

THE EFFECT OF CLIMATE ON HEALTHCARE INFECTIONS

Martin Kiernan

Visiting Professor, University of West London

Conjoint Fellow, University of Newcastle (NSW)

Conjoint Research Fellow, Avondale University (NSW)

Twitter: @emrsa15

Hosted by Prof. Jean-Yves Maillard
Cardiff University, Wales

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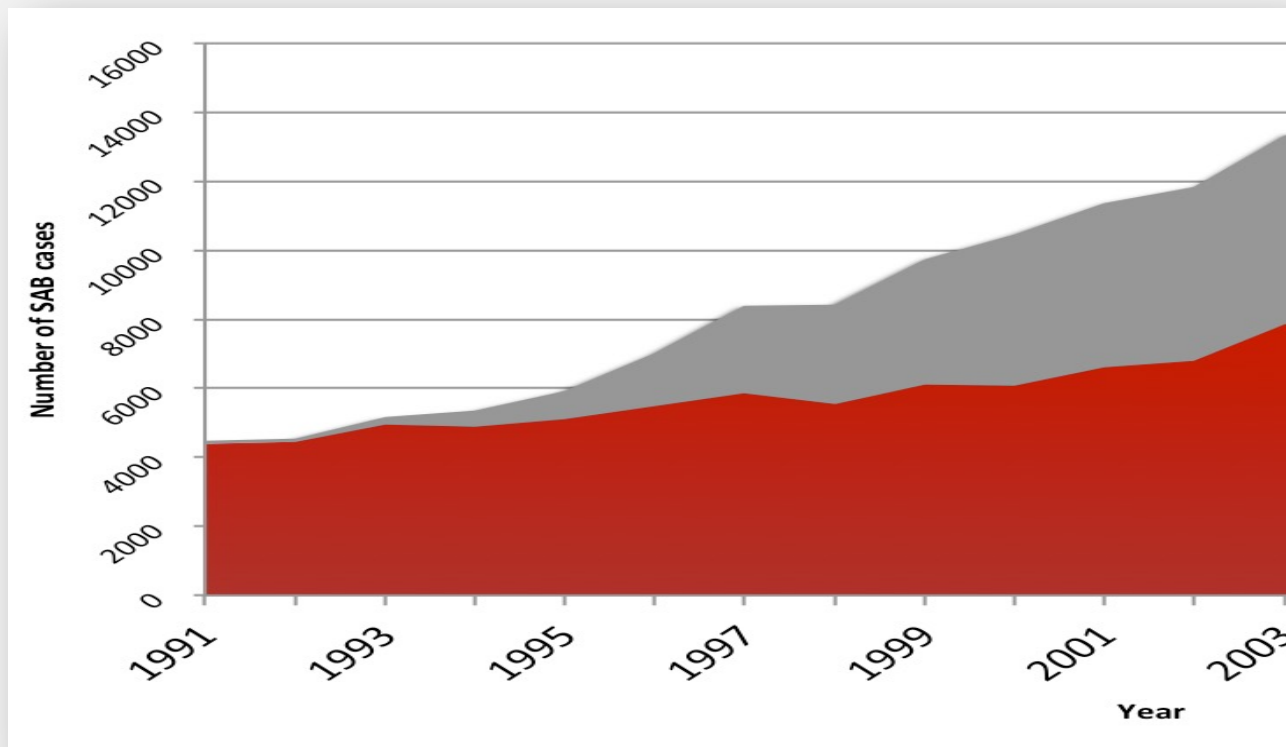
June 20, 2024

DECLARATION

- I have no financial declaration to make
- Co-host of the 'Infection Control Matters' podcast
 - www.infectioncontrolmatters.com
 - Available on Apple, Spotify and all podcast hosting sites
 - Disclaimer:
 - Caution: May cause drowsiness. Do not listen when driving or operating heavy machinery



