.e., rainfall and flooding).

They can also affect a wide range of enteric pathogens, especially those with an

environmental reservoir

Specific parameters within climate change scenarios that are likely to affect water-borne disease were mentioned earlier. Now we will take those parameters and narrow them down to specific impacts, which include:

Another issue that is more difficult to measure or predict is range expansion, either for a specific pathogen or for hosts in zoonotic pathogens.

As we investigate specific disease patterns, it is important to keep in mind that many of these waterborne/diarrheal diseases often display marked seasonal patterns. In some cases, the evidence of seasonality and information related to the drivers of seasonality can be used as a starting point to inform further investigations into the longer-term trends associated with climate change.

We'll now go into some of these influences one by one, with examples drawn from Asia and the Pacific.

How climate & weather affects food- & water-borne disease: Seasons

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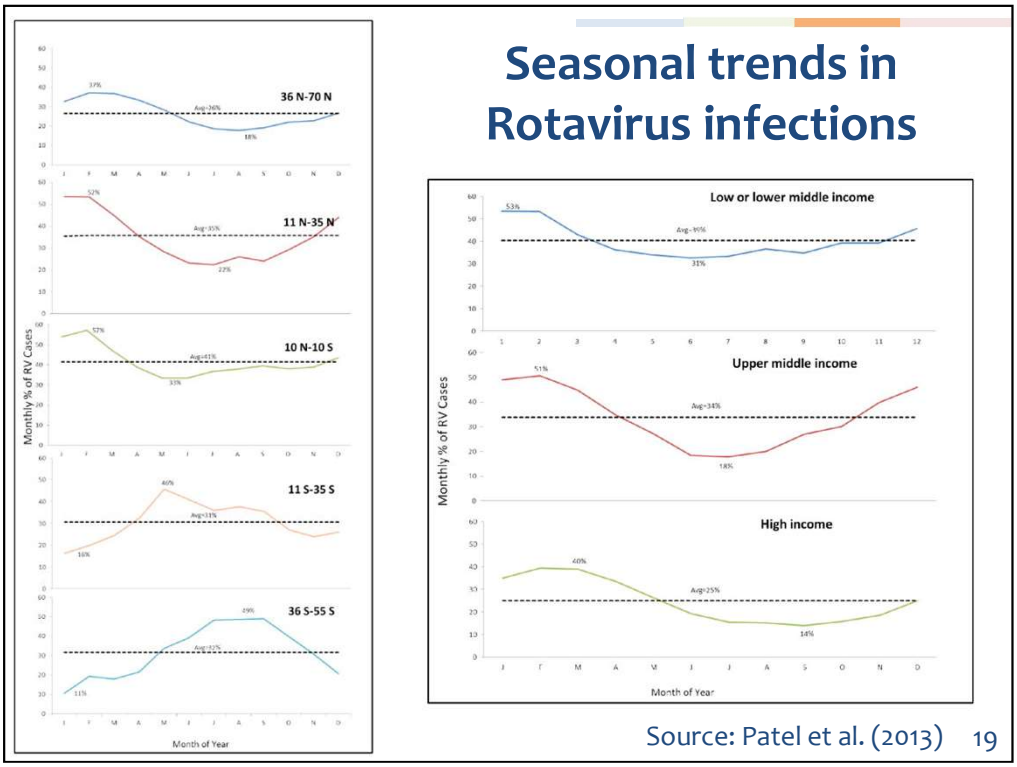
The first area of impact of climate and weather on diarrhoeal diseases and food- and water-borne diseases is seasons.



This chart of hospitalization rates for children with rotavirus infections shows the powerful trends in seasonality that are evident in many enteric (diarrheal) diseases.
Here we can see trends by latitude for the 99 studies since 1995 from Americas, Europe and Africa, and Asia and Oceania. Data are presented for each column from north to south.

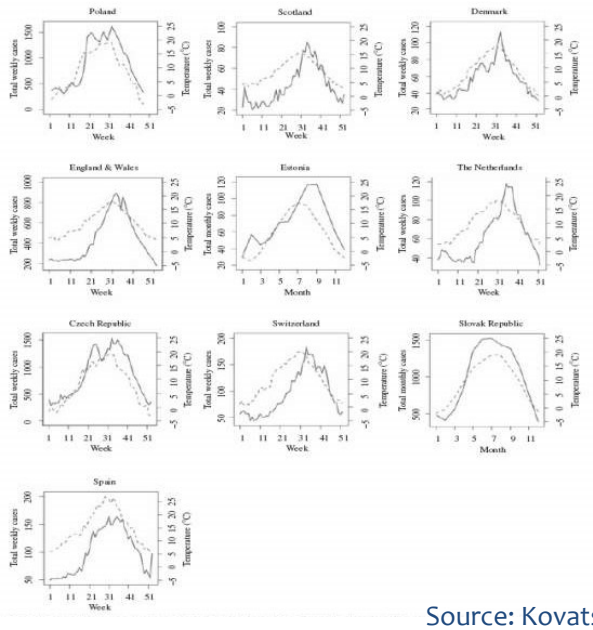
In all regions, rotavirus rates become increasing modal as latitudes increase, with the highest rates in the winter months for temperate zones in both the northern and southern hemispheres. In the lower latitudes of the tropics, this marked seasonality is damped down and finally, in the equatorial zones, there is almost no seasonality.

This series of charts does not indicate relative rates of infection between these areas, but it clearly shows that disease trends vary less by season in the warmest parts of the world. While this cannot be used to predict future scenarios, this is the kind of evidence that can be used to guide specific investigations into possible disease trends under a changing climate. For example, if seasonality is related to temperature, can we expect an expansion of the tropical patterns into temperate areas?

Another factor is socioeconomic status. Series of charts on the right side shows a difference in the magnitude of seasonality between countries with different economic status. Lower income countries have more prominent seasonality pattern.

While this slide shows baseline information for posing questions about disease trends and climate change, the next series of slides will illustrate how these next questions might be addressed.

Seasonal patterns of Salmonellosis



Source: Kovats et al. (2004) 20

KT: I shifted this slide here to fit under seasonal influences.

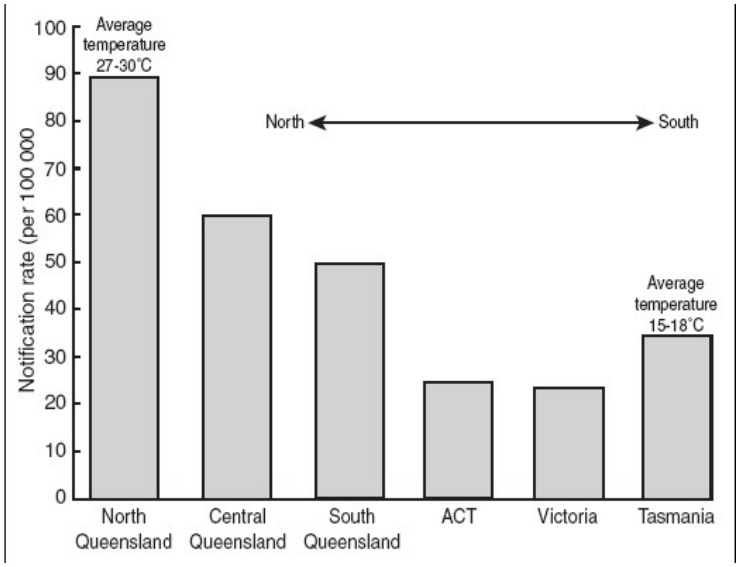
In the next few slides we will move onto specific diarrheal diseases, with a focus on *Salmonella* infections. This make up the most common causes of bacterial-associated gastroenteritis world-wide. These bacteria are also zoonotic, found commonly among both livestock and wild-life populations, and they also both show a similar seasonality with distinct peaks in reported cases occurring in the summer months, world-wide.

