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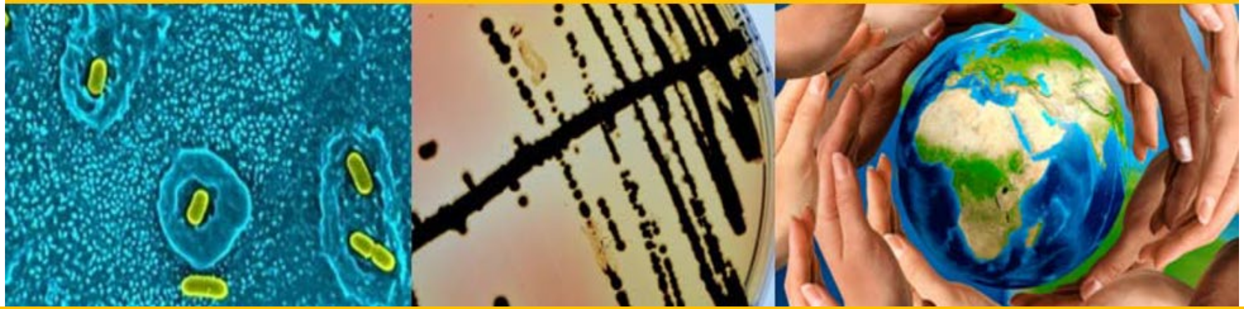


Climate Change and Public Health Part 2: Understanding, Mitigation, and Adaption

AGSC 5540: Food Policies and Regulations

11-18-2021

Tennessee State University, Nashville, TN

A. Fouladkhah: Director, Public Health Microbiology Laboratory

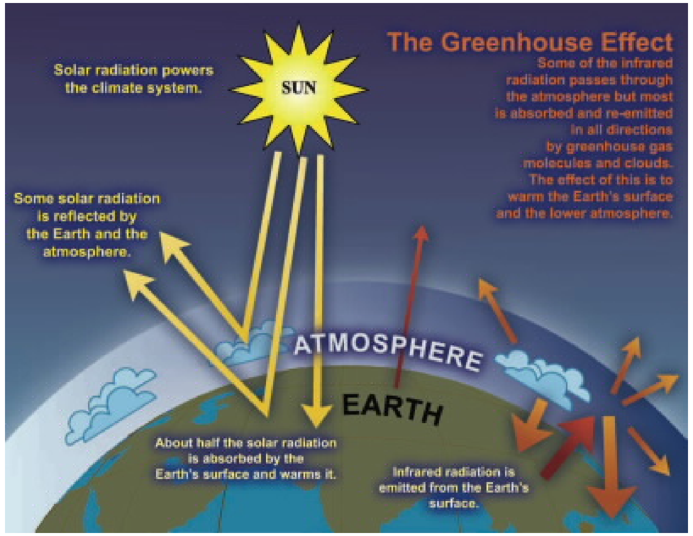
Weather and Climate: Variability and Change

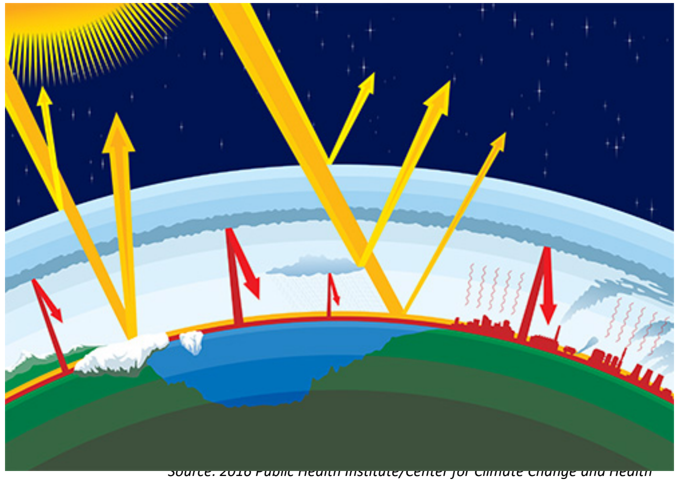
- **Weather** is the **temperature, humidity, precipitation, cloudiness and wind** that we experience in the atmosphere **at a given time in a specific location**.
- **Climate** is the *average weather over a long time period* (30 – 50 years) in a region.
- **Climate variability** refers to **natural variation in climate** that occurs over months decades. El Niño, which changes temperature, rain and wind patterns in many regions over about 2 – 7 years, is a good example of natural climate variability, also called natural variability.
- **Climate change** is "a **systematic change in the long-term state of the atmosphere over multiple decades or longer**."
- Based on statistical **modeling: There is <1% chance that** current warming of atmosphere since 1950 could be result of **climate variability.**

Source: 2016 Public Health Institute/Center for Climate Change and Health

What is the Cause of Climate Change?

