Climate Change and Infectious Diseases in North America

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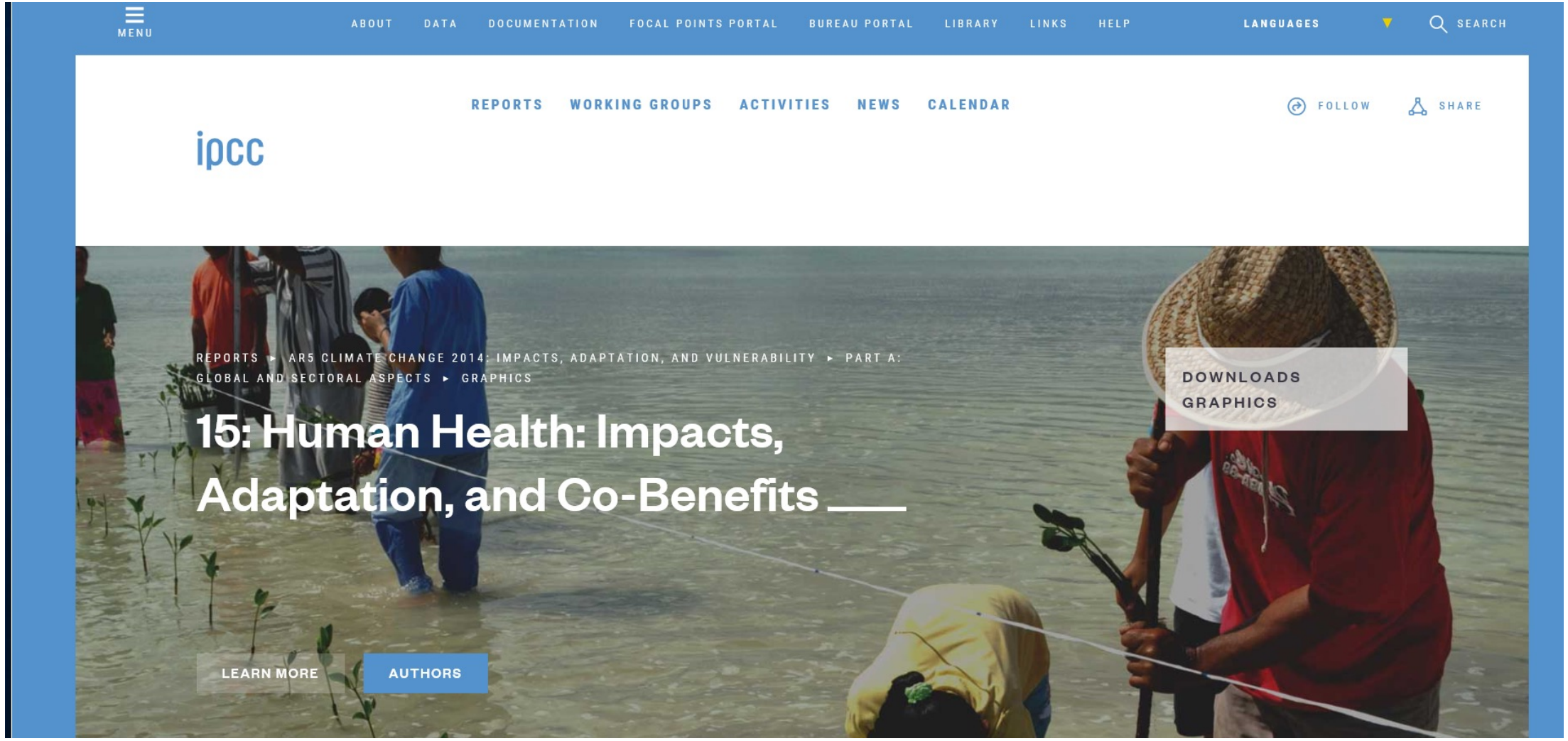
- **SPEAKER(S):** Naomi Hauser

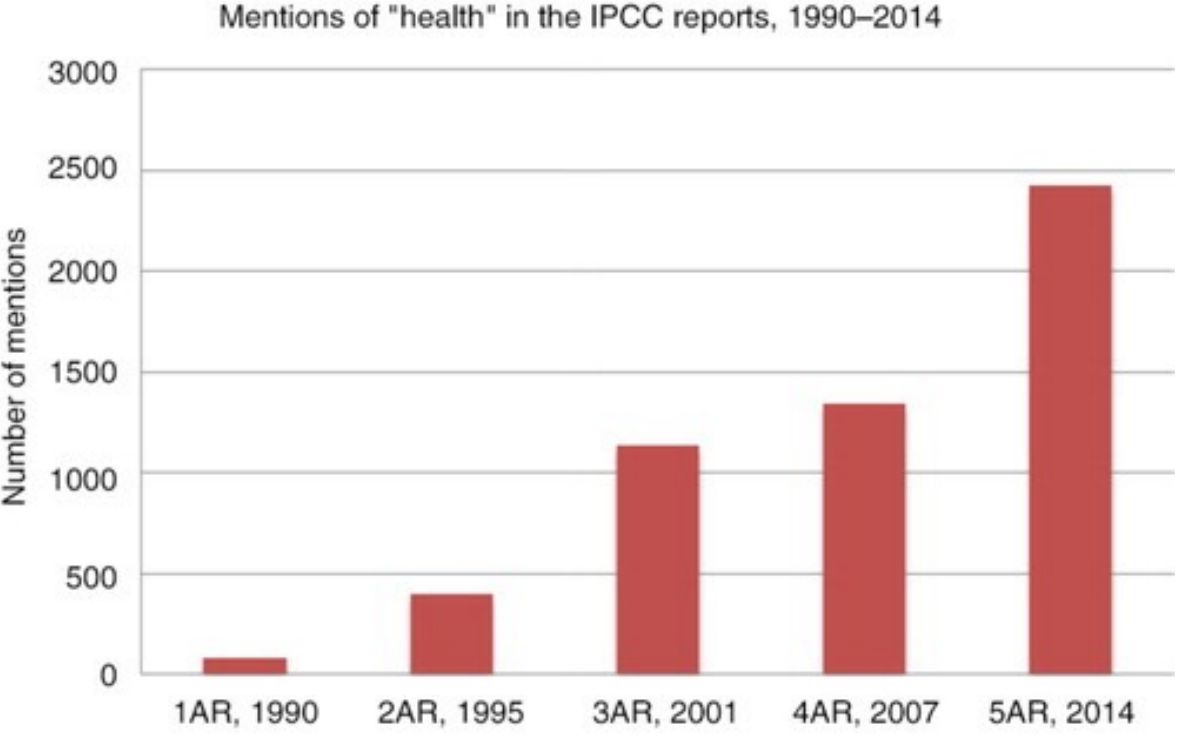
Objectives

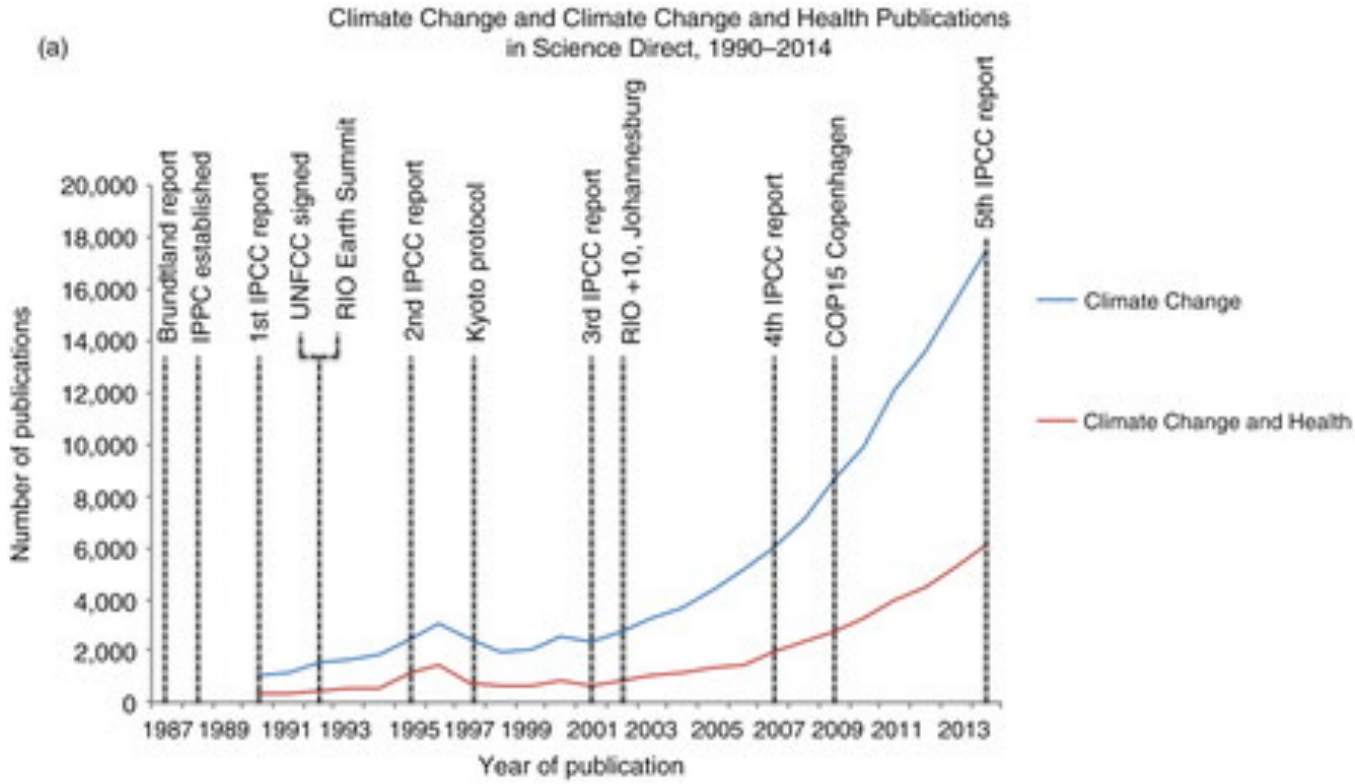
- Recall the relationship between climate change-induced extreme weather events and infectious diseases
- List several modes of infectious disease transmission
- Examine the healthcare industry's role in contributing to and treating climate change-related infectious diseases