Kovats et al. have investigated these trends across continental scales to determine the contribution of temperature to disease incidence.

In this figure, reported cases (solid line) are plotted with mean weekly temperature (dotted line) for nine countries. All show striking similar trends with peak salmonellosis cases occurring within one week of peak annual temperatures.

An estimated threshold level of 6° C was determined for the studied nations, such that the response to temperature was linear for temperatures greater than 6° C. Using this scenario, the authors found that as much as 41% of the cases could be attributable to climate (temperature).

Salmonella trends: Eastern Australia 2001



Source: Hall et al. (2002) 21

KT: I shifted this slide here to fit under seasonal influences

In addition to consistent patterns between temperature and peak incidence of disease across very wide geographic ranges, *Salmonella* infection also displays similar trends across latitudinal ranges.

In this figure, the rates of reported cases of salmonellosis show an increasing trend as you move toward territories in the lower latitudes in Australia. The trends are consistent with higher mean annual temperatures.

How climate & weather affects food- & water-borne disease: Temperature

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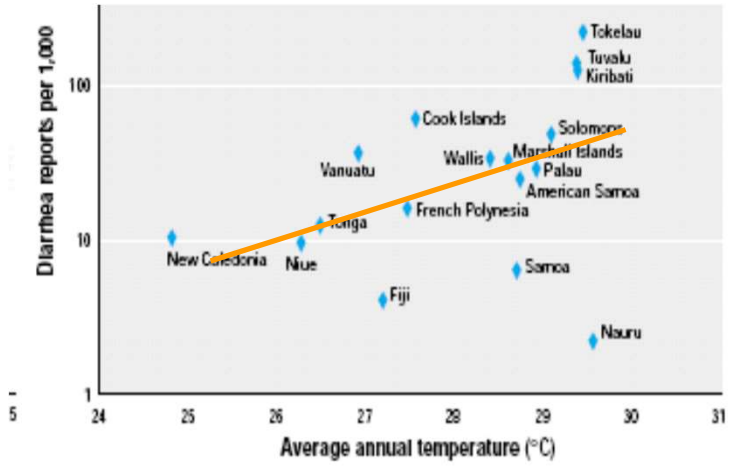
The second area we'll look at where climate & weather affects diarrhoeal diseases & food- & water-borne pathogens is temperature.

Annual temperature & reported diarrhoeal disease, Pacific Islands (1986 – 1994)



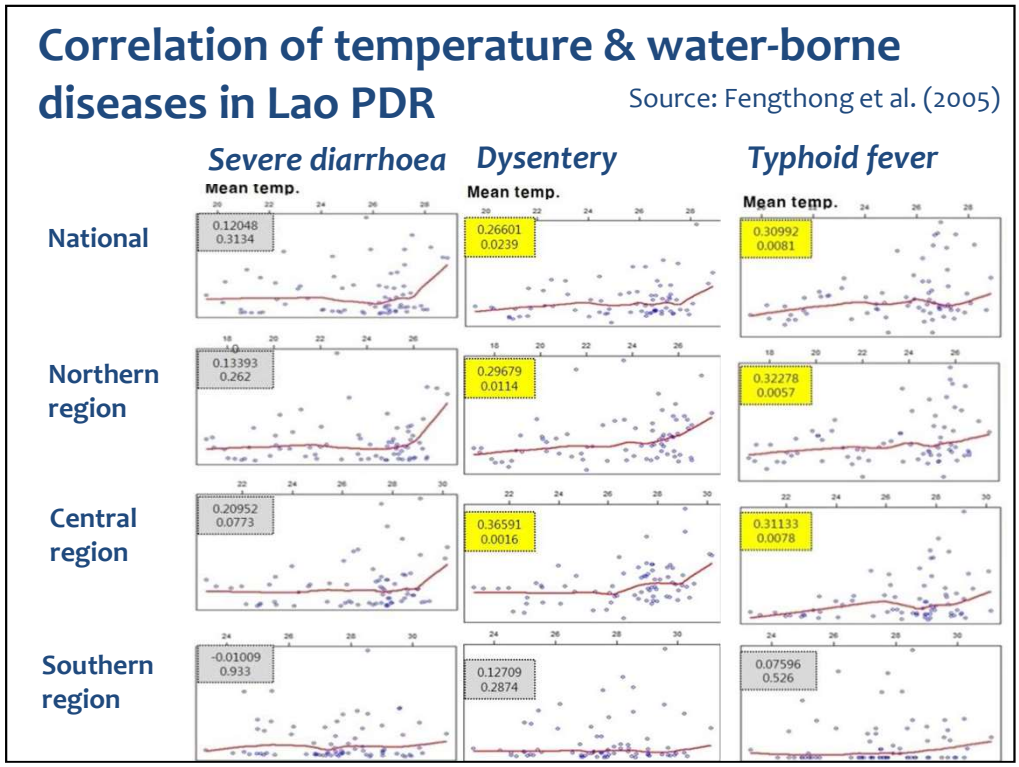
3% increase of diarrhoea for each 1°C increase in the previous month

Source: Singh et al. (2001) 23

In this study by Singh et al. (2001), the authors examined the relationship between annual average temperature at multiple Pacific Islands with rates of reported diarrheal diseases (no emphasis on the specific pathogen).

They noted a significant positive effect on temperature, which can be seen in this chart. As the annual average temperature increases, the rate of diarrheal cases increases.

CLICK to animate line. When modeled by month, there was a 3% (confidence interval 1.2–5.0%) in reported diarrhea for each 1° C increase in the previous month, controlled for season.



This study in Lao PDR also shows a correlation between various water-borne diseases and mean temperature. Dysentery and typhoid fever have linear correlation with mean temperature. However, severe diarrhoea has a threshold between 26 and 28° C.

How climate & weather affects food- & water-borne disease: Precipitation

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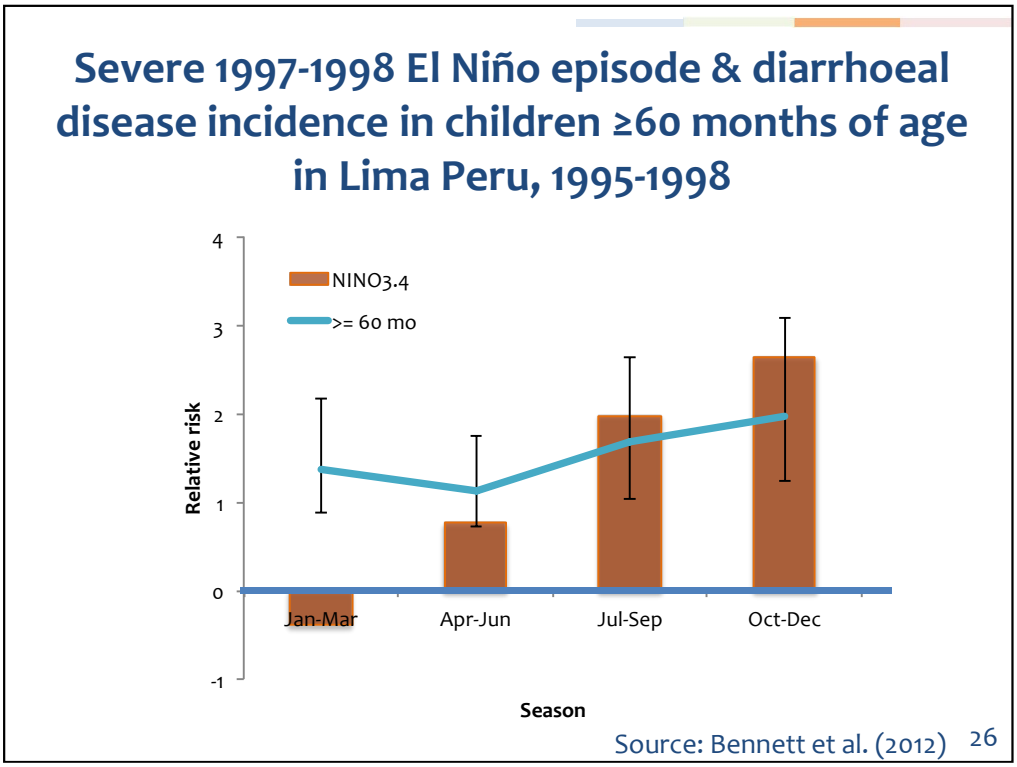
Let's now look at the affect of precipitation on food & water-borne disease.