- Climate change: caused by **change in the earth's energy balance**
- Energy balance: How much of the **energy from sun** that **enters** the earth is released **back to space**.
- Since industrial revolution from 1760s:
  - **Human activity**: Elevated greenhouse gasses (**GHG) in atmosphere**
  - **GHG trap suns energy** rather than reflecting back to space
  - High concentration of GHG: **Too much heat is trapped**
  - Leads to: The **earth temperature rising outside the range of natural variability**
- There are many GHG, with **different half-life**
- GHG are also called **Climate Active Pollutants**
- Because: Most have **negative health effects** for human and animals

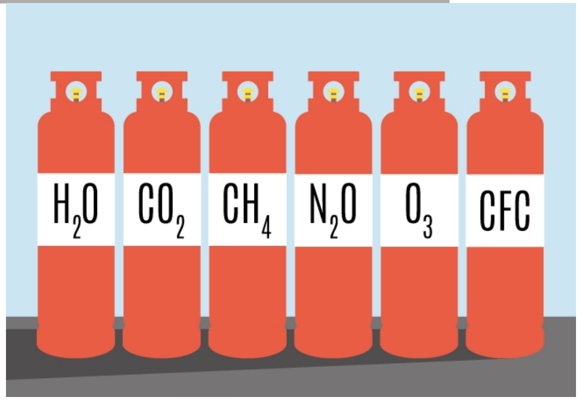




Source: 2016 Public Health Institute/Center for Climate Change and Health

Greenhouse Gases

- [**Carbon Dioxide (CO_2):**]
- Responsible for greatest amount of warming to date
- Accounts for 82% of human-caused GHG emission in the U.S.
- Most **CO_2 emission**:
  - Incomplete combustion of coal, oil and gas
  - These used for **electricity production**, **transportation**, and **industrial processes** (80% of CO_2 release in atmosphere)
- **Other important GHGs**:
- Methane
- Nitrous oxide
- Fluorinated gases
- Pure carbon from fuel combustion



Source: 2016 Public Health Institute/Center for Climate Change and Health

Greenhouse Gases

- **Global Warming Potential (GWP):** A measurement of ability to trap heat
- The GWP for CO_2 is set at "1" *e.g.* other GHG are compared to CO_2

GHG	% of US Emission	Source	Lifetime in Atmosphere	GWP
Carbon Dioxide (CO_2)	82%	Electricity production; transportation; industrial processes	c. 50-200 years	1
Methane (CH_4)	10%	Livestock; food decomposition; extraction of natural gas	12 years	25
Nitrous Oxide (N_2O)	5%	Vehicles; industrial processes	115 years	298
Pure Carbon	>1%	Diesel engines; wildfire; household cook stoves (developing countries)	c. Days to weeks	3,200
Fluorinated gasses (PFC, HFC, NF_3, SF_6)	>5%	No natural sources: Synthetic pollutants in coolants, pesticides, solvents, fire extinguishers	Some 1 year some >5,000 years	7,000-22,800

Source: 2016 Public Health Institute/Center for Climate Change and Health

Greenhouse Gases

- **Short-Lived Climate Pollutants (SLCP):**
- Have **short lifetime** but high **Global Warming Potential**
- Includes: **Methane, Pure carbon, and some fluorinated gases**.
- Their **global warming impact** will be occur **sooner**
- **CO_2 has low GWP**, it impact will be **felt later**

- **Ultimately, we would need:**
- Transition to **carbon-free** transportation and energy system
- Because: **CO_2 is the greatest threat to climate health**
- **Reducing Short-Lived Climate pollutants** may **"buy time"** while making the transition

Source: 2016 Public Health Institute/Center for Climate Change and Health

Short Term Plan: Reducing Short-Lived Climate pollutants

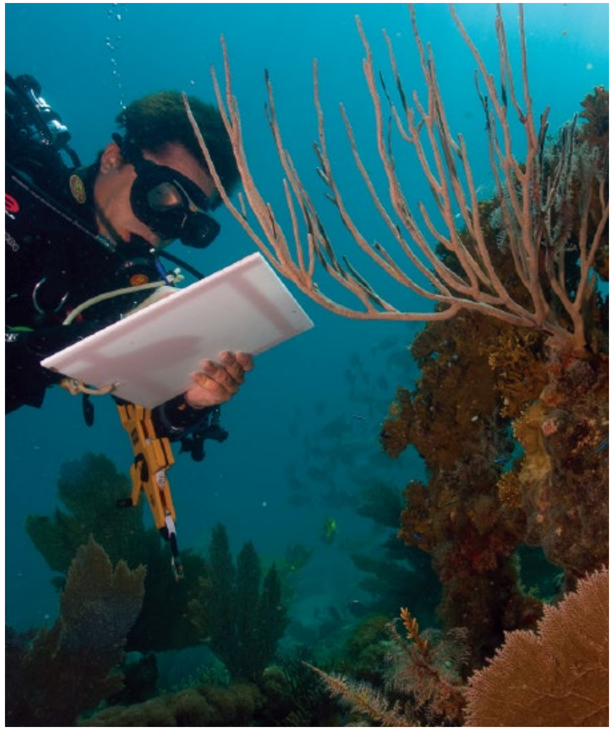
- **Reducing Short-Lived Climate Pollutants (SLCP)** significantly by 2030:
- **Reduce** global level of **sea level rise** by **20%** before 2050.
- Cut global warming in half by 2050
- Prevents **2.4 million premature death globally** each year
- Improves **health for disadvantage communities**.

- Health Benefits of reducing SLCP (**Climate Change Mitigation Co-Benefit**):
- Reducing **air pollution** related hospitalization
- Promotion of reduced **meat consumption**
- **Stricter emission standard** specially for diesel vehicles
- **Cleaner household cook stoves** in developing countries

Source: 2016 Public Health Institute/Center for Climate Change and Health

Overall Effects of Climate Change

- **Overall effects of climate change:**
- **Greater variability**, with "**wetter wets**", "**drier dries**" and "**hotter hots**"
- More **frequent and severe extreme heat** events
- More **severe droughts**
- **Intense precipitation**, such as **severe rains, winter storms and hurricanes**
- **Higher average temperatures** and **longer frost-free seasons (entomology concern)**
- **Longer wildfire seasons** and **worse wildfires**
- **Loss of snowpack and earlier spring runoff**
- Recurrent **coastal flooding with high tides and storm surges**



Source: 2016 Public Health Institute/Center for Climate Change and Health

What can we do about Climate Change

- **Climate Solutions:**
- (1) Mitigation
- (2) Adaption
- (3) Resilience

- **Mitigation:** “measures to reduce the amount and speed of future climate change by reducing emissions of heat-trapping gases or removing carbon dioxide from the atmosphere.”
- **Adaptation:** “adjustments in natural or human systems.”
- **Resilience:** “capability to anticipate, prepare for, respond to, and recover from significant threats with minimum damage to social well-being, the economy, and the environment.”