Climate Change and Human Health

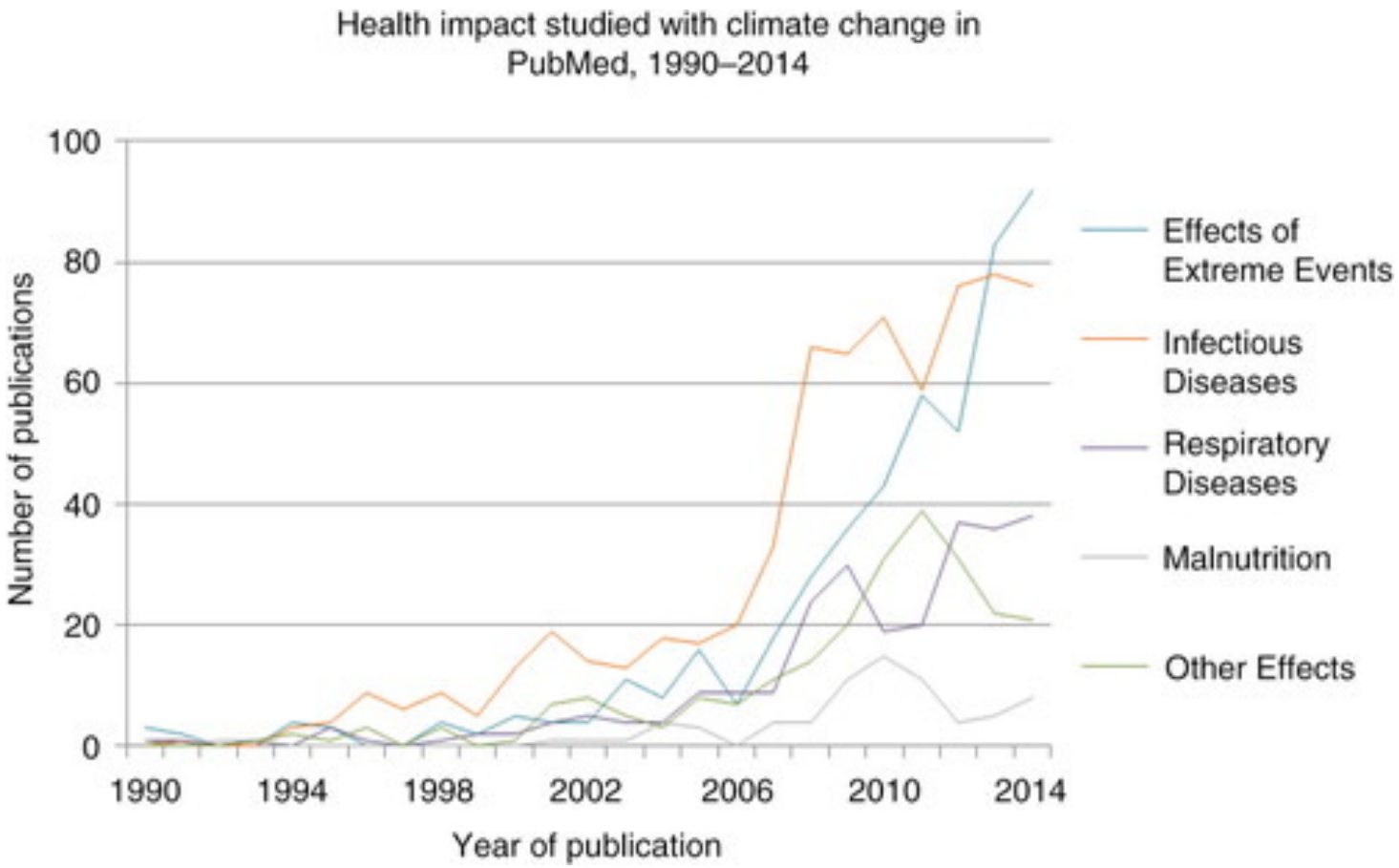


KR Smith et al. 2014: Human health: impacts, adaptation, and co-benefits. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change



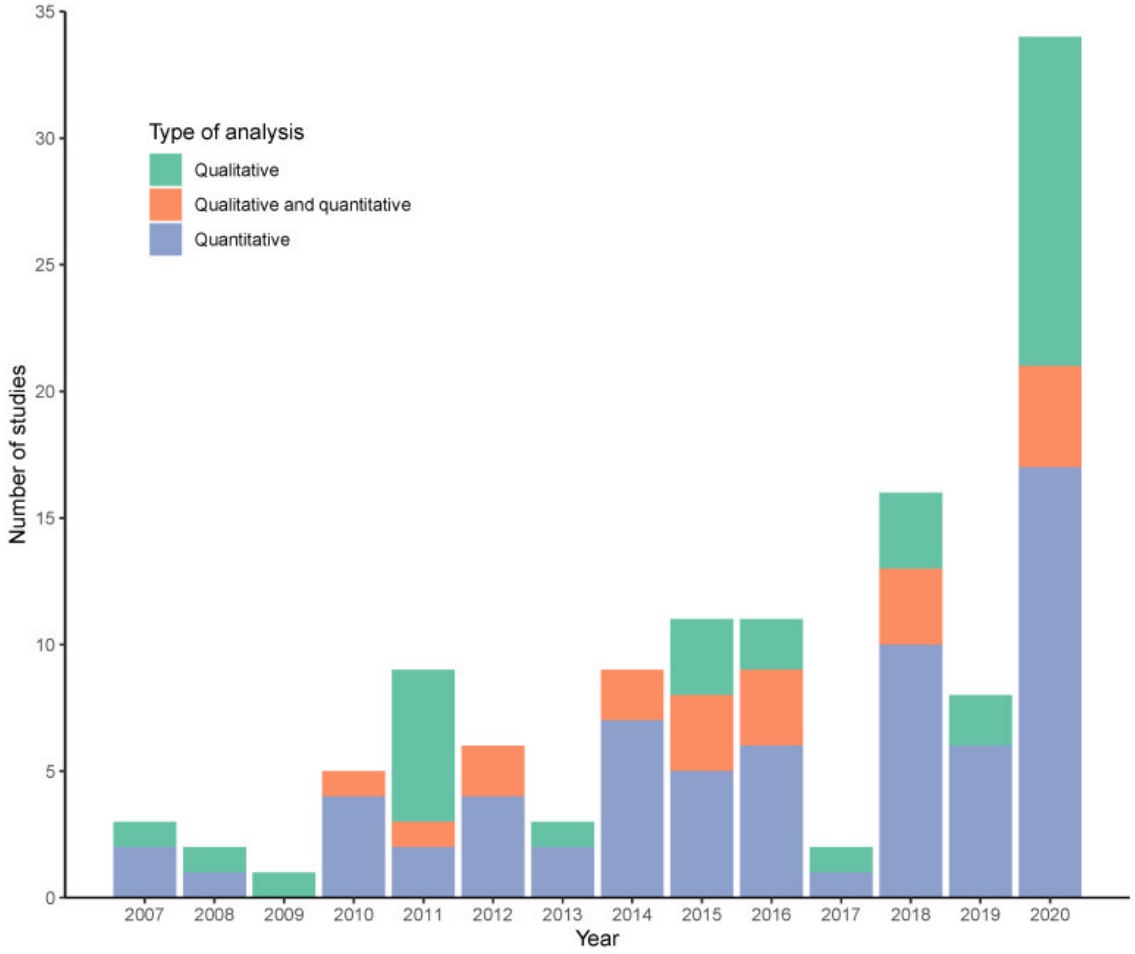


G. Verner et al. 2016. Health in climate change research from 1990 to 2014: positive trend, but still underperforming, Global Health Action, 9:1, DOI: [10.3402/gha.v9.30723](10.3402/gha.v9.30723)



G. Verner et al. 2016. Health in climate change research from 1990 to 2014: positive trend, but still underperforming, Global Health Action, 9:1, DOI: [10.3402/gha.v9.30723](10.3402/gha.v9.30723)

Climate change and mental health studies 2001-2020



F. Charson et al. 2021. Climate change and mental health: A scoping reiew, Int J Environ Res Public Health, 18(9): 4486, DOI: 10.3390/ijerph18094486.

Climate crisis: 233 journals 'call for emergency action' to limit global heating

Written by Robby Berman on September 14, 2021 — Fact checked by Catherine Carver, MPH

- World Health Organization
  - "Climate change affects the social and environmental determinants of health"
- Pan-American Health Organization
  - "Climate change is the biggest global health threat of the 21st century."
- American Public Health Association
  - "climate change is a health emergency"
- Environmental Protection Agency
  - "Climate change poses many threats to the health and well-being of Americans"
- US Global Change Research Program
  - "Climate change is a significant threat to the health of the American people"
- National Geographic
  - "Why climate change is still the greatest threat to human health"
- NPR
  - "Climate change is negatively affecting young people's mental health globally"