In addition to vibrio outbreak, El Niño also brought about an outbreak of diarrhoeal disease in Peru. Cohort study on the children in Lima shows that risk of diarrhoeal disease markedly increased during the episode of El Niño.

Local rainfall influences levels of pathogens in water, & exposure risk to humans

- Run-off
- Flooding
- Drought

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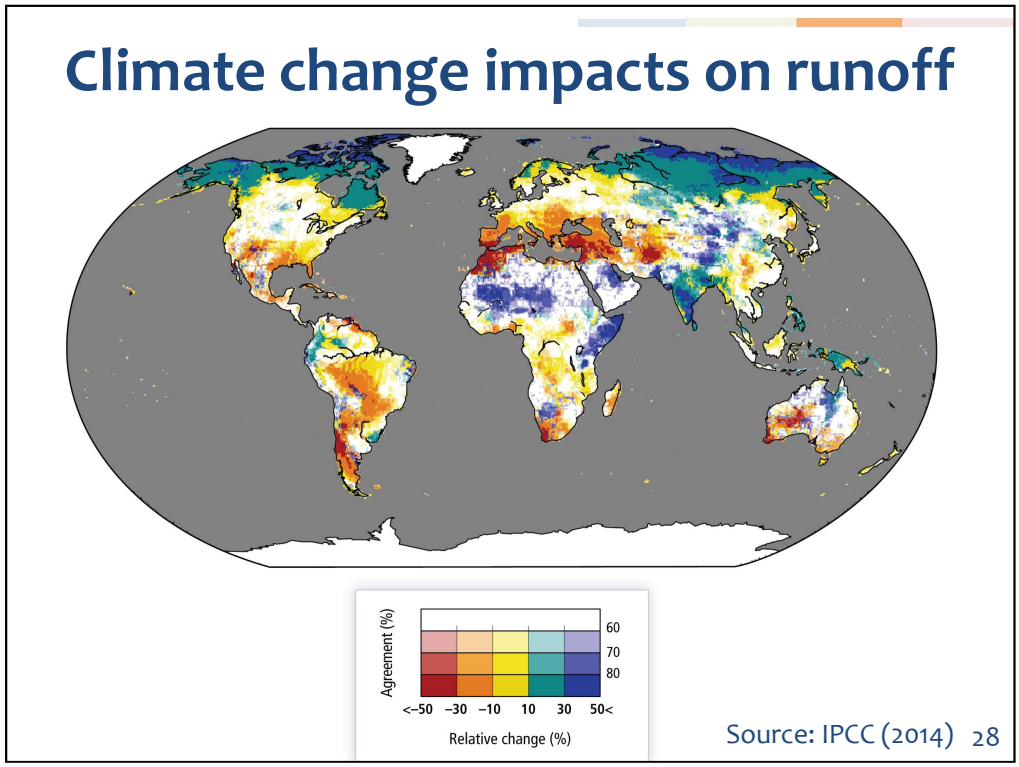
In addition to temperature, changes in the hydrologic cycle leading to either flooding (and run-off) or drought can influence both the levels of pathogens in waters and exposure risks to humans. We'll look at examples of the influence of run-off, flooding and drought on water and food-borne diseases now.



Predicted changes in precipitation and snowmelt patterns will also be evident in streamflow.

This map shows Percentage change of mean annual streamflow for a global mean temperature rise of 2° C above 1 980–201 0 (2.7° C above pre-industrial).

Color hues show the multi-model mean change across 5 General Circulation Models (GCMs) and 1 1 Global Hydrological Models (GHMs), and saturation shows the agreement on the sign of change across all 55 GHM–GCM combinations (percentage of model runs agreeing on the sign of change) (Schewe et al., 201 3).

Source: IPCC 5th Assessment Report – Working Group II

Flooding: Risk factors

- Direct contact with contaminated water
  - Skin
  - Respiratory
  - Ear & eye infections
- Ingestion of contaminated water (wells etc.)
  - Gastroenteritis
- Insufficient water treatment (i.e. problem at the tap)
- Additional secondary spread

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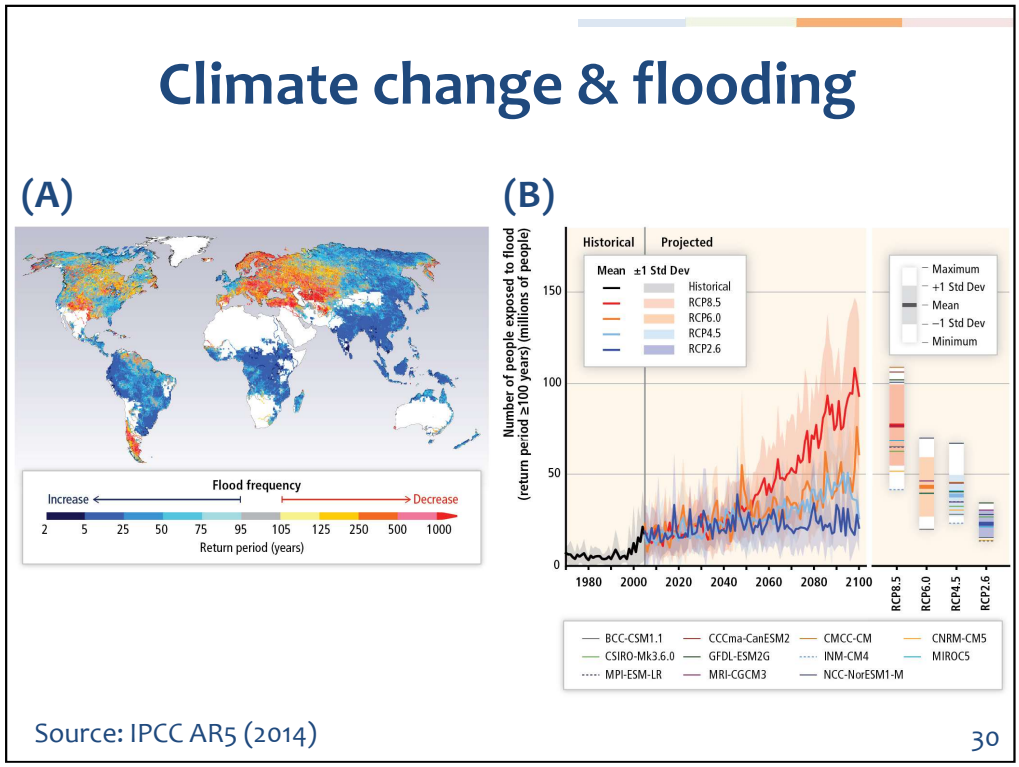
The major issues associated with flooding that influence water-borne disease include:

Direct exposure/contact with contaminated water. Following large flood events, sewage overflows and failed septic systems are common and can result in contaminated standing water. Direct exposure to flood waters commonly lead to infections of the skin, respiratory system, eyes, and ears.

Floods can also result in contaminated water sources and gastroenteritis due to ingestion of untreated or insufficiently treated water.

Floods can also facilitate the secondary spread of disease due to poor hygiene following flood events and the displacement of people.