Climate Change Mitigation

- **Purpose of Climate Change Mitigation:**
- Prevent reaching or surpassing "**tipping points**"

e.g. **Collapse of the West Antarctic Ice Sheets:** could lead to very **rapid sea level rise**

e.g. **Melting of permafrost:** large release of methane gas

Source: https://www.nrdc.org/stories/permafrost-everything-you-need-know

- **Catastrophic climate changes**: surpass our ability to adapt

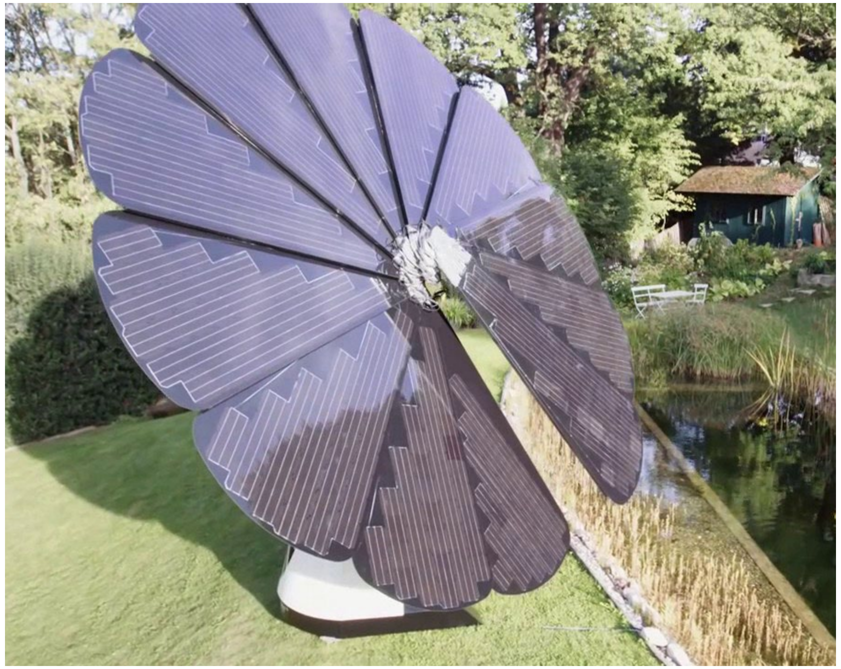
e.g. Parts of **Southwest Asia** may have recently passed body's **survival threshold for heat**

IPCC Report (International Governmental Panel on Climate Change)

- **Currently** global temperature **1°C higher than pre-industrial level**.
- **Business as usual**: Earth temperature **rises > 4°C** by end of century
- **Paris agreement in 2015 (200 countries) :** keep temperature **rise below 1.5°C compared** to preindustrial level (**some climate scientists: not enough**)

Climate Change Mitigation

- Climate Change Mitigation Strategies:
- Use of clean and renewable energy for **electricity production**
- **Walking, biking**, using **low-carbon (or zero-carbon) vehicles**
- **Reducing meat consumption**
- **Less flying**
- **Changing agricultural practices (lab-grown meat?, insects?)**
- **Limiting deforestation**
- **Planting trees**



Climate Change Adaptation

- **Purpose of Climate Adaption:**
- Reduce harmful impact of climate change
- Allow communities to thrive in the face of climate change

- **Mitigation strategies:**
- **Cool roofs** and **air conditioning**: adapt to **heat waves**
- **Seawalls and restoration of wetlands:** adapt to **sea level rise**
- **Emergency preparedness planning: extreme weathers and vector-borne diseases**

Exercise 1

- What is Weather, Climate, Climate Variability, and Climate Change? Based on statistical models, what is the chance that current global warming since 1950 is due to climate variability?
- What are the main greenhouse gases?
- What is Global Warming Potential (GWP)? What is the GWP, current US emission, and lifetime of Carbon Dioxide, Methane, Nitrous Oxide, Fluorinated gases, and pure carbon?
- What are Short-Lived Climate Pollutants (SLCP) and why are they important?
- What are Climate Change Co-Benefits of reducing Short-Lived Climate Pollutants?
- What is the purpose of Climate Change Mitigation and what are some practices examples?
- What is IPCC?
- According to IPCC what is the current temperature increase compared to pre-industrial level? What would be temperature increase under “business as usual” scenario? What is the goal of Paris agreement for control of temperature in the current century?
- What is the purpose of Climate Change Adaption and what are some practical examples?

Climate Change and Health and Food Safety

- **Three Effects of Climate Change on Health and Food Safety**
- **Climate change (direct effects):** Changes in survival and transmission patterns of bacteria, viral, and parasitic agents.
- **Climate-dependent (indirect effects):** Temperature and moisture affects fungal growth and formation of mycotoxins.
- **Extreme weather events and natural disasters:** Climate change increases frequency and severity extreme weather events.

Climate Change: Bacteria, Viruses, and Parasitic Protozoa

- **Bacteria, Viruses, and Parasitic Protozoa**
- Collectively estimated to cause 2 billion illness globally
- Causing 31 million (DALY) Disability-Adjusted Life Year
- 29% of these disease are estimated to be foodborne.