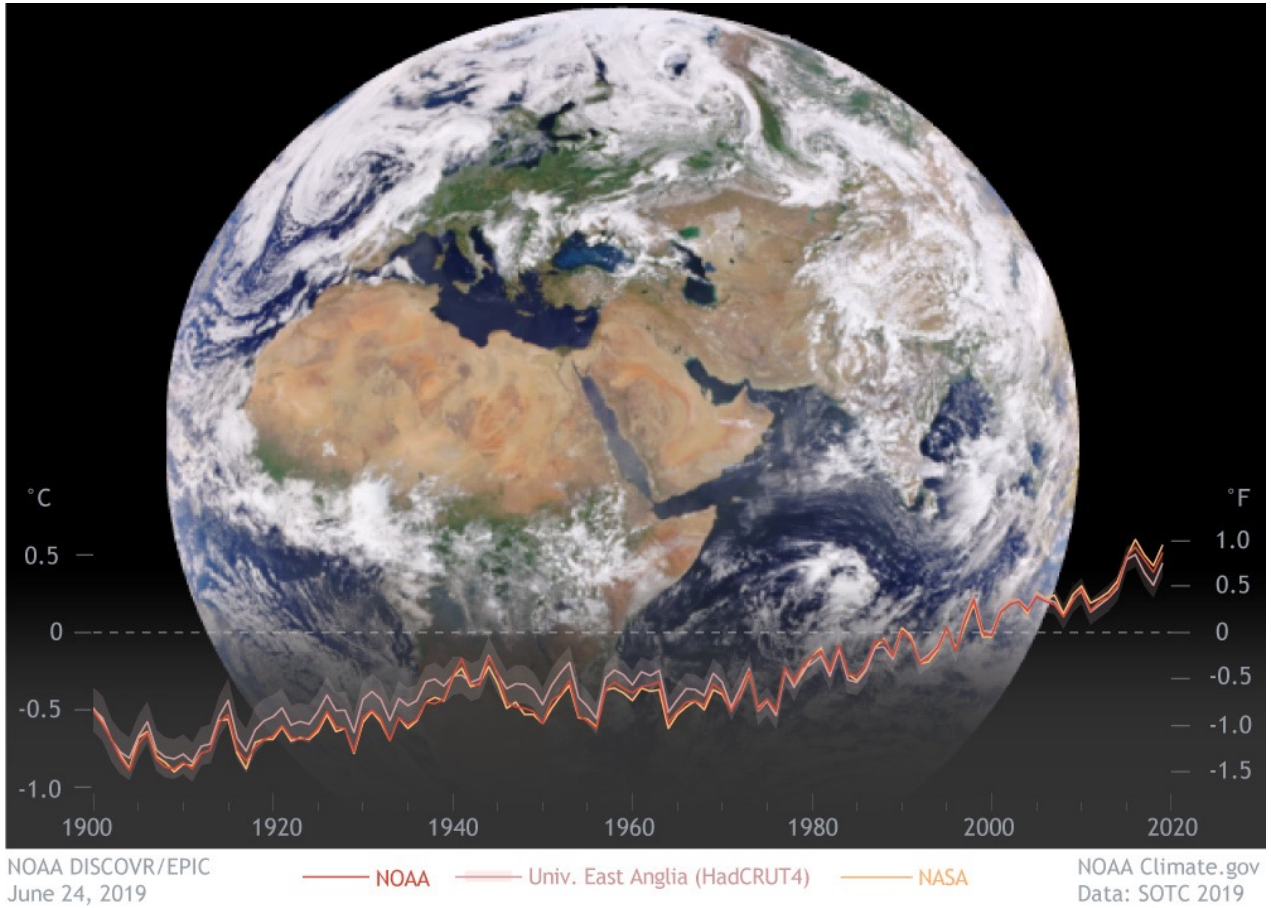
Extreme weather events

NASA, Global Climate Change: Vital signs of the planet

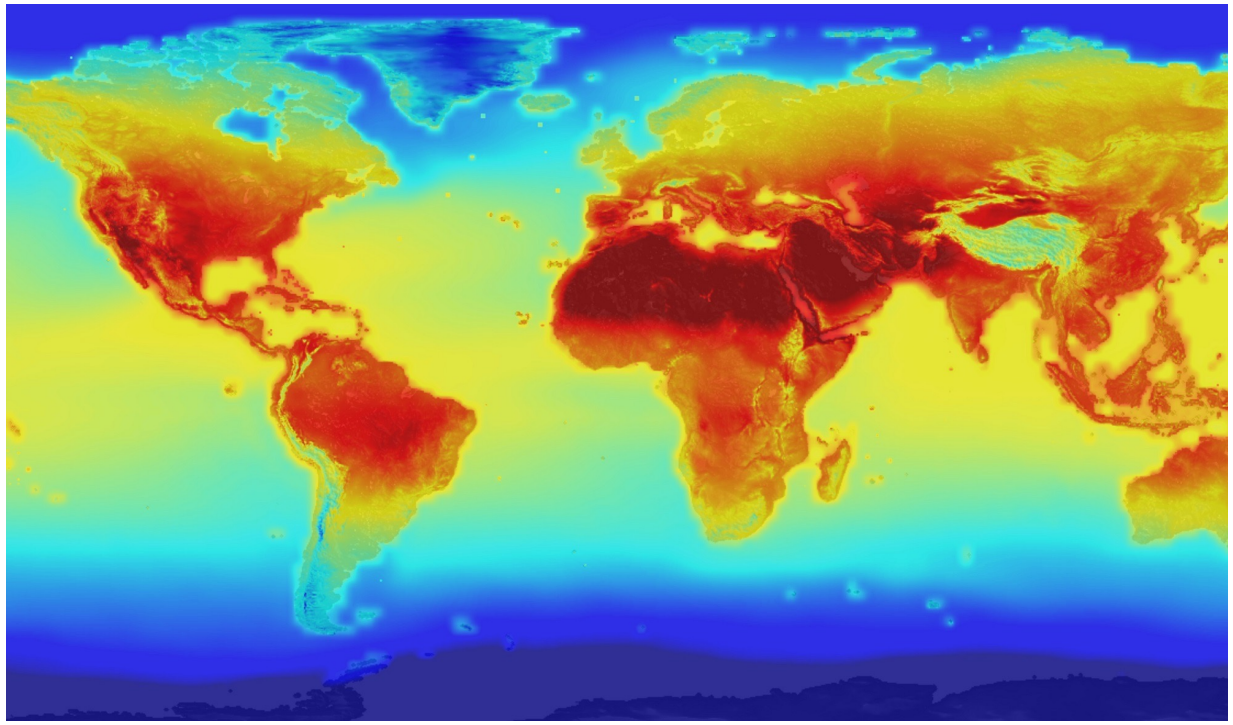
Health impacts

- Allergies
- Pregnancy and newborn complications
- Heart and lung disease
- Risks for children
- Dehydration
- Kidney disease
- Heat stroke
- Skin disease
- Digestive illnesses
- Mental health conditions
- Neurologic disease
- Nutrition
- Trauma
- **Infectious diseases**

Climate change primer



Rebecca Lindsey and LuAnn Dahlman. Climate Change: Global Temperature. Climate.gov.