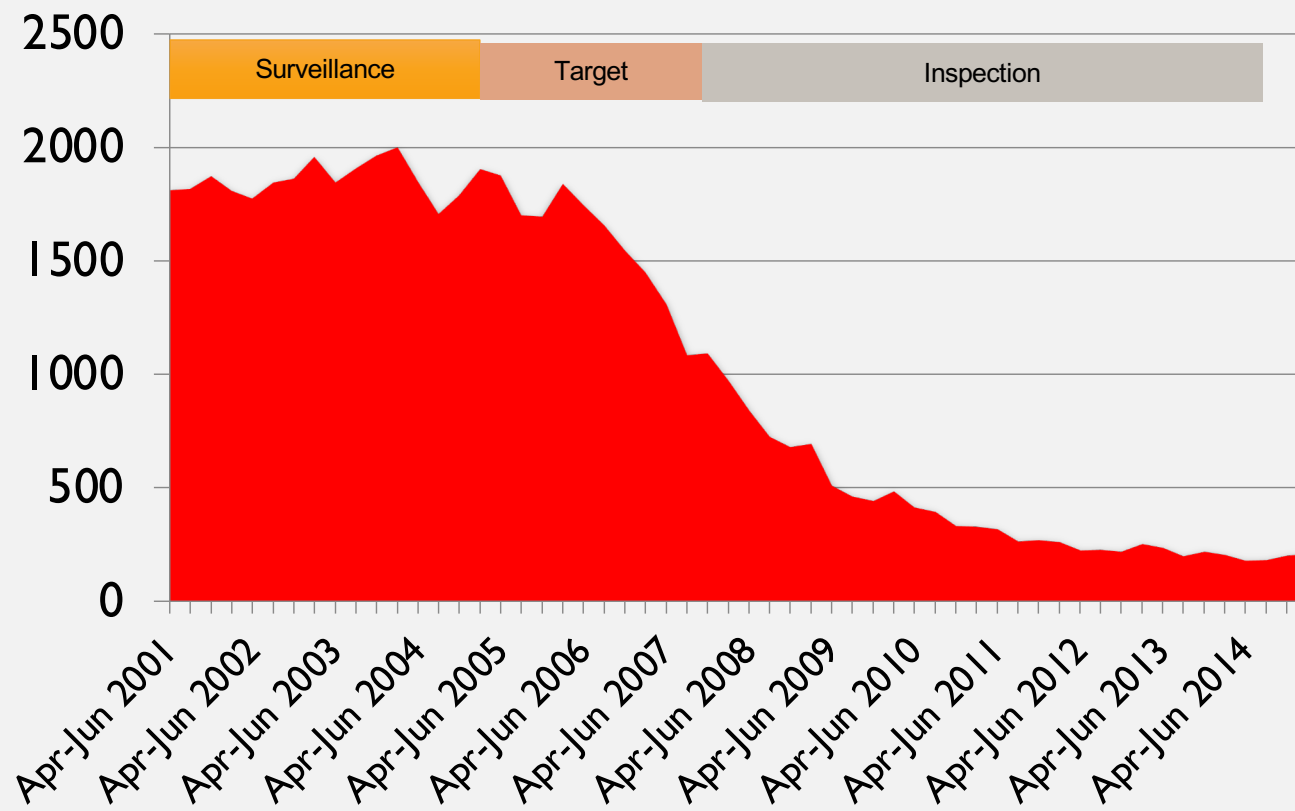
RISE OF S. AUREUS BACTERAEMIA ENGLAND 1991-2003