- **Temperature and humidity** could greatly affect the **growth** of organisms:
- ***Salmonella* as an example**: 50,000 global death in 2010.
- **1°C increase** (above 5°C) in weekly temperature lead to **5 to 10% increases in** cases (WHO, 2018)
- ***Vibrio Cholerae*:** currently 760,000 global illness/24,000 death per year.

Vibrio spp.

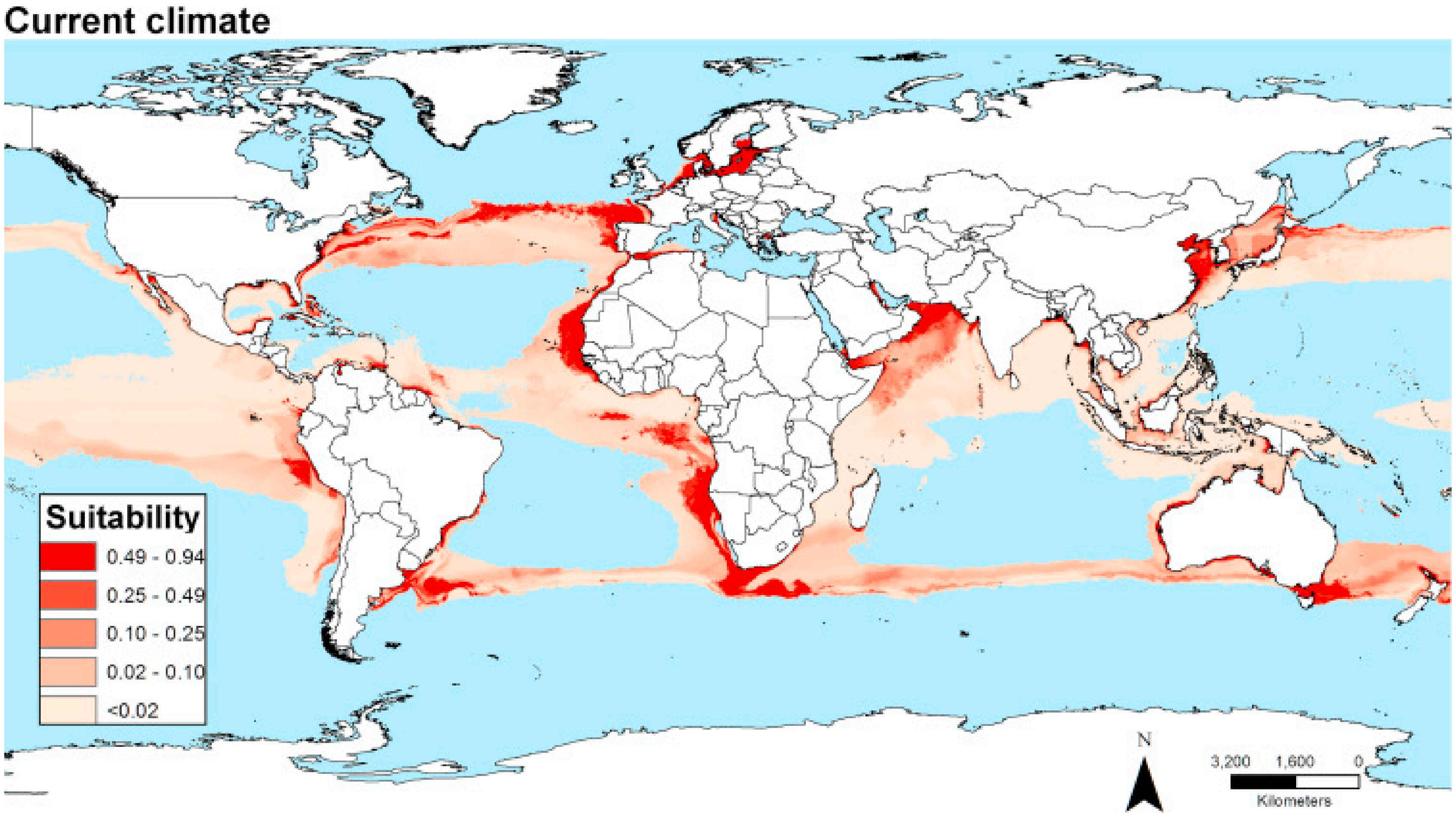
Currently 760,000 global illness/24,000 death per year.

- Causing about **80,000 illness and 100 death** annually in the United States.
- **Infection symptoms** vary depending on strain, ranging from diarrhea to high fever
- Vibrio is a **halophilic bacterium** and is a major concern in aquaculture industry
- **Primary sources**: Salt water environments and seafood
- Requires salt to reproduce (halophile)

Growth parameters	Minimum	Optimum	Maximum
Temperature	41°F (5°C)	99°F (37°C)	114°F (45.3°C)
pH	4.8	7.8-8.6	11
a_W	0.94	0.98	0.996 (10% NaCl)
Other	Non-sporeformer, requires salt		
Atmosphere	Facultative - grows with or without oxygen		