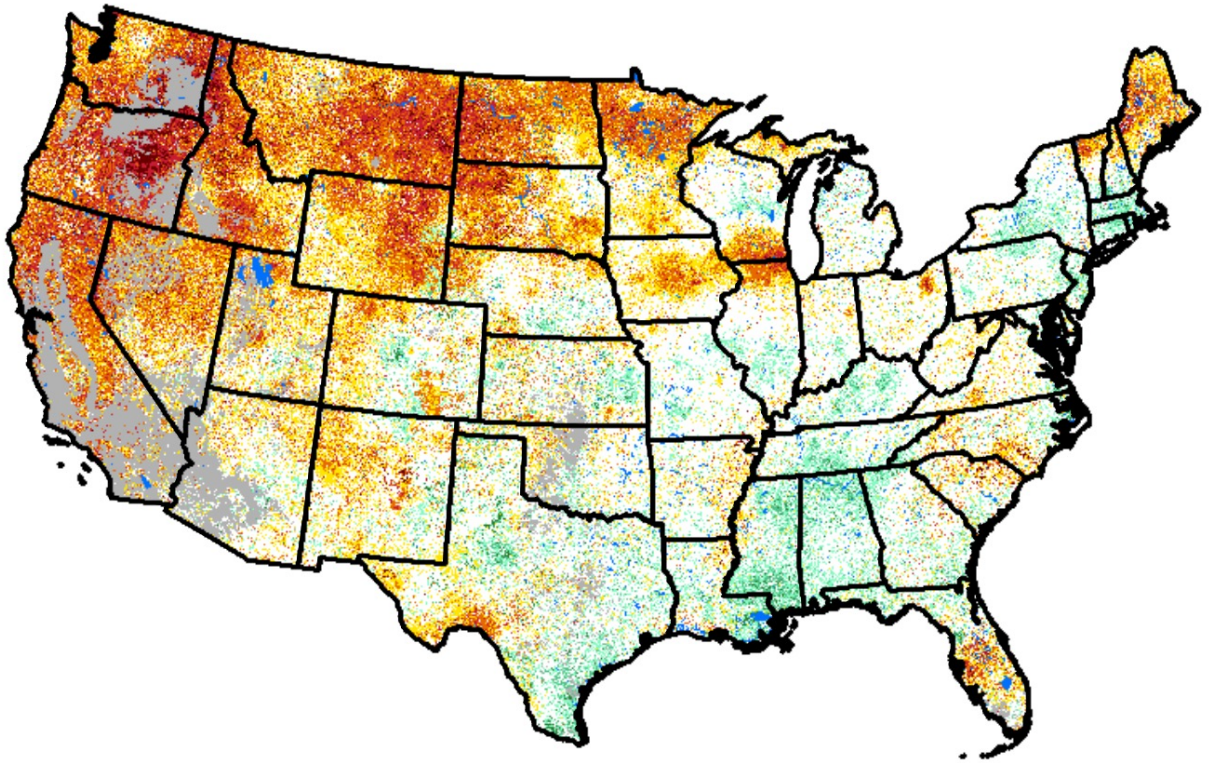


NASA, Global Climate Change: Vital signs of the planet

Extreme weather events

NASA, Global Climate Change: Vital signs of the planet

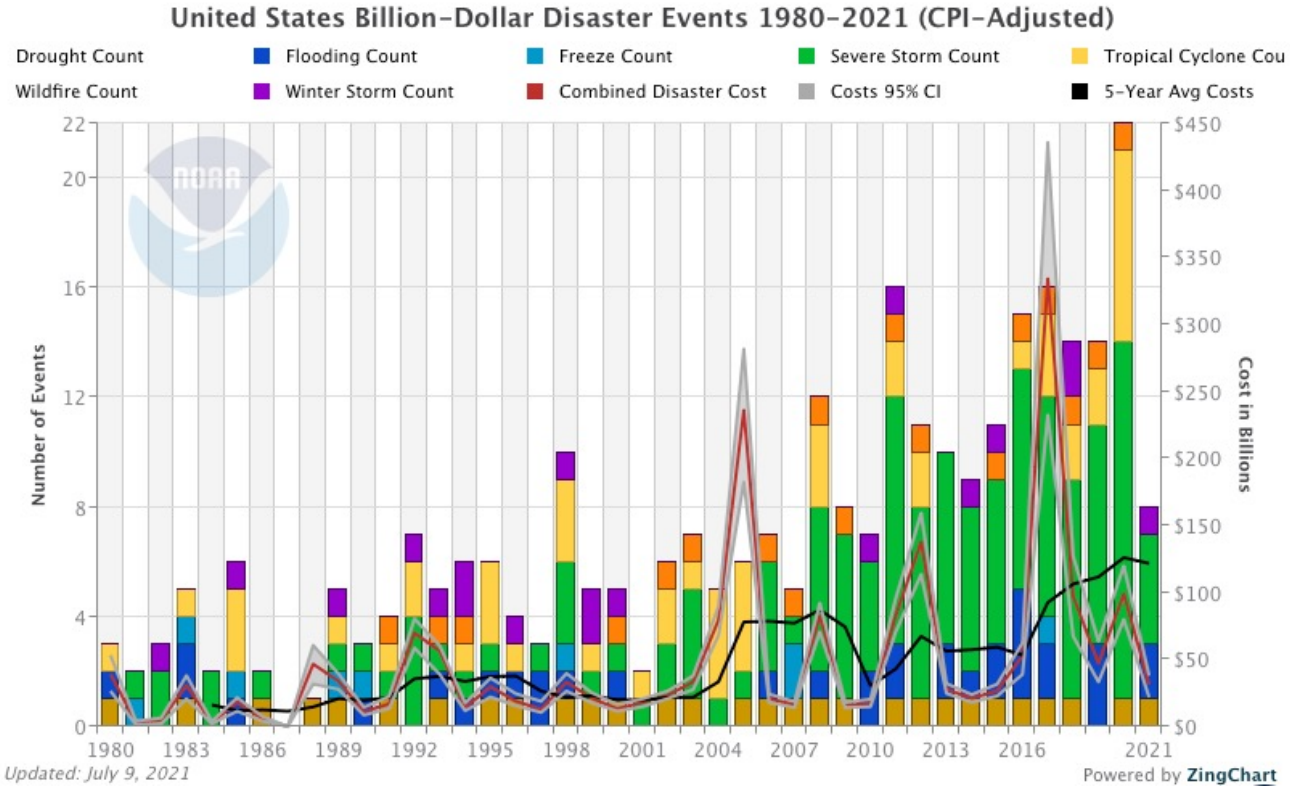
Vegetation condition



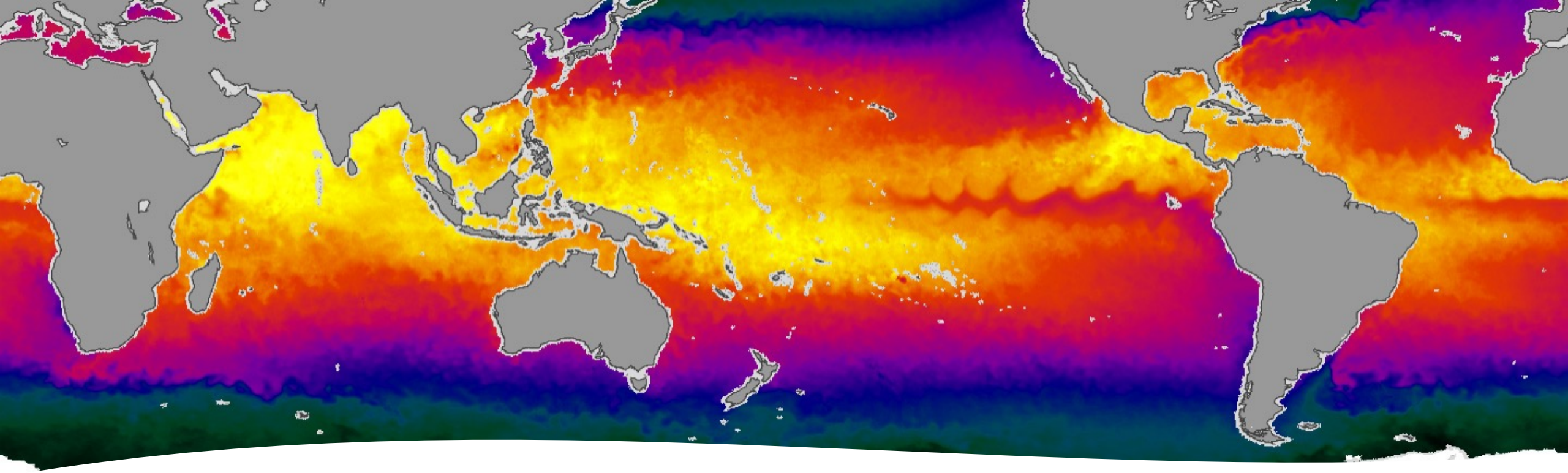
Vegetation Drought Response Index (VegDRI)

US Billion-Dollar Disaster Events 1980-2021

- 298 billion-dollar disasters since 1980
- 22 in 2020 alone
  - Record-breaking wildfire season in CA
    - >10M acres of land burned, twice the previous 2018 record



NOAA. National Centers for Environmental Information.



Water

- Temperature
- Salinity
- Currents
- Seasonality patterns

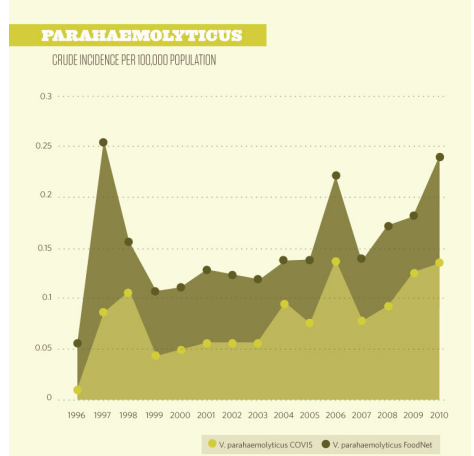
- Water-borne infections
  - Ingestion, inhalation, direct inoculation

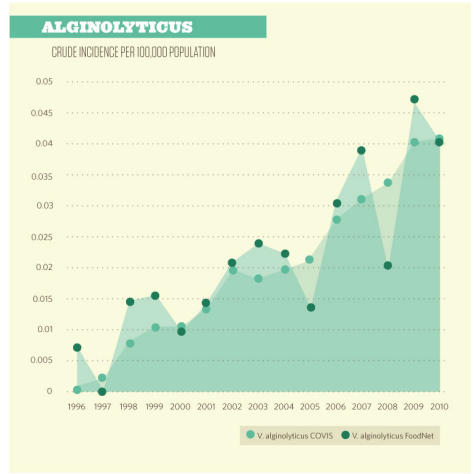
Vibrio spp.

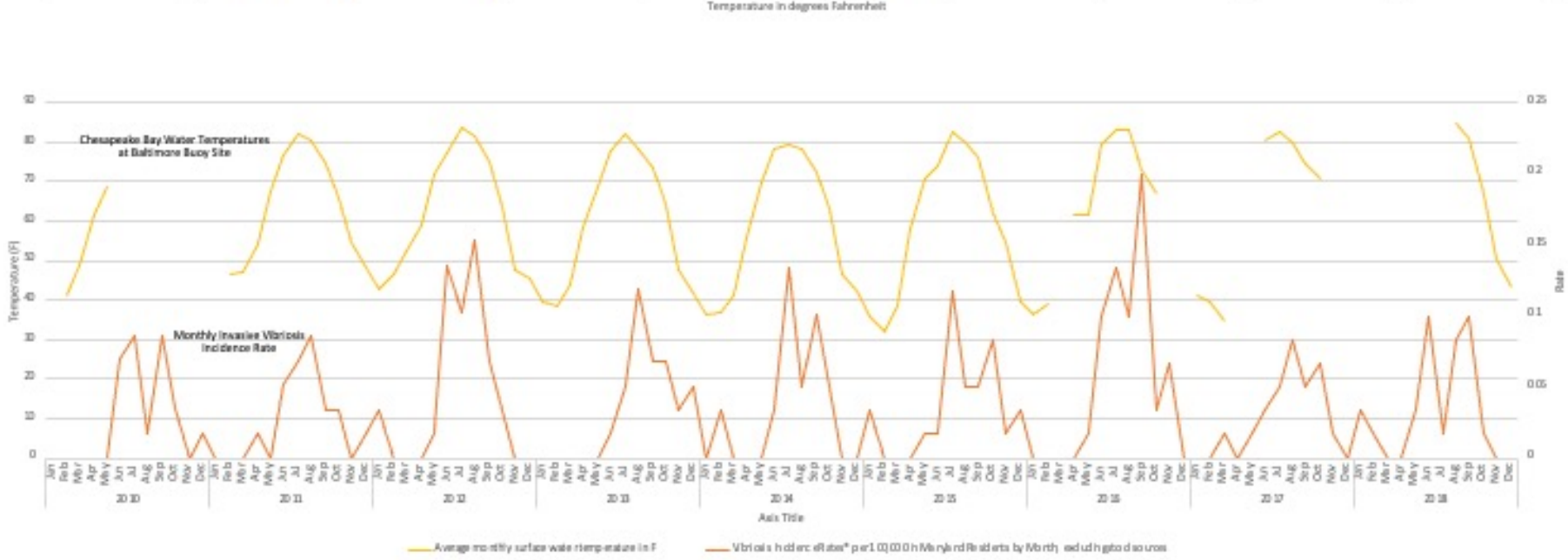
- Sea surface temperatures are associated with the abundance, geographic distribution, and duration of risk of *Vibrio* spp. infections
- V. cholerae
- Non-cholera Vibrio
  - V. parahaemolyticus
  - V. vulnificus
  - V. alginolyticus
- GI infection via ingestion, wound infection via direct inoculation
- 80,000 illnesses and $300 million in the US each year

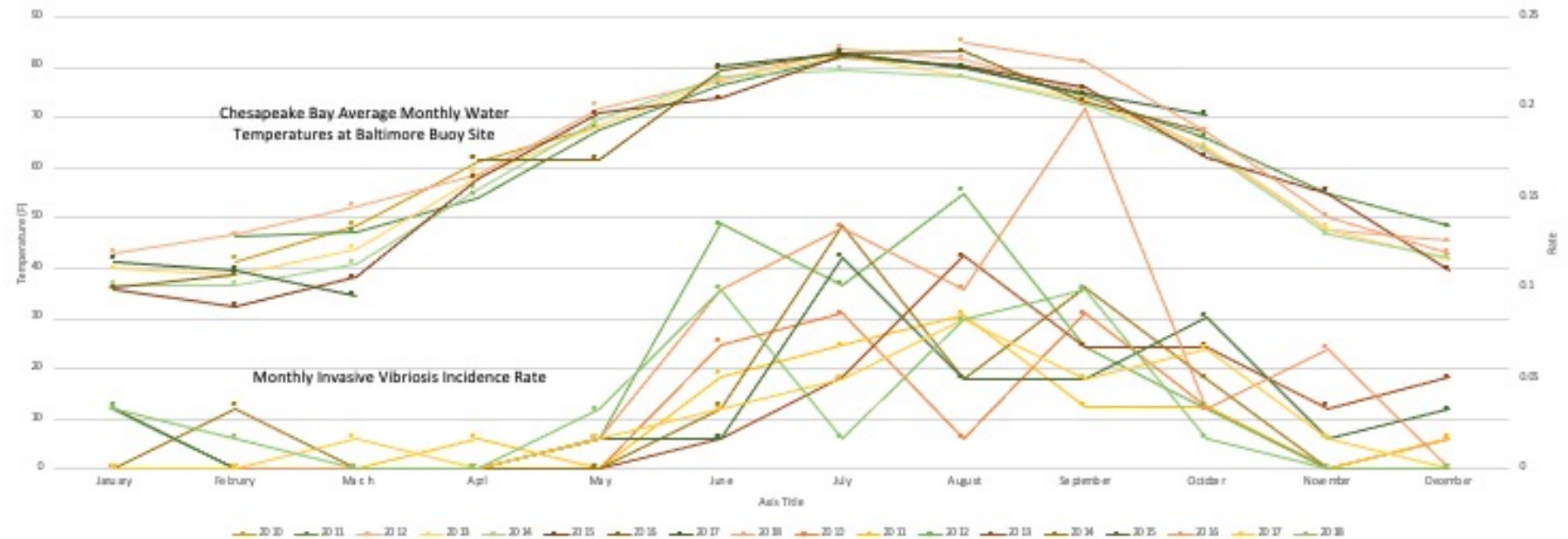
Vibrio spp.