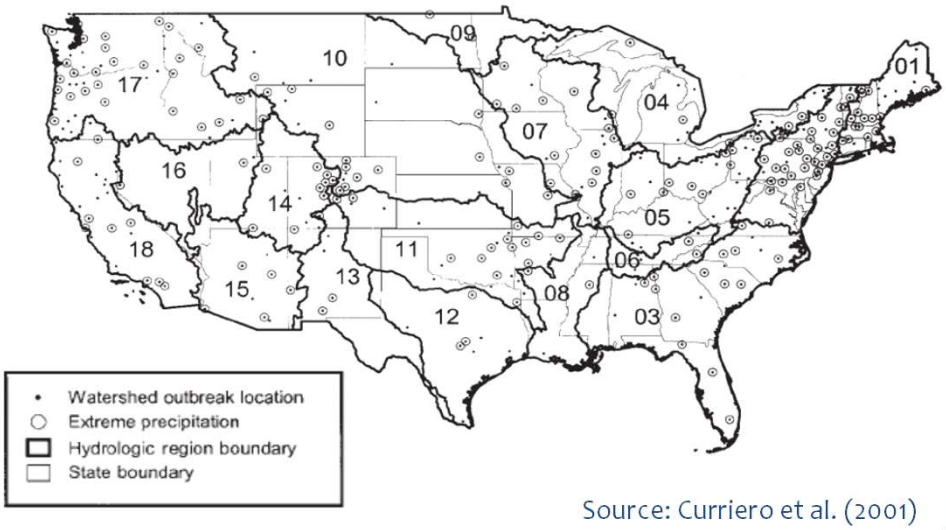


a) Multi-model median return period (years) in the 2080s for the 20th century 1 00-year flood (Hirabayashi et al., 201 3), based on one hydrological model driven by 1 1 Coupled Model Intercomparison Project Phase 5 (CMIP5) General Circulation Models (GCMs) under Representative Concentration Pathway 8.5 (RCP8.5). At each location the magnitude of the 100-year flood was estimated by fitting a Gumbel distribution function to time series of simulated annual maximum daily discharge in 1 971 –2000, and the return period of that flood in 2071 –21 00 was estimated by fitting the same distribution to discharges simulated for that period. Regions with mean runoff less than 0.01 mm day–1, Antarctica, Greenland, and Small Islands are excluded from the analysis and indicated in white.

b) Global exposure to the 20th-century 1 00-year flood (or greater) in millions of people (Hirabayashi et al., 2013). Left: Ensemble means of historical (black thick line) and future simulations (colored thick lines) for each scenario.

Shading denotes ±1 standard deviation. Right: Maximum and minimum (extent of white), mean (thick colored lines), ±1 standard deviation (extent of shading), and projections of each GCM (thin colored lines) averaged over the 21 st century. The impact of 21 st century climate change is emphasized by fixing the population to that of 2005. Annual global flood exposure increases over the century by 4 to 1 4 times as compared to the 20th century (4 ± 3 (RCP2.6), 7 ± 5 (RCP4.5), 7 ± 6 (RCP6.0), and 1 4 ± 1 0 (RCP8.5) times, or 0.1 % to 0.4 to 1.2% of the global population in 2005). Under a scenario of moderate population growth (UN, 201 1), the global number of exposed people is projected to increase by a factor of 7 to 25, depending on the RCP, with strong increases in Asia and Africa due to high population growth.

Extreme precipitation & water-borne disease outbreaks

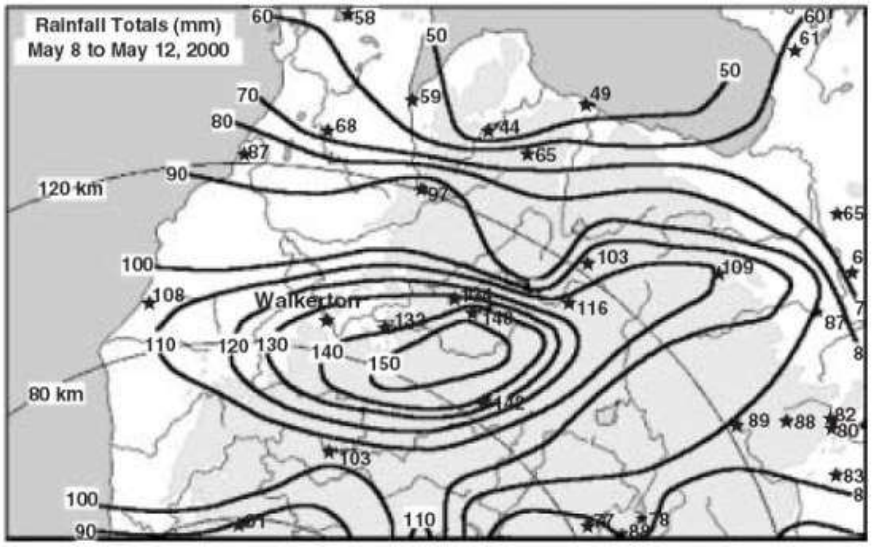


Source: Curriero et al. (2001) 31

In looking at the end point of outbreaks of water-borne disease in association with rainfall, Curriero et al. (2001) reported that 51% of drinking water outbreaks in the United States between 1948 and 1994 occurred following rainfall events in the 90th %-ile and 68% were preceded by rainfall events in the 80th percentile, on a watershed level. Associations were noted for both surface water and groundwater.

This map shows large watershed boundaries and each dot represents a water-borne disease outbreak. The open circles designate a > 90th %-ile rain event.

E.g. Walkerton (Canada) rainfall, 2000

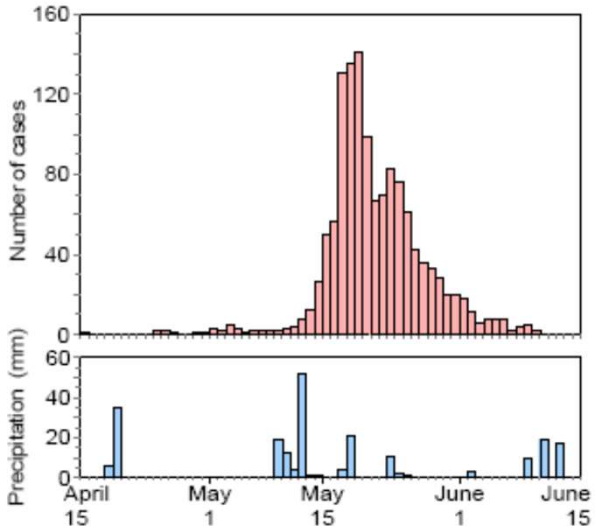


Source: Auld et al. (2004) 32

An example of the effects of extreme precipitation on water-borne disease where we can elucidate some of the mechanisms, in addition to the health end points, is the Walkerton, Ontario outbreak of May 2000.

Rainfall levels were historically high in the days preceding the disease outbreaks. Near the outbreak area, rainfall reached up to 150 mm within a 4-day period. This was estimated to be a 60- to 100-year event for this area.