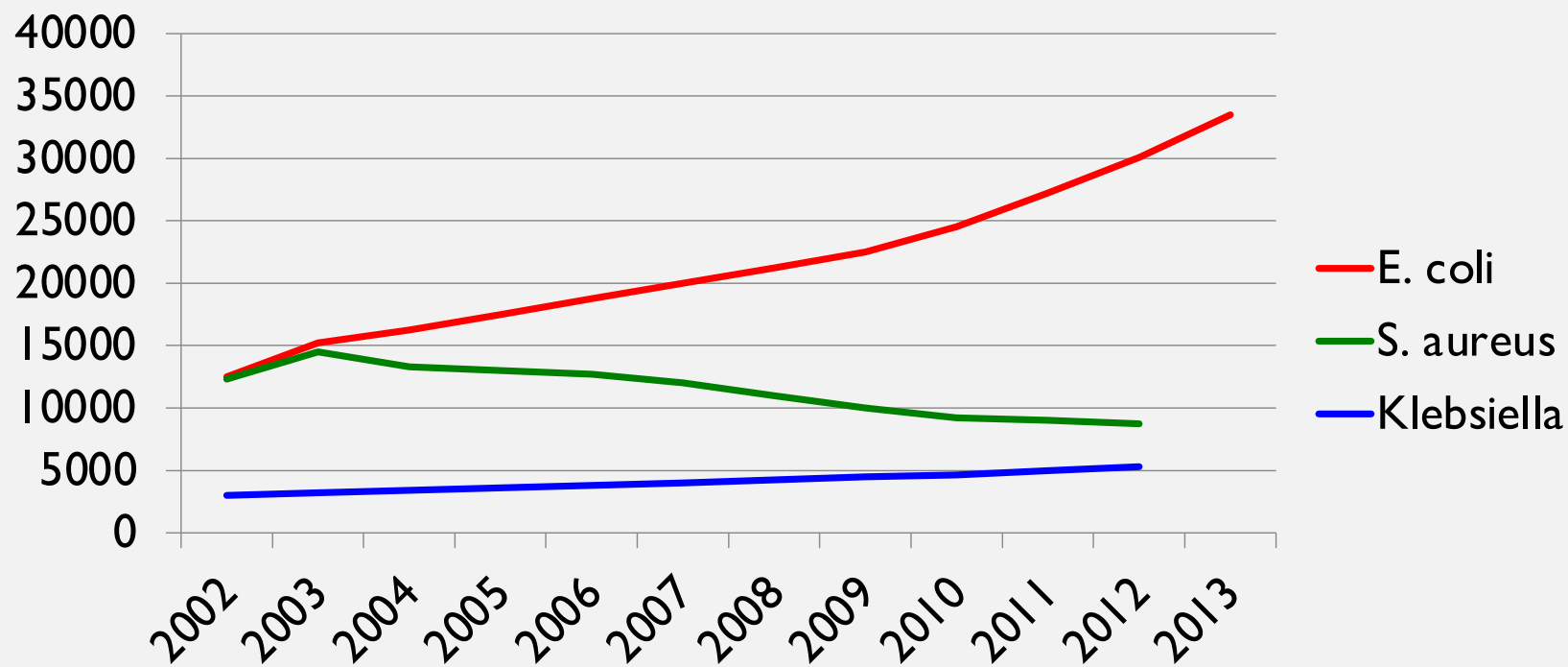
MRSA
MSSA

Slide adapted from Susan Hopkins, HPA/PHE

Quarterly MRSA Bloodstream Infections England: 2001-15



CHANGE IN BACTERAEMIA IN ENGLAND ALL REPORTS 2002-13: DATA SOURCE HPA/PHE



E. COLI BLOODSTREAM INFECTIONS WERE RISING – WHY?

- Medical device usage
 - Catheters?
- Microbial factors
 - Uropathogenic strains (ST131)?
 - Antimicrobial resistance?
- Human factors
 - Obesity/biliary stones?
 - Age?
 - Water sporting activity?
 - Sexual activity?
- Seasonal increases in contamination of food, water or environmental sources