- Coastal and estuarine water – warm and brackish
- Gulf Coast, Mid-Atlantic, Northeast, Washington, Hawaii
- 15yr increase in vibriosis incidence from 1996-2015
- Warming sea surface temperatures associated with increased incidence of V. vulnificus
- Prolonged warm sea surface temperatures associated with longer detection period for V. vulnificus and parahaemolyticus
- Broader salinity tolerance with higher temperatures



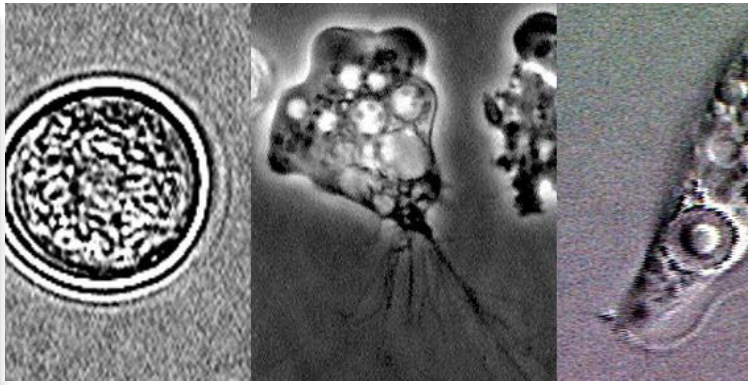


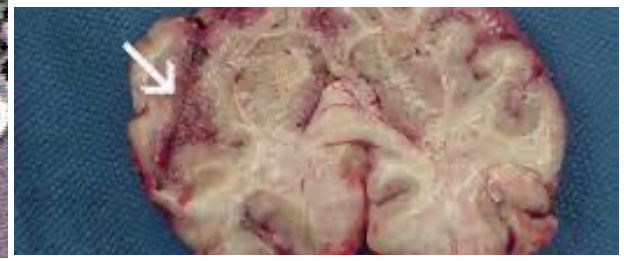

Temperature in degrees Fahrenheit
Chesapeake Bay Water Temperatures at Baltimore Buoy Site
Monthly Invasive Vibriosis Incidence Rate
Temperature (F)
Rate
2010
2011
2012
2013
2014
2015
2016
2017
2018
Axis Title
Average monthly surface water temperature in F
Vibriosis Incidence Rate* per 100,000 Maryland Residents by Month exclusive of food sources

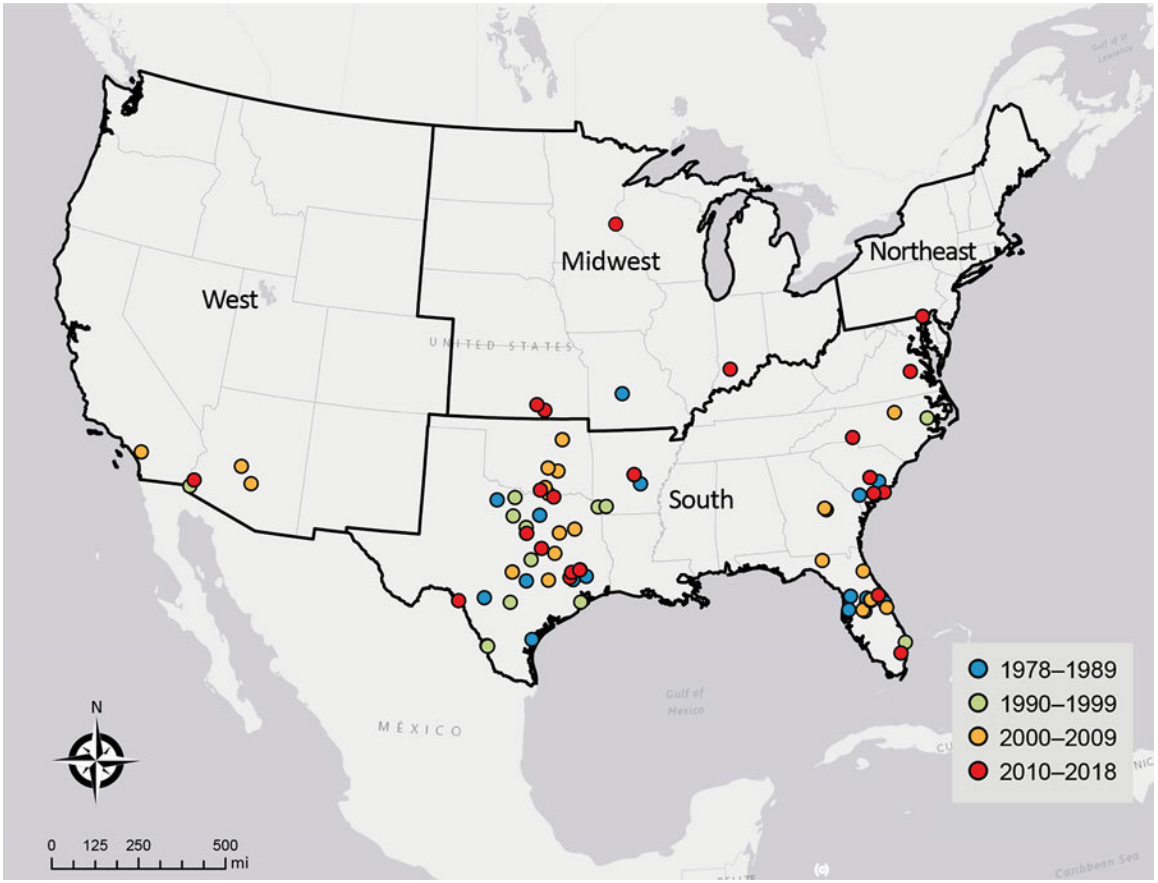

Chesapeake Bay Average Monthly Water Temperatures at Baltimore Buoy Site
Monthly Invasive Vibriosis Incidence Rate
Temperature (F)
Rate
January
February
March
April
May
June
July
August
September
October
November
December
Axis Title

Naegleria fowleri

- Cause of primary amebic meningoencephalitis
- About 8 cases/year in the US
- The ameba is found in soil and freshwater
- 1937-2013
  - 142 cases across 18 states primarily in the southeast
  - 4 northernmost cases identified in or after 2010
- 1978-2010:
  - 6 out of 7 northernmost cases all occurred after 2010
- 13.3km shift northward each year

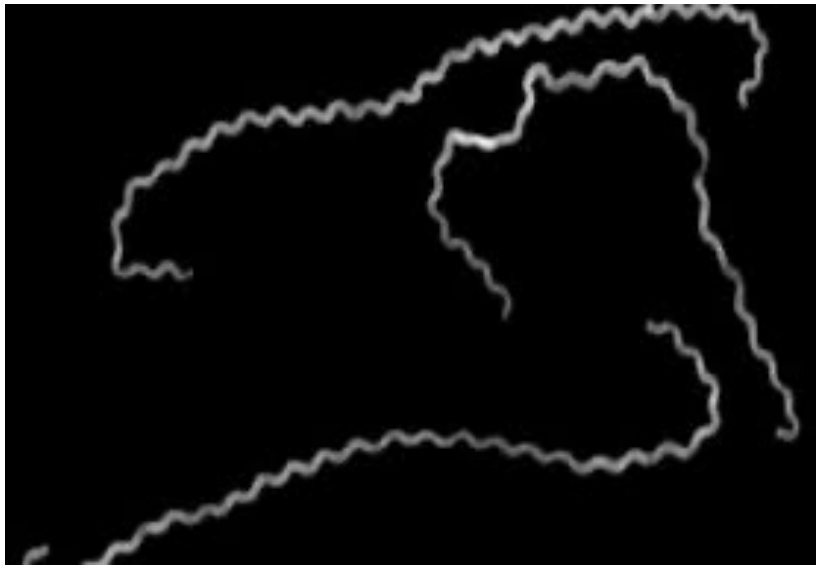






Leptospira interrogans

- Spirochetal bacterium
- Contact with/ingestion of animal urine
- Asymptomatic infection to flu-like syndrome to MOF
- Hawaii 2004
  - Heavy rains flooded the University of Hawaii campus
  - 2 cases among those exposed to the standing flood water



Soil and Plant Biota

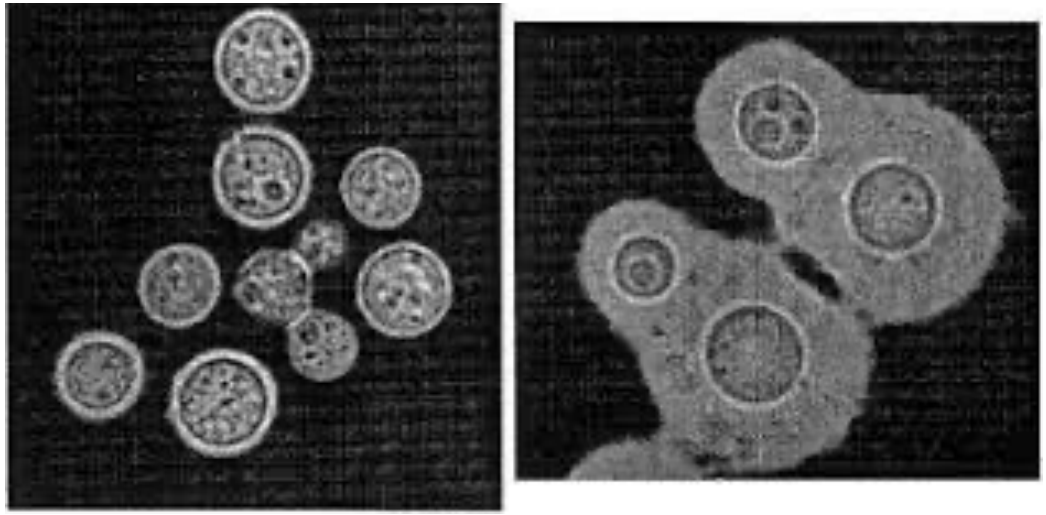
- Soil- and plant-dwelling pathogenic microbes
- Human infectious diseases
- Agricultural crop infectious diseases

Fusarium spp.

- Crop infections
- Occur with warmer weather conditions
- Mycotoxins
- Contaminate food crops
- Acute toxic effects
- Cancer

Cryptococcus gattii

- Wood and soil reservoirs
- Inhalation of spores followed by dissemination
- First identified in Vancouver Island, Canada in 1999
- Sunny, moderate temperature, above-freezing winters
- Melanization in response to environmental stress
- Associated with increased temperature tolerance (heat and cold)
- Now found in WA, OR, CA, ID



Candida auris?