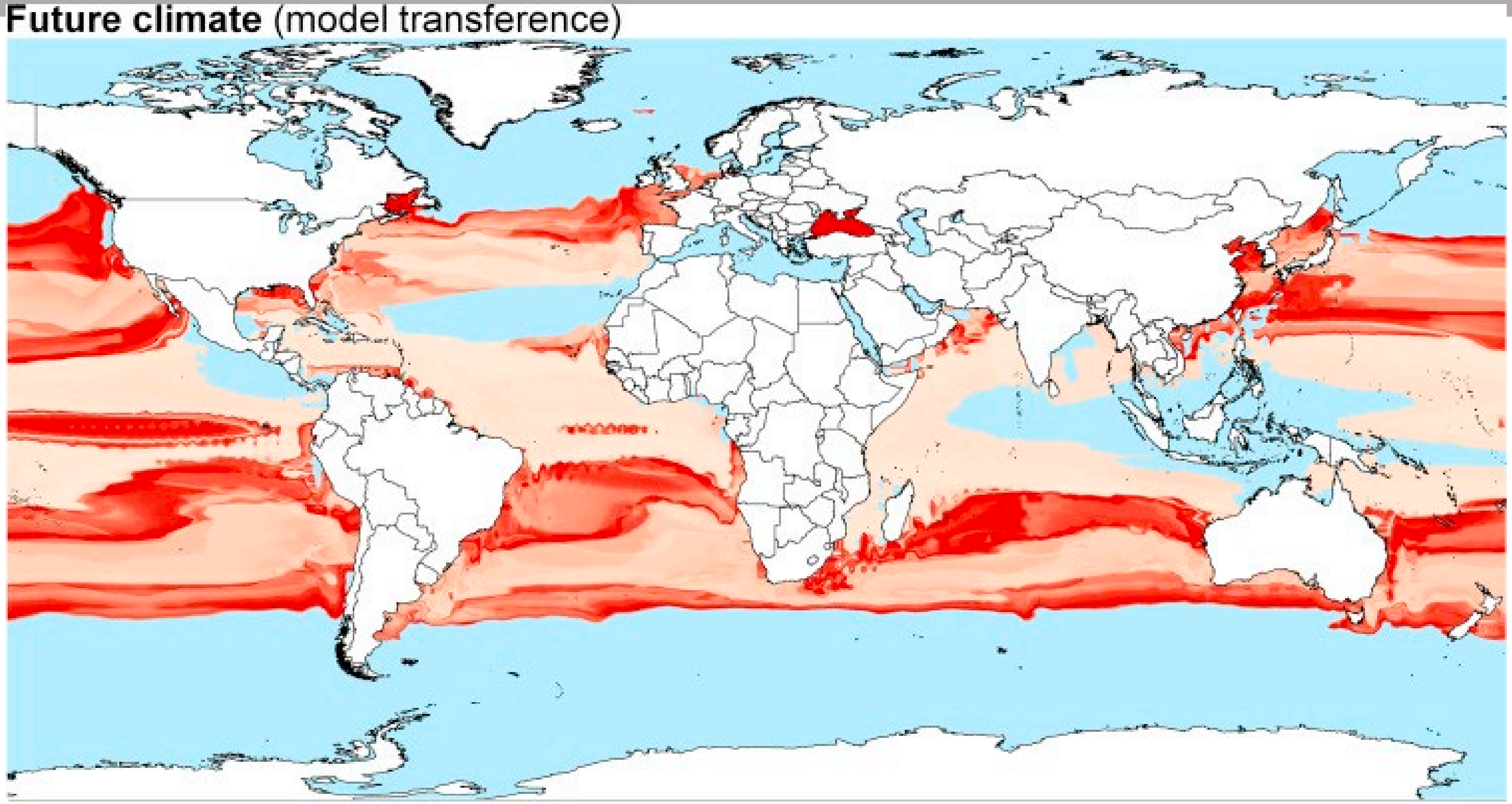
Sources: Seafood Hazards Guide 2011, ICMSF 1995 and Bad Bug Book 2nd edition