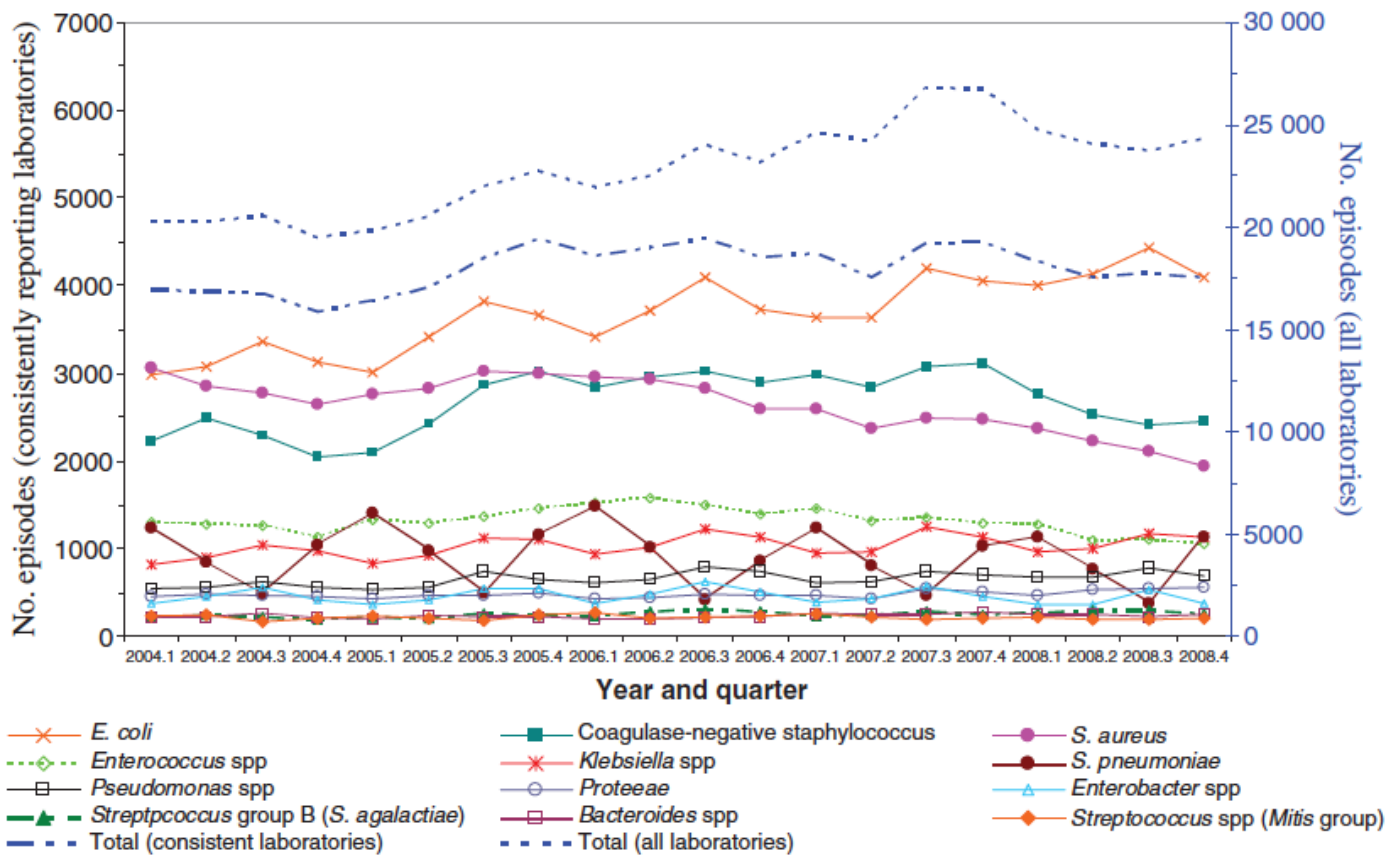


ANALYSIS OF THE ISSUES

- ARHAI Surveillance Group recommended short-term task and finish group (2013)
 - Enhanced surveillance (35 Trusts) provided a better dataset
 - Abernethy, J., et al., *Epidemiology of Escherichia coli bacteraemia in England: results of an enhanced sentinel surveillance programme*. J Hosp Infect, 2017. **95**(4): p. 365-375.
- 70% detected on admission
- Catheters 10% at most, mostly in hospitals
 - Small amount of biliary
- Most infections occur in elderly females with a GP visit in preceding 2 wks with UTI
 - 64% within previous 12 months
 - Often treated with an antibiotic to which the organism was resistant

UK DATA SUGGESTED PATTERNS

WILSON J. ET AL CLINICAL MICRO INFECT, SEPT 2010



I AM NOT

- Atmospheric Scientist
- Meteorologist
- Climatologist
- Ecologist
- Geophysicist
- Environmental Scientist
- Geochemist
- Astrophysicist
- Hydrologist
- Geographer



WEATHER VS. CLIMATE

- **Weather**
 - Short term effects relating to atmospheric conditions
 - Changeable within minutes
- **Climate**
 - Describes the prevailing weather in a region
 - Changeable over a long (or short!) timescale



WHAT IS WEATHER?

- Atmospheric conditions in a particular place at a specific time, some of which influence infections
 - Temperature
 - Precipitation
 - Humidity
 - Wind (?)
- Some don't (to the best of my limited knowledge)
 - Atmospheric Pressure
 - Cloud Cover
 - Visibility