- Climate-relate changes + increased human contact
- Microbial evolution
- Geographic redistribution
- Curtobacterium studies
  - Rapid shifts in:
    - Community composition
    - Individual abundance
    - Phenotypic changes
    - Genotypic changes

Air

- Longer fire seasons
- Longer droughts
- Inhalation of microbes
- Infections of burns

Wildfires and human health

The NEW ENGLAND JOURNAL of MEDICINE

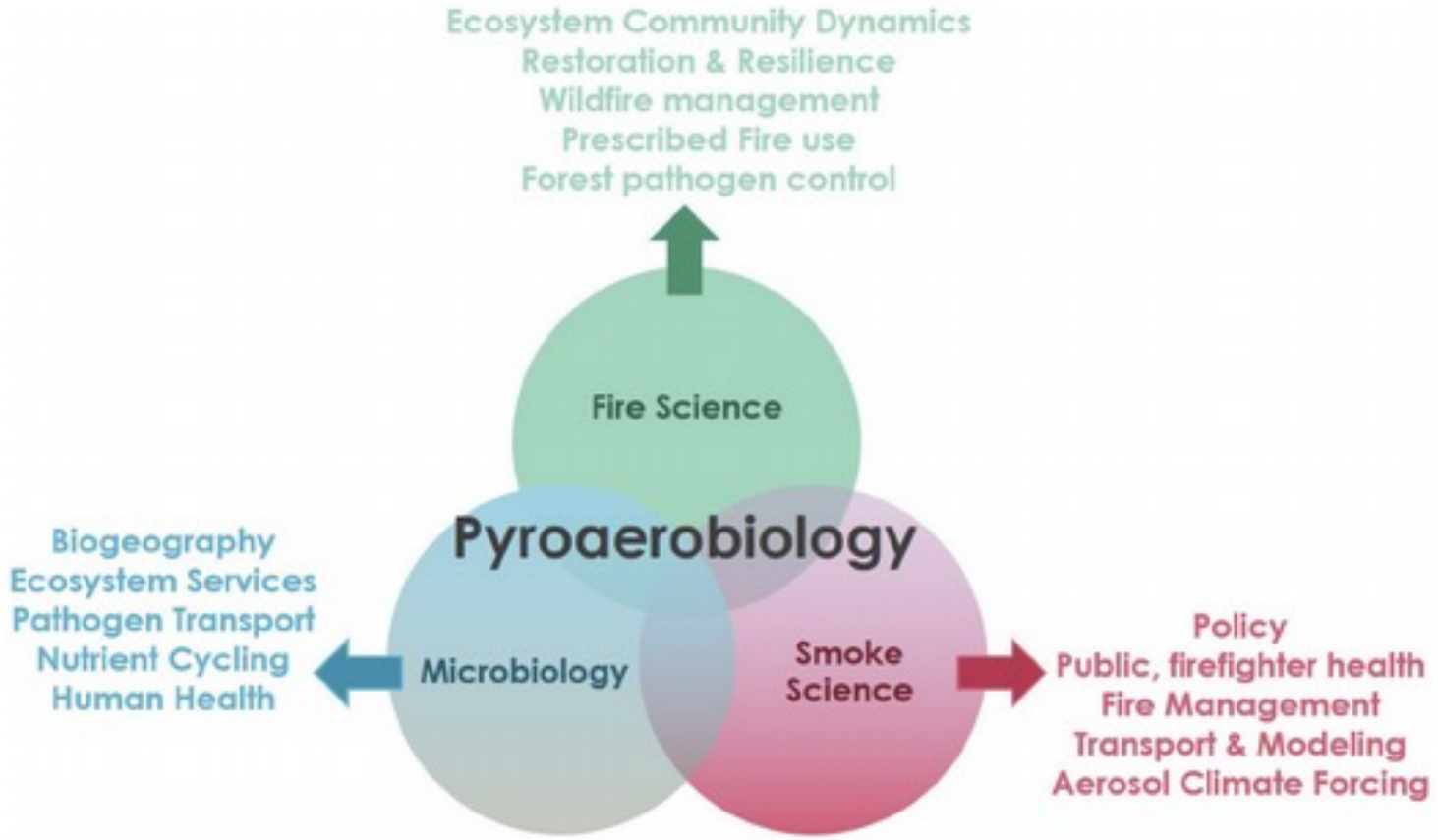
SPECIAL REPORT

Wildfires, Global Climate Change, and Human Health

Rongbin Xu, M.B., B.S., Pei Yu, M.B., B.S., Michael J. Abramson, M.B., B.S., Ph.D., Fay H. Johnston, B.M., B.S., Ph.D., Jonathan M. Samet, M.D., Michelle L. Bell, Ph.D., Andy Haines, M.B., B.S., M.D., Kristie L. Ebi, Ph.D., M.P.H., Shanshan Li, M.D., Ph.D., and Yuming Guo, M.D., Ph.D.

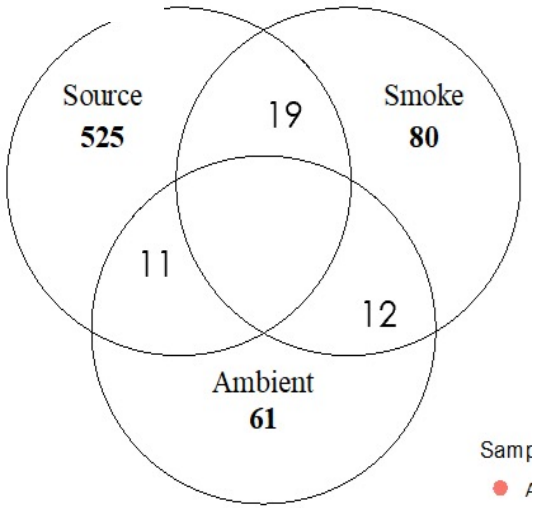
MB Rongbin Xu et al. 2020. Wildfires, global climate change, and human health. NEJM 2020; 383:2173-2181.

Wildfires change atmospheric ecology

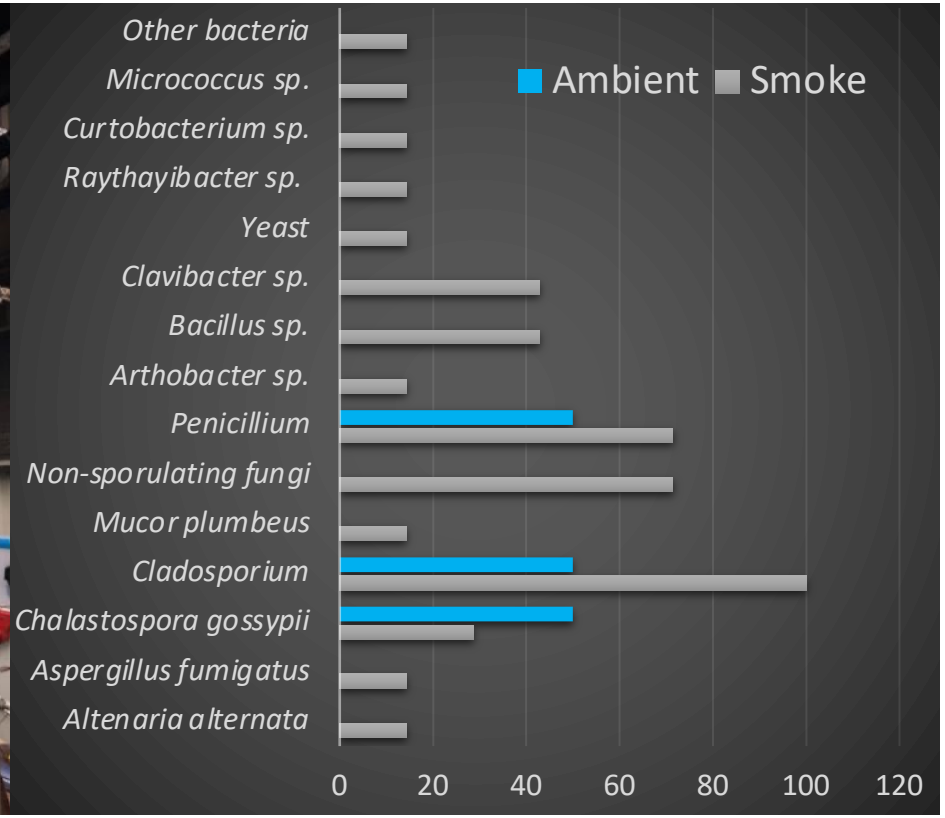


Kobziar, L. N., Pingree, M. R. A., Larson, H., Dreaden, T. J., Green, S., and Smith, J. A.. 2018. Pyroaerobiology: the aerosolization and transport of viable microbial life by wildland fire. Ecosphere 9(11):e02507. [10.1002/ecs2.2507](10.1002/ecs2.2507)

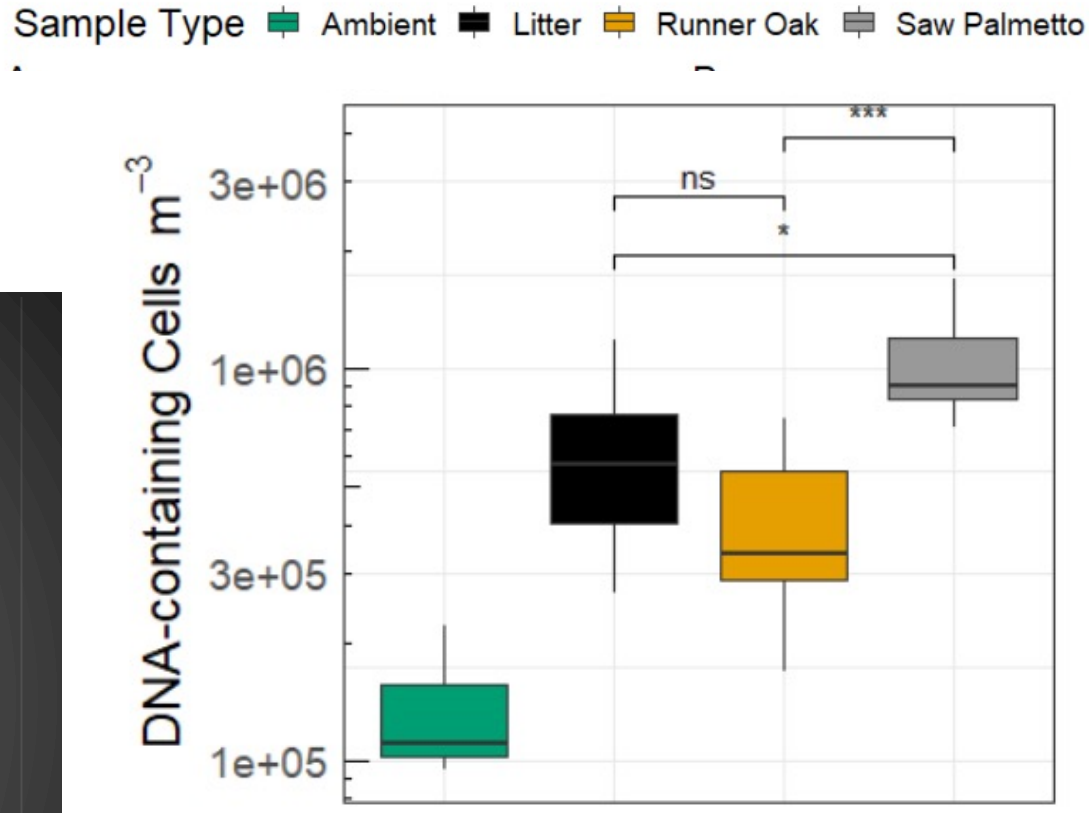
Inoculation



Lab isolations



Comparisons among fuel types



Moore, Bomar, Kobziar, Christner. 2020. Wildland fire as an atmospheric source of viable bioaerosols and biological ice nucleating particles. ISME Multidisciplinary Journal of Microbial Ecology.