E.g. Walkerton (Canada) outbreak Illness onset dates & precipitation

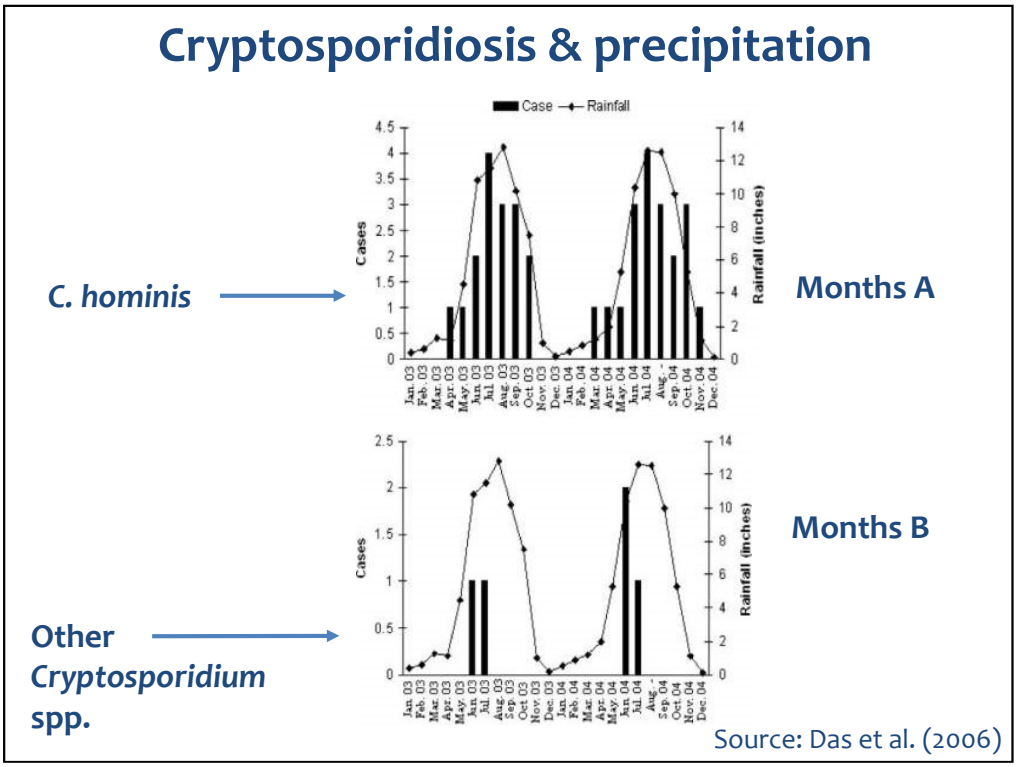


Source: Worthington et al. (2002) 33

Over a short timeframe, 2,300 people became ill in a community with a total population of 4,800. Of these, 7 deaths were reported (mostly children). The outbreak was primarily due to *Campylobacter* and *E. coli* O157:H7 infections.

This outbreak was linked to fecal contamination in a groundwater well. Although inquiries showed a breakdown in the multiple barrier approach to water protection, the outbreak was ultimately related to extremely high rainfall amounts preceding the outbreak, which resulted in contamination of the well.

In this chart, the progression of the outbreak is noted in the top graph while daily precipitation is shown in the bottom.



Cases of the protozoan parasitic disease, cryptosporidiosis, can also be linked to preceding rainfall levels, as shown in this chart, which reflects cases and rainfall by month in Kolkata, India.

Like both *E. coli* and *Campylobacter*, *Cryptosporidium* is a zoonotic agent and is often associated with cattle, water fowl, and other reservoirs that can contribute to contamination, in addition to human waste. Results from this study indicate that infections from both human specific strains (*C. hominis*) and zoonotic strains (i.e., *C. parvum*) follow similar patterns with increasing incidence with increased rainfall. This illustrates that contamination from run-off with either human or animal waste results in clinical cases.

Rainfall, run-off & pathogen contamination

- Building evidence for the association between diarrheal disease & increased precipitation, especially with heavy rainfall events
- In addition, several studies note increased pathogen loads related to floods, run-off, & heavy precipitation including:
  - Enteric viruses (e.g. enteroviruses, noroviruses, adenoviruses)
  - Protozoan parasites (e.g. *Cryptosporidium*, *Giardia*, others)
  - Enteric bacteria (e.g. *Salmonella*, *Campylobacter*, *E. coli*, fecal indicator bacteria)

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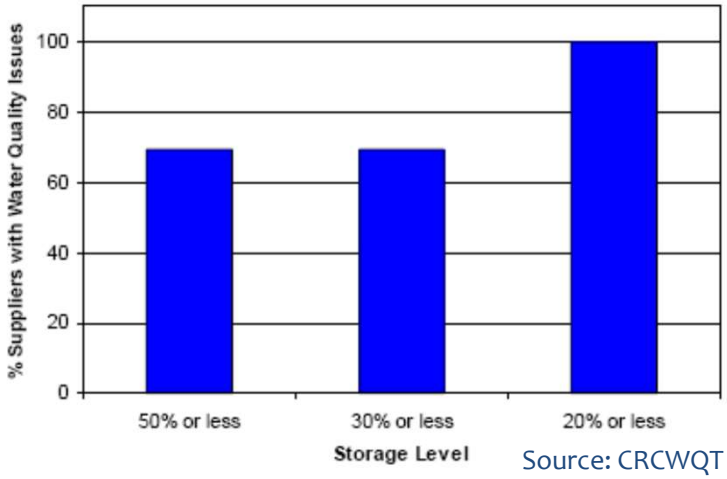
Drought effects on water quality

Correlation between storage level & supplies with water quality issues

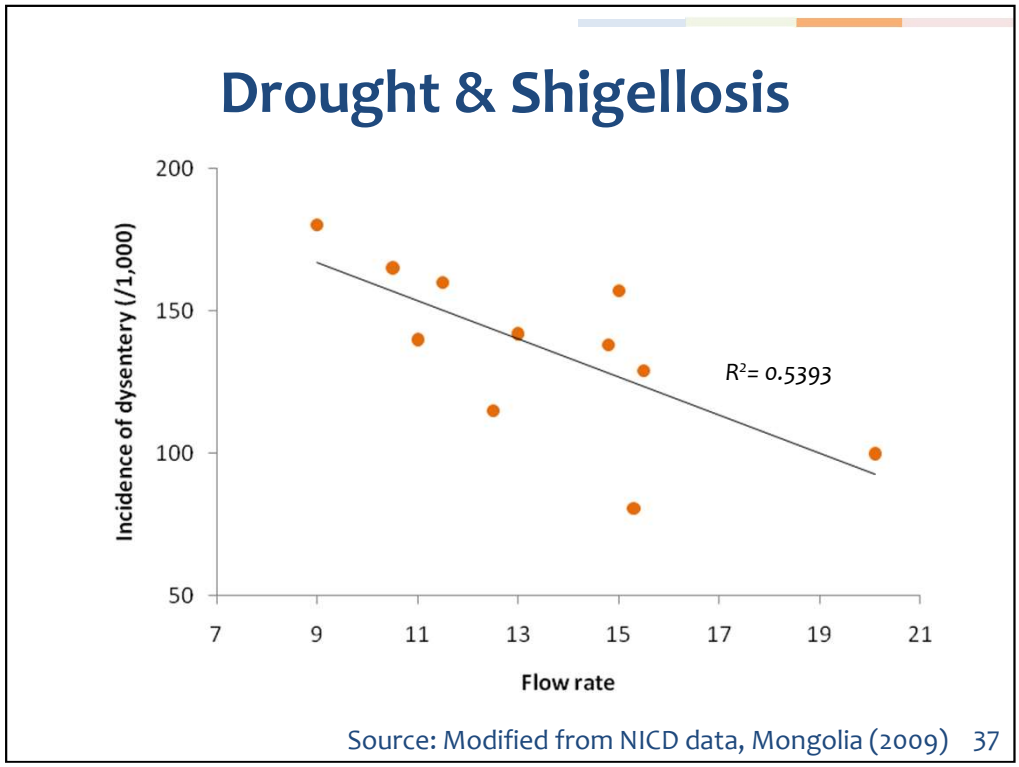


Source: CRCWQT (2005) 36

While there are fewer specific studies relating water-borne disease incidence to drought and projection of changes in disease incidence with drier conditions, it is accepted that reductions in water supply can be expected to result in increasing pressures on limited water sources. Additionally, as water sources are more limited they potentially experience increasing concentrations of pathogens due to a variety of influences, including increased water use for multiple purposes and the contribution of wastewater (treated or untreated) to the total water volume.