Vibrio cholerae proliferation in sea water:
Current Climate



Escobar LE et al. Acta Tropica 2015;149:202-11

Vibrio cholerae proliferation in sea water:
Business-as-Usual Projection in 2100



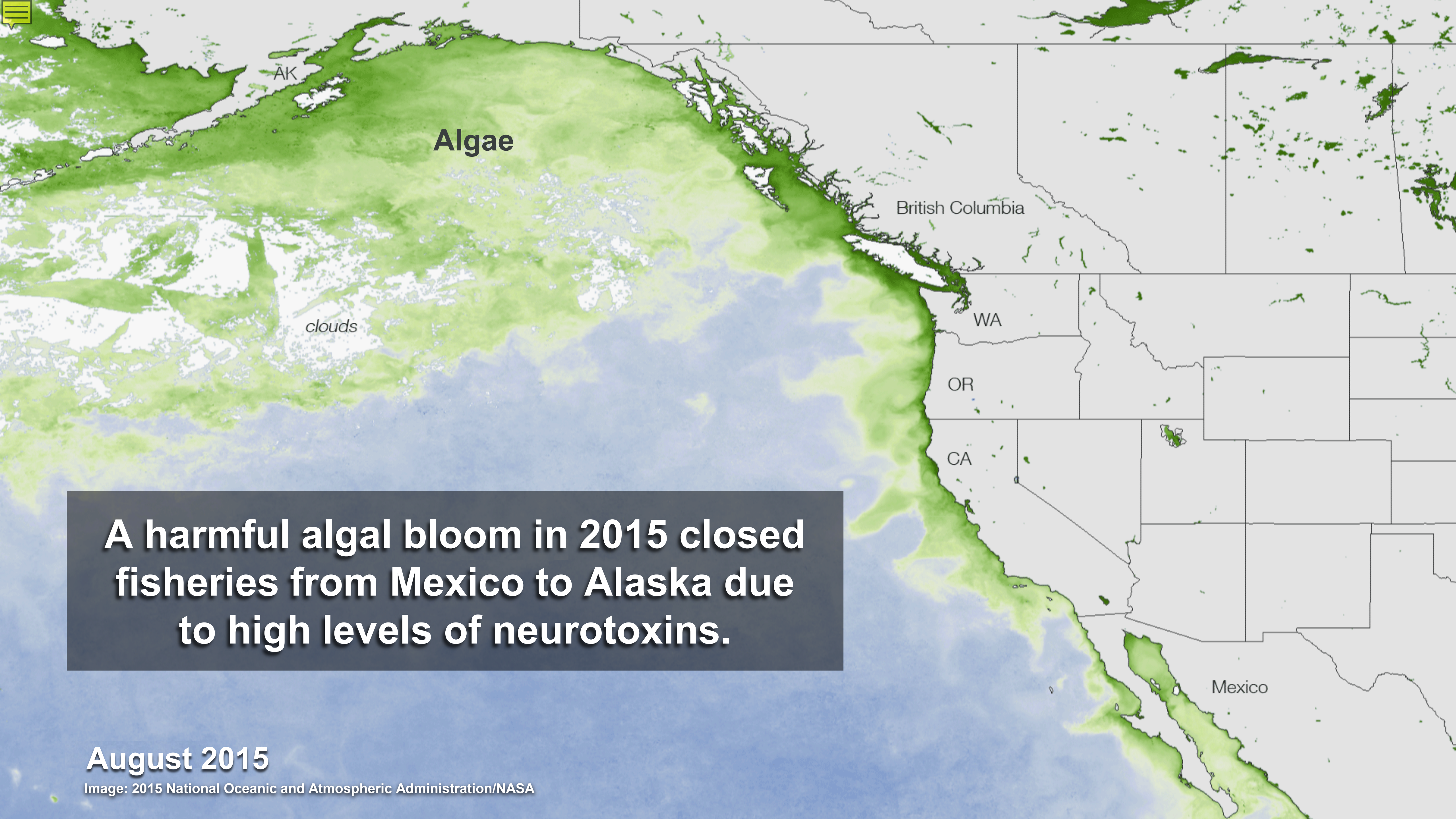
Escobar LE et al. Acta Tropica 2015;149:202-11

Climate Change: Mycotoxin and Phycotoxins

- **Mycotoxins: (Aflatoxin, fusarium, patulin etc.)**
- Compounds produced by **variety of fungi**
- At very **high concentrations acute health problem** and death
- **Long-term exposure**: various **forms of cancer**
- Estimated **25% of world's yearly crop** contaminated with mycotoxins
- Occur more frequently in **hot and humid regions**
- Human exposure:
- **Dietary exposure**: **direct** (contaminated crop) or **indirect** (animal derived food consumed contaminated feed)
- **Change in climate** could **increase moisture** in some areas **12-14%** (FAO, 2016)

Climate Change: Mycotoxin and Phycotoxins

- **Mycotoxins:**
- **At 2°C increase**, **aflatoxin** growth will become an emerging concern in **North America** and **Europe**.
- Similar trends could lead to **Fusarium** production in **Maize products**
- **Elevated climate: increases in algal bloom, algae produce toxins= phycotoxins**
- **Phycotoxins:** a concern in **water-filtering organisms** such as **mussels and clams**
- Another exp. of **phycotoxins: Ciguatoxins** from algae: **Ciguatera fish poisoning**
- **Ciguatera fish poisoning:**
  - *Most common seafood poisoning*
  - *Has been increasing in last two decades*



A harmful algal bloom in 2015 closed fisheries from Mexico to Alaska due to high levels of neurotoxins.

August 2015

Image: 2015 National Oceanic and Atmospheric Administration/NASA

Climate Change: Veterinary Drugs

- **Elevated temperature could lead to:**
- Enhanced **survival** of pathogens
- Increases in **vector-borne** diseases
- Increases in **parasite prevalence** in animals (FL, TN)
- Heat-stress: **increases susceptibility of animals to disease**

- These require **increase in veterinary drugs use, may lead to:**
- **Increased residue in animal foods** (chronic and acute human health)
- Increased **antimicrobial resistance** in human and animal pathogens

Climate Change: Pesticides

- **Increases in extreme temperature and rainfall:**
- Attraction of **pests, plant diseases, weeds**
- Changes in **pesticide use pattern is likely**
- Excessive rainfall could: **water pollution with pesticides**
- Specially of concern for: Polychlroniated Biphynols (**PCBs**) and **dioxins (environmentally stables chemicals).**

- **Mitigation:**
- Use of **draught-resistant crops**
- Changing **planting and harvest dates**
- **High-yield water-sensitive crops**

Climate Change: Zoonosis

- **Zoonosis, Vectorborne Diseases, and other Animal Diseases:**
- **Elevated temperature could result in:**
- Survival and **proliferation of the pathogen** (*e.g. Salmonella* serovars)
- Changes in **migration pathways** (*e.g.* for avian influenza)
- Changes in **carriers and vectors** (*e.g.* Zika virus)
- Changes in **natural ecosystem** (e.g. Ciguatera fish poisoning)

- **These changes could lead to:**
- Increased **outbreak and sporadic cases**
- Increased need for **antibiotics and antimicrobials**

Salmonella serovars (Non-typhoidal)

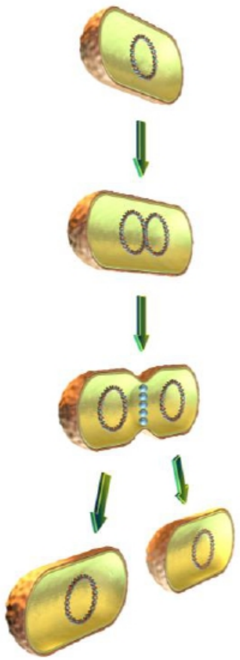
- **Annual illness (death): 1,027,561 (378) in humans**
- **Infection** causes nausea, vomiting, diarrhea, fever, headache
- **Primary sources**: Intestinal tract of people and animals
- **Transmitted by** meat, poultry, eggs, raw milk, unpasteurized juice, many other foods (nuts, spices, produce, chocolate, flour)
- **Contributing factors**: cross-contamination, undercooked food, poor agricultural practices