Is Exposure to Wildfires Associated with Invasive Fungal Infections?

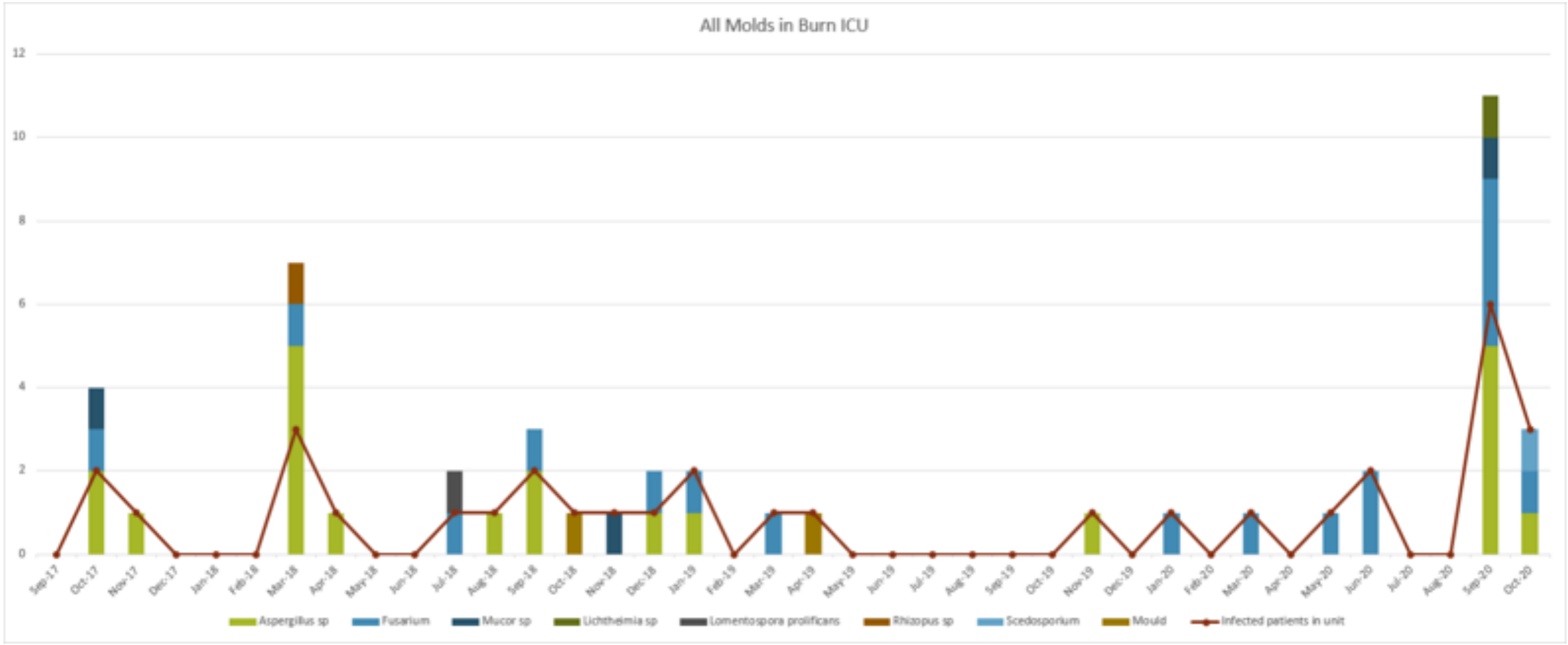
J. S. Mulliken[1], A. G. Rappold[2], M. Fung[1], J. M. Babik[1], S. B. Doernberg[1]

[1]Division of Infectious Diseases, University of California San Francisco, San Francisco, CA,
[2]National Health and Environmental Effects Research Laboratory, United States Environmental Protection Agency, Durham, NC

Table I: Incidence rate ratios (95% CI) for IFI admissions by wildfire exposure and season

	Large wildfire within 200 miles (compared to months with no fire)	Fall season (compared to Summer)
Invasive mold	1.18 (1.11-1.25)	1.24 (1.15-1.33)
Aspergillosis	1.22 (1.11-1.32)	1.35 (1.21-1.50)
Coccidioidomycosis	1.22 (1.07-1.40)	1.36 (1.14-1.62)
Invasive *Candida*	1.03 (0.90-1.18)	1.01 (0.85-1.20)

JS Mulliken et al. Is Exposure to Wildfires Associated with Invasive Fungal Infections? [abstract]. Am J Transplant. 2019; 19 (suppl 3). Accessed May 11, 2021.


All Molds in Burn ICU
12
10
8
6
4
2
0
Sep-17
Oct-17
Nov-17
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Augl-18
Sep-18
Oct-18
Nov-18
Dec-18
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Augl-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Augl-20
Sep-20
Oct-20
Aspergillus sp
Fusarium
Mucor sp
Lichtheimia sp
Lomentospora prolificans
Rhizopus sp
Scedosporium
Mould
Infected patients in unit

Microbiology of wildfire victims differs significantly from routine burns patients: Data from an Australian wildfire disaster

Norelle L. Sherry [a,b], Alexander A. Padiglione [a,c,*], Denis W. Spelman [a,b], Heather Cleland [c]

[a] Department of Infectious Diseases, Alfred Hospital, Prahran, Victoria, Australia
[b] Department of Microbiology, Alfred Hospital, Australia
[c] Victorian Adult Burns Service, Alfred Hospital, Australia

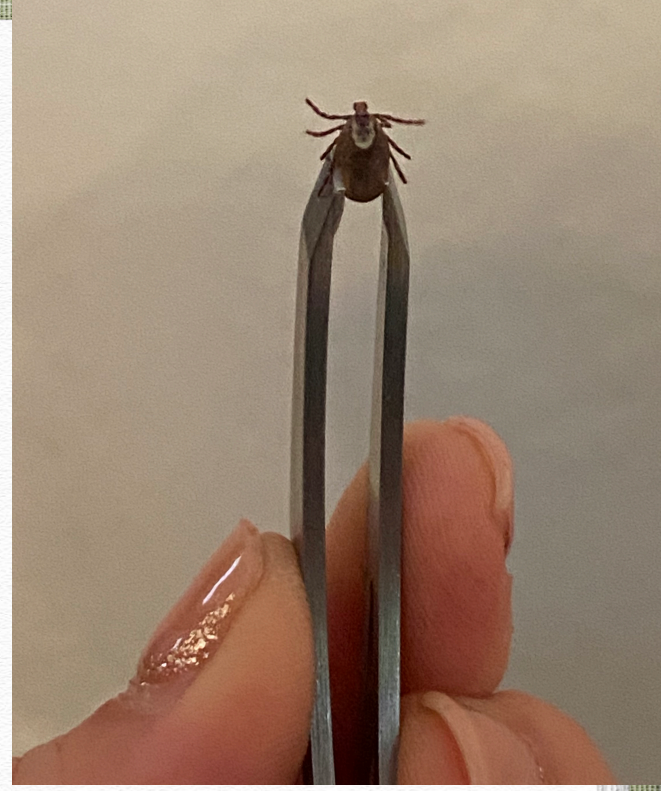
No. patients with any positive culture (respiratory or wound) at 72 h	10 (56%)	7 (19%)	0.04
Wound cultures			
No. patients with positive wound culture at 72hrs	7 (39%)	7 (19%)	0.18
Monomicrobial	5 (71%)	3 (8%)	
Polymicrobial	2 (29%)	4 (11%)	0.59
Gram positives	2 (15%)	9 (75%)	
Gram negatives	11 (85%)	3 (25%)	0.005
Respiratory cultures			
No. patients with positive respiratory culture at 72 h	4 (22%)	3 (8%)	0.21
Monomicrobial	2 (50%)	1 (33%)	
Polymicrobial	2 (50%)	2 (66%)	1
Gram positives	3 (50%)	2 (40%)	
Gram negatives	3 (50%)	3 (60%)	1

NL Sherry et al. Microbiology of wildfire victims differs significantly from routine burns patients: Data from an Australian wildfire disaster, Burns, Volume 39, Issue 2, 2013, Pages 331-334.

Insect vectors

- Anthropogenic change
- Extreme weather events
- Habitats
- Geographic distribution

Any idea what kind of tick this is?



Is that a tick?

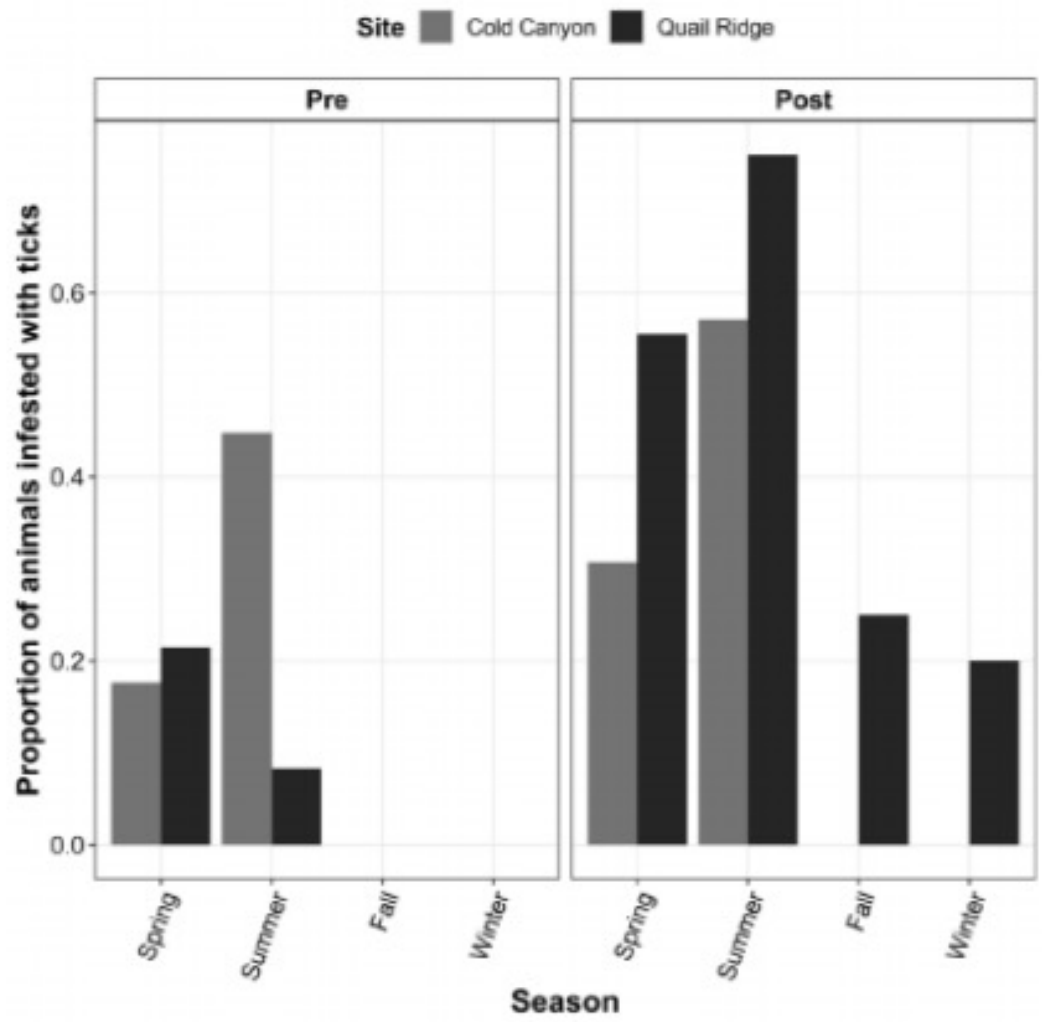
Lyme disease

- Most prevalent vector-borne disease in the US
- Endemic to the Northeast and Midwest
- Caused by Borrelia burgdorferi
- Transmitted by Ixodes ticks
- Early disease defined by bullseye rash
- Identified in the US in the 1970s
- Identified in Canada in 2004
- Geographic range of the tick vector and reservoir host (white-footed mouse) are expanding northward with warming climate