The effects of reservoir storage volume on water quality in general is noted in this figure. When volume is at 20% or less of capacity, all users will experience water quality issues.

Note I shifted this slide up one, given the overall title of 'drought effects on water quality', which also relates to the next slide on drought & Shigellosis. KT



This data is sourced from Mongolia. Reports on the annual flow rate of the Tul River, which flows across Ulaanbataar in Mongolia, in which more than half of the population lives, is highly correlated with the incidence of dysentery – on the vertical axis. Shortage of water – represented in the flow rate on the horizontal axis - may be related with a lowered aquifer, leading to the shortage of water supply. Shigella outbreak is strongly related to water shortage, bringing about a typical water-washed disease.

How climate & weather affects food- & water-borne disease: Sea level rise

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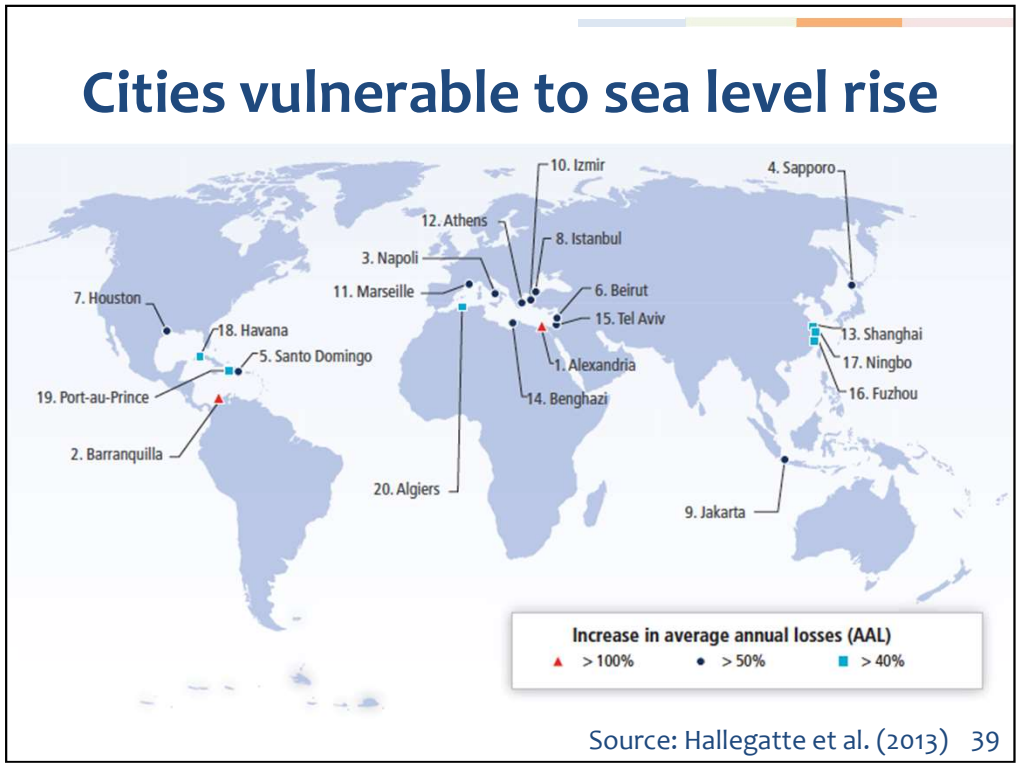
The fourth area of impact of climate and weather on diarrhoeal diseases and food- and water-borne diseases is sea level rise.

Sea levels are expected to rise world-wide, associated with both melting glaciers, polar ice caps, and thermal expansion.

The effects of sea level rise will impact coastal zones via periodic flooding (storm surge) as well as incremental rise in water level. These will result in a decrease in fresh water availability, loss of infrastructure (due to flooding), and an influx of marine pathogens.



This figure shows the areas considered to be highly vulnerable to increased sea levels due both their elevation and population sizes. Many of these are in delta areas that must already deal with periodic flooding.

The 20 coastal cities where average annual losses (AALs) increase most (in relative terms in 2050 compared with 2005) in the case of optimistic sea level rise, if adaptation maintains only current defense standards or flood probability (PD).

Vibrio spp.

- *Vibrio* are commonly estuarine & marine bacteria & include at least 12 known pathogens to humans
  - *V. vulnificus*
  - *V. parahaemolyticus*
  - *V. cholerae*
- In general, this group replicates easily in natural waters & biota, especially under high temperatures
  - Directly related to increasing water temperatures

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Among the bacteria, *Vibrio* species also show a strong seasonal trend, with the highest cases reported in summer months, and a direct relationship with increasing temperatures.

This genus includes common marine species, only a few of which are pathogenic to humans; however, among this group are three significant pathogens – *V. vulnificus*, *V. parahaemolyticus,* and *V. cholerae.*

All of these replicate in the marine or estuarine environment, especially at warm water temperatures (growth begins at temperatures > 15° C). Both *V. vulnificus* and *V. parahaemolyticus* infections are commonly associated with shellfish. *V. cholerae* is unique in its ability to grow in fresh waters and can be transmitted through drinking water. Additionally, *V. cholerae* is unique in its ability to be transmitted person-to-person.

Because these are primarily "environmental" bacteria rather than primarily "enteric" and they proliferate easily in the environment, more is known about the mechanisms linking climate drivers to the pathogen itself.

Cholera: South Asia

- Yearly epidemics correspond to natural environmental cycles & contamination
  - Influx of estuarine water
  - Plankton blooms
  - Monsoons
  - Warm temperatures
- Cycles can be modelled for year to year changes in outbreaks

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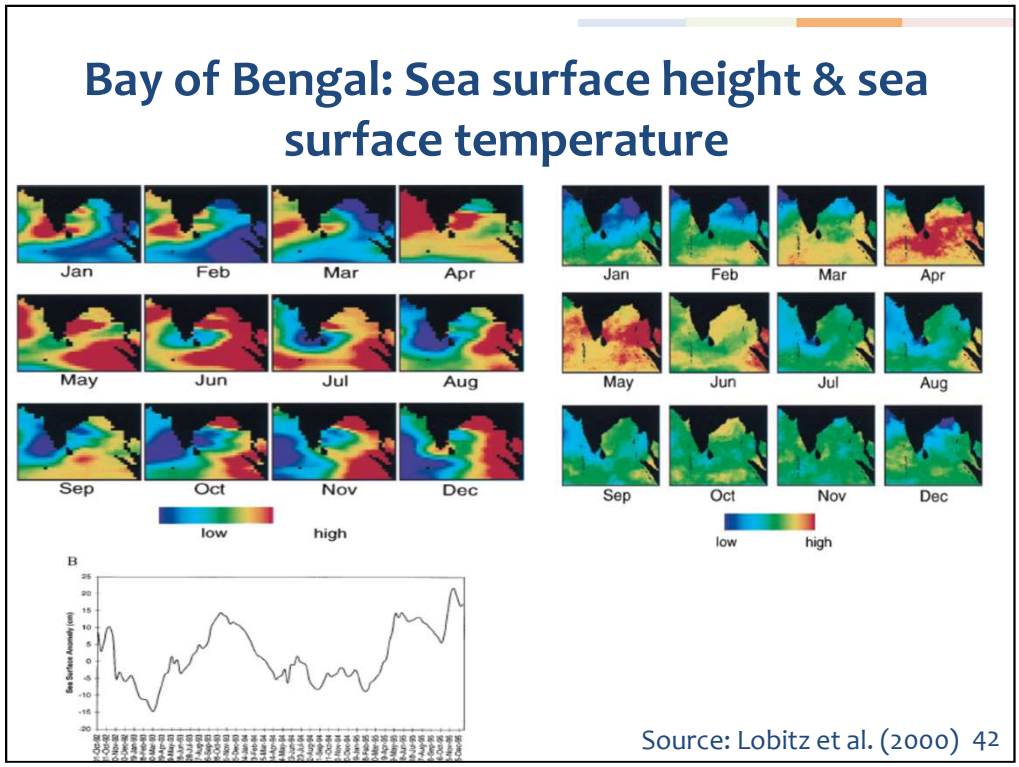
Because the *Vibrio* species are native marine bacteria, this group may be expected to be among the primary concerns with water-borne disease associated with sea level rise. In many areas of the world that are particularly prone to sea level rise (many parts of south Asia), cholera (*V. cholerae*) is already an ongoing problem.