Growth parameters	Minimum	Optimum	Maximum
Temperature	41°F (5.2°C)	95-109°F (35-43°C)	115°F (46.2°C)
pH	3.7	7-7.5	9.5
a_W	0.94	0.99	>0.99
Other	Non-spore former		
Atmosphere	Facultative - grows with or without oxygen		

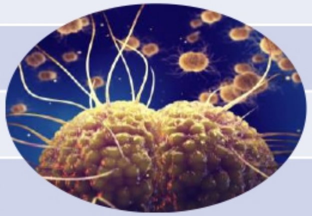
Sources: ICMSF 1995 and Bad Bug Book 2nd edition, Scallan et al., 2011, and FSPCA

Bacterial Multiplication

<u>Binary Fission</u>: 20 minutes or less when intrinsic and extrinsic factors are optimal.



Time	# of Bacteria
0 minutes	1
20 minutes	2
40 minutes	4
1 hour	8
2 hours	64
4 hours	4,096
6 hours	262,144
8 hours	16,777,216
12 hours	68,719,476,736



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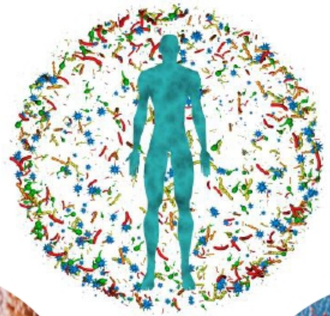

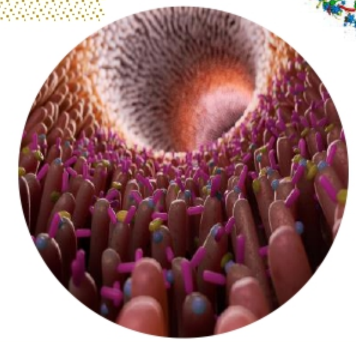

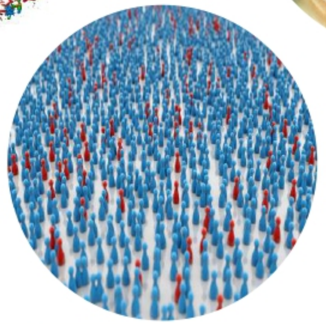

Bacteria	Estimated Infective Dose*
Salmonella serovars	<10 cells
Shiga toxin-producing *E. coli*	10 to 100 cells
Cronobacter sakazakii	10 to 100 cells
Listeria monocytogenes	<1000 cells
Campylobacter spp.	5000 to 10,000 cells
Staphylococcus aureus	>100,000 cells
Vibrio cholerae	1,000,000 cells

** Calculated for oral ingestion based on epidemiological data from outbreaks and human feeding trials of volunteers. Data obtained from BBB of Food and Drug Administration (2nd edition).*

Public Health Microbiology Laboratory: Education, Research, Outreach, and Technical Assistance: https://publichealthmicrobiology.education/

Climate Change and Public Health Microbiology

Non-typhoidal *Salmonella enterica* serovars

- **Global death:** 50,000 global death in 2010 (WHO, 2020)
- **Public Health Burden in the U.S.:** >1 million annual cases in 2011 (CDC, 2011)

Climate Change:

- **1 °C increase : 5 to 10% increases in Salmonellosis (WHO, 2010)**
- 2500 to 5000 additional global death
- 50,000 to 100,000 U.S. morbidity

At our current rate (2021 IPCC report)

- >1.5 °C by 2040
- >4.8 °C by 2100

Biology | Aliyar Fouladkhah

Changing climate

A 'threat multiplier' for foodborne and waterborne infectious diseases and antibiotic resistance

Dr Aliyar Cyrus Fouladkhah of Tennessee State University is an Assistant Professor in Public Health Microbiology. His laboratory explores preventive measures for the spread of infectious diseases, antibiotic resistance, and food security in the landscape of changing climate. His research aims to provide better understanding of the ecology, epidemiology and effectiveness of control measures of enteric and environmental pathogens at planktonic and biofilm stages, including several foodborne and waterborne bacteria. His work contributes to reducing the current burden of premature morbidity and mortality associated

According to the U.S. Centers for Disease Control and Prevention, achieving safe and healthier foods is one of the top ten achievements of 20th century public health. Despite the marked progress, considerable challenges remain to further assure the safety and security of food and water supplies, with one in six adults in the United States experiencing illness from foodborne pathogens in a typical year. Foodborne diseases cause an estimated 420,000 deaths worldwide each year. Furthermore, climate change is expected to enhance the spread of infectious diseases since changes in environmental temperatures appreciably augment the multiplication of bacterial pathogens.

The research group of Dr Aliyar Fouladkhah at Tennessee State

in Guatemala, Dominican Republic, and South Africa.