Response of small mammal and tick communities to a catastrophic wildfire and implications for tick-borne pathogens

Emily L. Pascoe, Benjamin T. Plourde, Andrés M. Lopéz-Perez, and Janet E. Foley✉

Tick species	Percentage of ticks collected			
	Cold Canyon		Quail Ridge	
	Pre	Post	Pre	Post
***Ixodes* spp.**	**100% (n=42)**	**55.81% (n=24)**	**87.50% (n=7)**	**31.25% (n=45)**
Ixodes pacificus	59.52 % (n=25)	41.86% (n=18)	75.00% (n=6)	28.47% (n=41)
Ixodes spinipalpis	2.38% (n=1)	0%	12.50% (n=1)	0%
Ixodes woodi	38.10% (n=16)	6.98% (n=3)	0%	0%
Unidentified *Ixodes* sp.	0%	6.98% (n=3)	0%	2.78% (n=4)
***Dermacentor* spp.**	**0%**	**44.19% (n=19)**	**12.5% (n=1)**	**68.75% (n=99)**
Dermacentor occidentalis	0%	44.19% (n=19)	0%	68.06% (n=98)
Dermacentor variabilis	0%	0%	12.5% (n=1)	0%
Unidentified *Dermacentor* spp.	0%	0%	0%	0.69% (n=1)



Wildfires change host ecology

Table 2. Numbers of each small mammal species trapped before and after the Wragg Fire in 2015 which burned Stebbins Cold Canyon Reserve in northern California, compared with nearby Quail Ridge Reserve, a control site that did not burn. Number of captures includes all successful trap events, including animals that may have been recaptured. Individuals were distinguished from all captures by the presence of uniquely numbered metal eartags and only counted once.

	Pre-fire		**Post-fire**	
	CC	**QR**	**CC**	**QR**
Number of captures	**120**	**37**	**371**	**67**
Microtus californicus	0	0	12	1
Mus musculus	0	0	20	0
Neotoma fuscipes	120	37	7	2
Peromyscus species	0	0	332	64
Number of individuals (% of all captures)	**85**	**24**	**291**	**53**
Microtus californicus	0	0	12 (4.12%)	1 (1.89%)
Mus musculus	0	0	20 (6.87%)	0
Neotoma fuscipes	85 (100%)	24 (100%)	5 (1.72%)	2 (3.77%)
Peromyscus species	0	0	254 (87.29)	50 (94.34%)
Mean recapture rate (range of number of recaptures)	**1.41 (1–3)**	**1.54 (1–3)**	**1.27 (1–4)**	**1.26 (1–4)**
Microtus californicus	0	0	1 (1)	1 (1)
Mus musculus	0	0	1 (1)	0
Neotoma fuscipes	1.41 (1–3)	1.54 (1–3)	1.40 (1–2)	1 (1)
Peromyscus species	0	0	1.31 (1–4)	1.28 (1–4)

Population displacement

- In 2019, 33.4M people were displaced worldwide
- 23.9M were displaced due to weather-related events
- Floods, hurricanes, fires often associated with temporary movement
- Droughts and famines may lead to more permanent relocation
- Temperature extremes and natural disasters may be associated with food insecurity and changes in infectious disease epidemiology

Overcrowding in shelters and camps

- 2005, Hurricane Katrina
- 27,000 people were evacuated from LA to a single shelter in Houston, TX
- Within 2 weeks, >1,000 people developed gastroenteritis
- Half of the people tested positive for Norovirus

Long-term health impacts

- Delayed or missed diagnoses
- Changing ID epidemiology
- Missed routine childhood vaccinations

- Doubled rate of gonorrhea among high school students after Katrina
- 25% decreased rate of HIV screening during Hurricane Sandy, 2012

Extreme weather events and COVID-19

- February 2021 TX snowstorms
  - Delayed delivery of around 1 million

  COVID-19 vaccines, >700k to TX

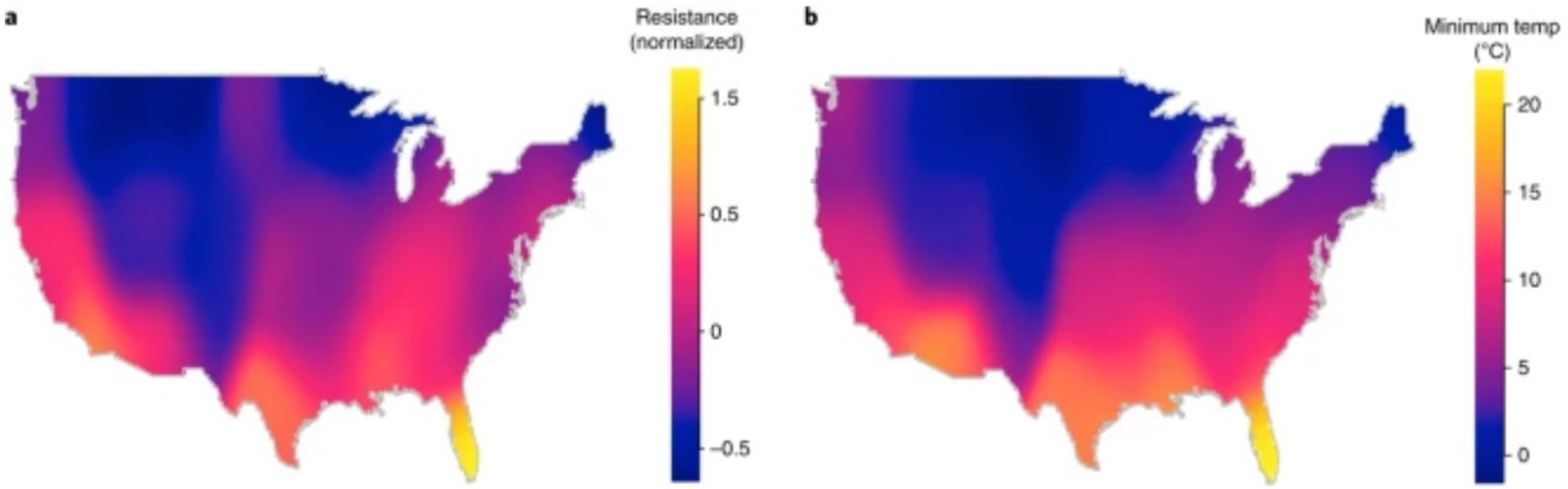
- Fall 2020 NV wildfires
  - “A 10ug/m3 increased in the 7-day average PM2.5 concentration was associated with a 6.3% relative increase in the SARS CoV2 test positivity rate”
  - “corresponded to an estimated 17.7% increase in the number of cases during the time period most affected by wildfire smoke”

D. Kiser et al. SARS-CoV-2 test positivity rate in Reno, Nevada: association with PM2.5 during the 2020 wildfire smoke events in the western United States, Journal of Exposure Science & Environmental Epidemiology, 2021, 31, 797-803.

Antimicrobial resistance

- Possible link between climate change and AMR
- Warm temperatures
  - Increased bacterial growth
  - Increased horizontal gene transfer
- E.coli, K.peumoniae, S.aureus AMR patterns associate with increasing local temperatures

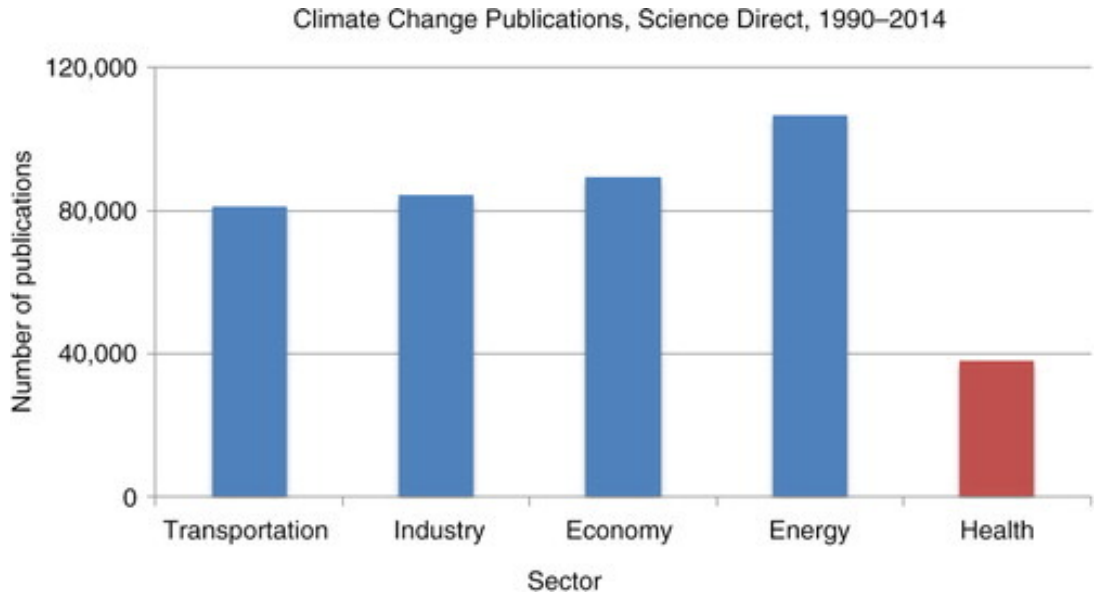
Fig. 1: Antibiotic resistance increases with increasing temperature.



DR MacFadden et al. Antibiotic resistance increases with local temperature, Nature Climate Change, Volume 8, 2018, pages 510-514.

The healthcare sector

- 5% of global greenhouse gas emissions
- 10% of domestic greenhouse gas emissions



Glenn Verner, Stefanie Schütte, Juliane Knop, Osman Sankoh & Rainer Sauerborn (2016) Health in climate change research from 1990 to 2014: positive trend, but still underperforming, Global Health Action, 9:1.