Because cholera has both an environmental (water) and human host (gut) life stage, outbreaks can be initiated or perpetuated by either influx of estuarine water or by wastewater contamination (during outbreaks).

We know much about the mechanisms that result in *V. cholerae* growth in the environment and how it may intersect with various climate or weather parameters.

V. cholerae proliferates:
in warm waters
in association with plankton

Additionally, cholera outbreaks are linked tightly with monsoon seasons (which may be more related to spread from contaminated sources rather than influx from the environment).



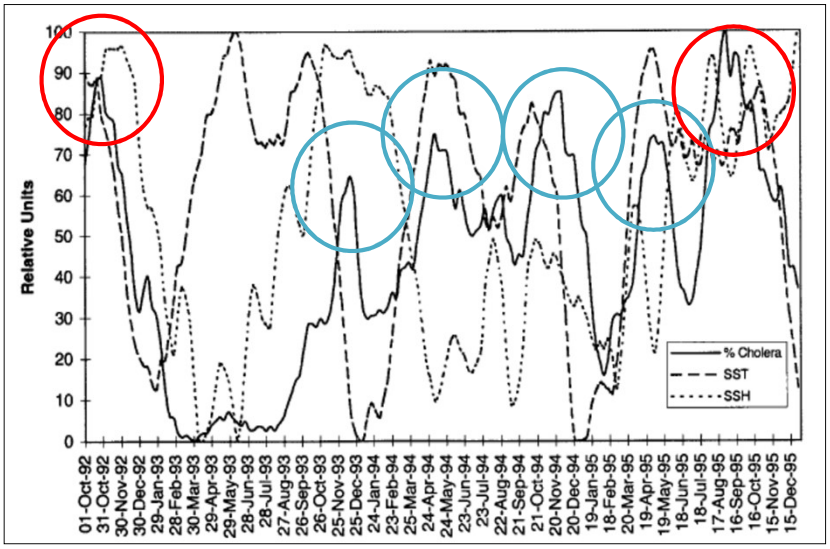
In 2000, Lobtiz et al. described the use of remote sensing to model the highest risk period for cholera in the Bay of Bengal.

The authors investigated multiple types of remotely sensed data to attempt these models.

Here are the Advanced Very High Resolution Radiometer (AVHRR) satellite images that show changes in sea surface height by month. The red color indicates high water levels and blue indicates low water levels. These data act as a proxy for marine/estuarine water influx.

Sea surface temperature data were also captured over the same space and time scales. Higher temperatures are noted in orange and red.

Bay of Bengal: Cholera & sea surface height



Source: Lobitz et al. (2000) 43

By combining both sea surface height data and sea surface temperature data, trends with cholera rates begin to emerge.

Peaks in cholera cases over the study period (solid lines) correspond with peaks in either sea surface height or sea surface temperature (highlighted with **red and blue** circles). When peaks in sea surface height (marine water intrusion and proxy for sea level rise scenario) coincide with peaks in sea surface temperature (proliferation of the bacteria), we see the greatest peaks in cholera.

From this we might speculate that increases in both temperature and sea level as projected in climate change scenarios, would increase the burden from cholera.

Measures to address water- & food-borne diseases associated with climate change

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Let's finish Module 9 by looking at measures that can be taken to address water- & food-borne diseases associated with climate change.

The image in the top right is an example, is a project called SWASHTHA - Strengthening Water, Air, Sanitation and Hygiene Treasuring Health in Nepal, which is a practical program attempting to address the fact that water sanitation related diseases are amongst the top killers in Nepal.

Water-borne disease: summary

- Climate projections for increased warming & increased extreme events suggest water-borne diseases may increase
- Mitigation & adaptation will be enhanced by understanding the ecology of pathogens
  - What underlying factors provide the link to climate?
  - How do changing landscapes affect disease incidence under changing climate conditions?

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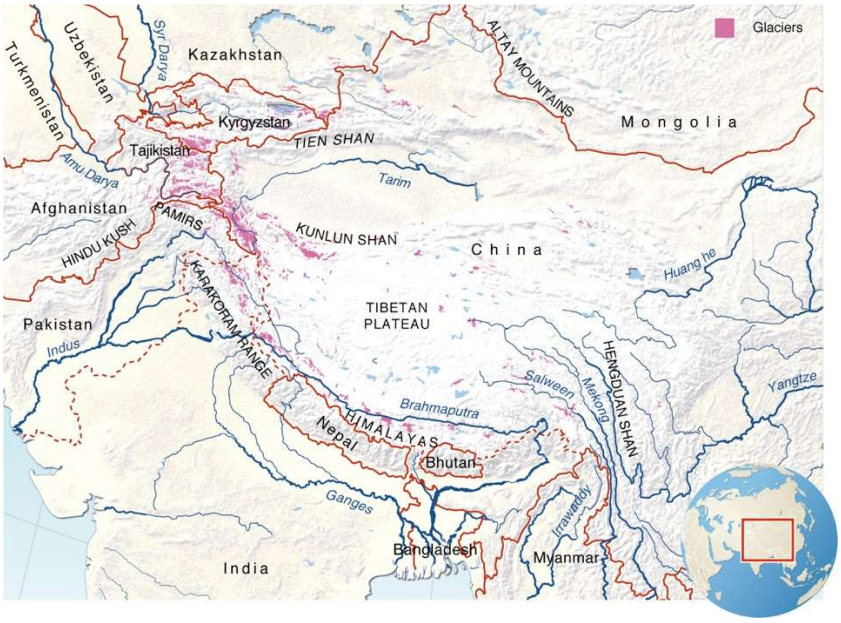
In summary, evidence, although limited, suggests that water-borne diseases will increase under projected climate change scenarios due to effects from increased temperatures, heavy storm events, drought, and sea level rise.

As we move forward, it is important that we continue to collect basic surveillance data on these climate sensitive diseases as well as improve our understanding of the mechanisms by which climate influences these pathogens.

The water tower of Asia



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Rapid glacier melting would result in a drastic reduction in the contribution to the river flow. Current permanent rivers would become seasonal.

Melting glaciers together with disturbed rainfall patterns will increase the amount of water-induced hazards such as floods, flash floods, landslides, debris flows, and droughts. Rainfalls will increase in high latitudes and decrease in most subtropical land regions, many of which are already affected by drought.

Population growth and increasing demand for water due not only to higher temperatures – demand for irrigation water will increase by 10% for an increase in temperature of 1°C – but also to higher standards of living, could adversely affect more than a billion people by the 2050s. Increasing withdrawal rates of groundwater and decreasing recharge time of the aquifers will accelerate the water crisis, notably in drier areas (Gosain et al., 2006).