THE ROLE OF CLIMATE CHANGE

Microbial pathogens have an incredible ability to evolve and move towards '*fitness*' in response to changes in their environment. Climate change will have pronounced effects on the proliferation, survival, and spread of microbial pathogens, and thus on the prevalence of foodborne and waterborne diseases. More than 200 diseases, known to be transmitted through contaminated food and water, may provide examples of the effects of climate change on the magnitude of infectious diseases. One example of this is salmonellosis, an infection caused by nontyphoidal *Salmonella enterica* serovars, which is currently responsible for over one million

microorganisms MDPI

Editorial

Safety of Food and Water Supplies in the Landscape of Changing Climate

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Received: 15 September 2019; Accepted: 16 October 2019; Published: 18 October 2019

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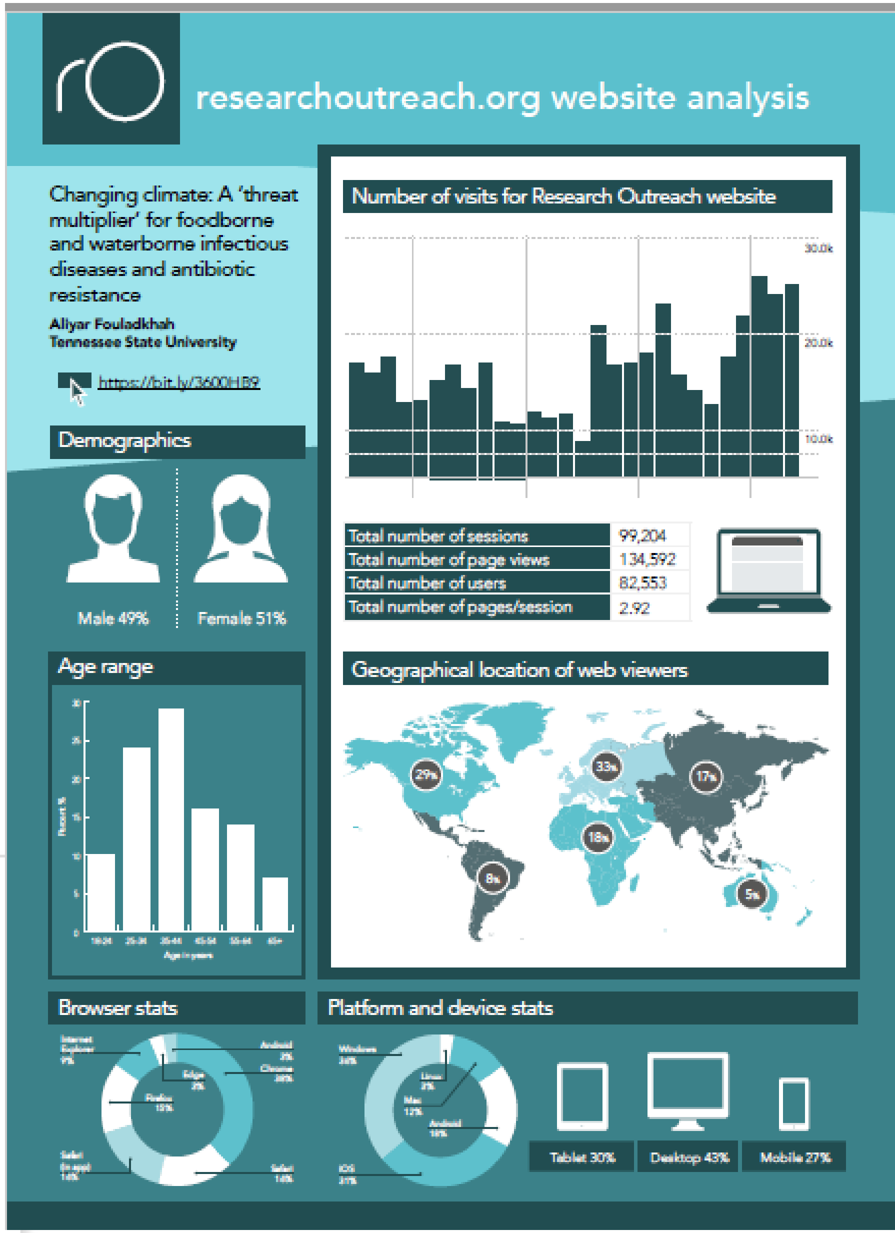
In response to evolving environmental, production, and processing conditions, microbial communities have tremendous abilities to move toward increased diversity and fitness by various pathways such as vertical and horizontal gene transfer mechanisms, biofilm formation, and quorum sensing [1,2]. As such, assuring the safety of water and food supplies from various natural and anthropogenic microbial pathogens is a daunting task and a moving target. Recent outbreaks of *Listeria monocytogenes* in South Africa associated with a ready-to-eat product (affecting close to 1000 individuals) and the 2018 outbreak of Shiga toxin-producing *Escherichia coli* O26 associated with ground meat in the United States (leading to the recall of more than 132,000 pounds of products) are bitter reminders of the devastating influences of foodborne diseases on the public health and food manufacturing [3,4].

Recent epidemiological studies of world populations indicate that 420,000 people lose their lives every year due to foodborne diseases, with around one-third of those being 5 years of age or younger. It is further estimated that every year, 1 in 10 individuals experience foodborne diseases around the globe, leading to an annual loss of 33 million healthy life years [5]. These episodes of food and water



Impact Analyses of the Climate Change Study

Available at:
https://researchoutreach.org/articles/changing-climate-threat-multiplier-foodborne-waterborne-infectious-diseases-antibiotic-resistance/

Exercise 2

- What are the three main effects of climate on food safety?
- Please name two main foodborne bacteria that could cause enhanced public health problems in the changing climate?
- Please name two main mycotoxins that could cause enhanced public health problems in the changing climate?
- What are phycotoxins? Please provide one example of foodborne phycotoxins?
- What is the effects of climate change on zoonosis diseases?
- What is the effects of climate change on pesticides use and how the negative effects could be mitigated?

Thank you

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