The water tower of Asia

River	Area sq km	Mean discharge (m^3/s)	% of Glacier melt in river flow	Population x 1,000	Population density	Water per person m^3/year
Indus	1,081,718	5,533	44.8	178,483	165	830
Ganges	1,016,124	18,691	9.1	407,466	401	~2500
Brahma	651,335	19,824	12.3	118,543	182	~2500
Irrawaddy	413,710	13,565	unknown	33,097	80	18,614
Salween	271,914	1,494	8.8	5,982	22	23,796
Mekong	805,604	11,048	6.6	57,198	71	8,934
Yangtze	1,722,193	34,000	18.5	368,549	214	2,265
Yellow	944,970	1,365	1.3	147,415	156	361
Tarim	1,152,448		40.2	8,067	7	754
Total				1,324,800		

Source: ICIMOD (2008) 47

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Measures to address water- & food-borne diseases

- The effects of climate change on water & foodborne diseases can be mitigated
  - Focus on public health response
  - Focus on basic infrastructure
  - Increased attention to treatment options
- We have the tools to address problems & prevent disease
- Understanding how climate may increase risk can be used to prioritize adaptation or rapid response measures

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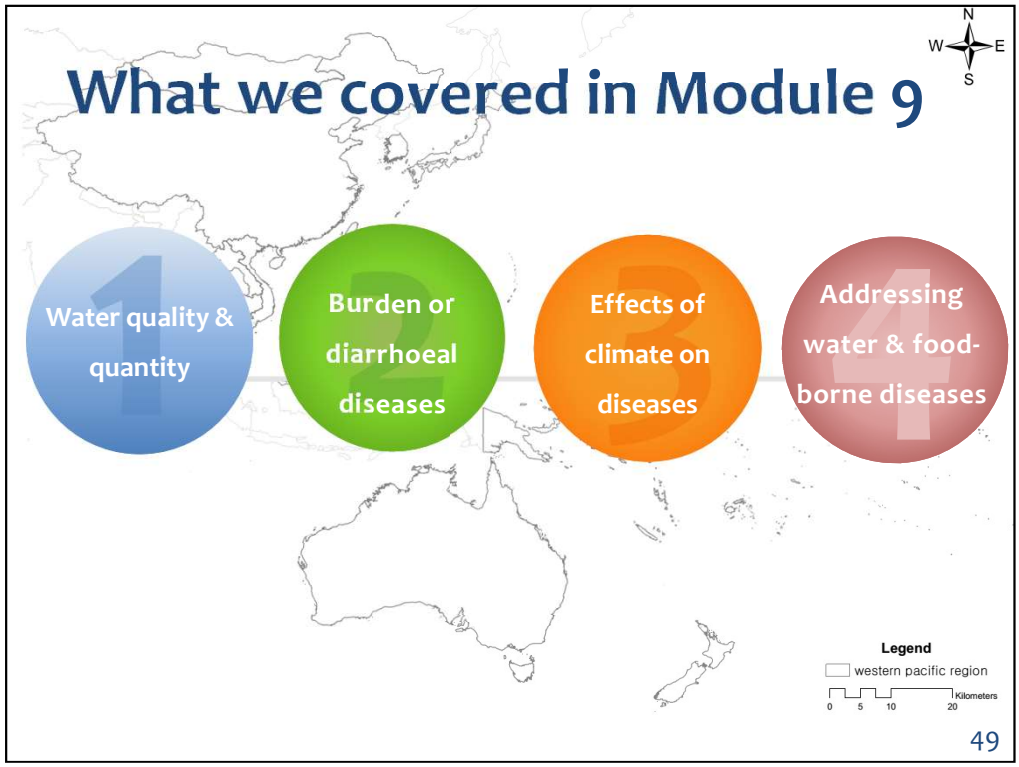
Our ability to adapt to and implement basic public health practices to protect water quality may mitigate the projected disease trends.

These measure include following the same sound practices that the public health community always uses to prevent disease including awareness of vulnerabilities, investments in the upkeep and development of infrastructure to ensure clean water, and focused attention on best management practices for treatment of water.

While trends suggest that the risk to human health due to water stress and water and foodborne disease, adequate attention and investment in sound sanitation practices and education of the public will go a long way in mitigating these risks.

Recommended reading: 2007 IPCC reports: The Physical Science Basis, page 53, Box TS5



Here's what we covered in Module 9:

1. Water quantity and quality
2. Burden of diarrhoeal diseases
3. How climate and weather affects diarrhoeal diseases and food- and water-borne pathogens
   - Season
   - Temperature
   - Precipitation (flooding and drought)
   - Sea level rise
4. Measures to address water & food-borne diseases

Key messages in Module 9

- Waterborne diseases are mostly transmitted by faecal-orally transmitted diseases
- Climate can influence waterborne diseases in different ways depending on the local environment & population
- Mitigation & adaptation will be enhanced by understanding the ecology of pathogens

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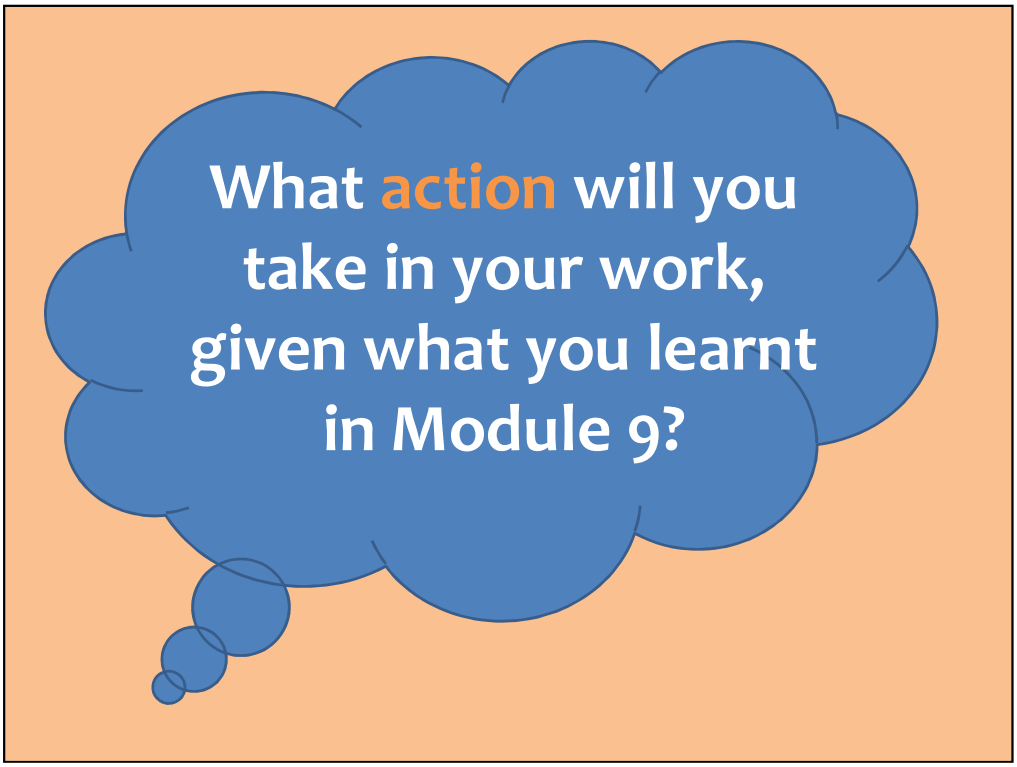
The key learnings to take away from Module 9 are: (**CLICK** for each)

- Water-borne diseases are mostly transmitted by faecal-orally transmitted diseases
- Climate can influence waterborne diseases in different ways depending on the local environment & population
- Mitigation & adaptation will be enhanced by understanding the ecology of pathogens

Q: Are there any questions on these?



To finish off Module 9, I'll ask you to spend the next few minutes looking over your notes and reflecting on the key learnings from this module for you.

Please take some notes on any action steps you'd like to take once you're back at work, based on what you've learnt around water and food-borne diseases.

Encourage quiet reflection (verbally if needed). At the end of **2 minutes**: "Thanks. I look forward to hearing some of the actions that were captured over the coming days."

Coming up next…

Module 10:

Food security & nutrition in a changing global climate

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