A N
A C C O U N T

Of the Principal

Variations of the Weather,

And the Concomitant

Epidemical Diseases,

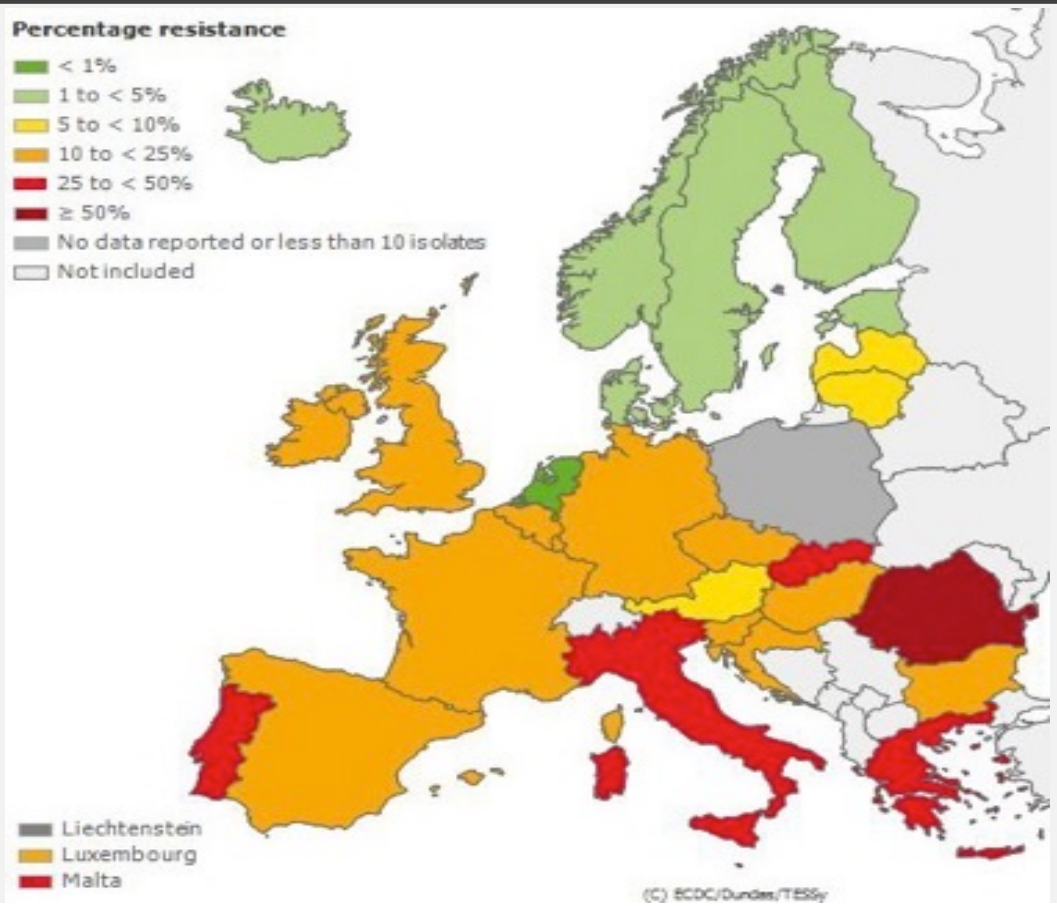
From the Year 1726, to the End
of the Year 1734.

As they appeared at *RIPPON*, and the
adjacent Parts of the County of *TORK*.

By *WILLIAM HILLARY*, M.D.
at *BATH*.

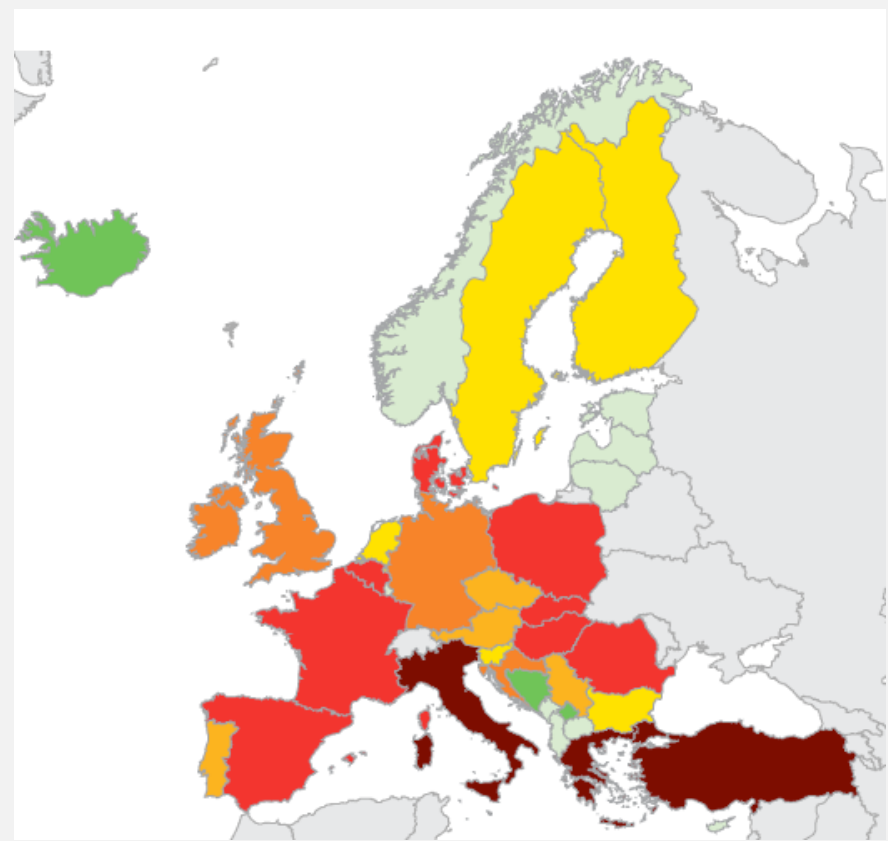
PICTURES WORTH 1,000 WORDS?

MRSA



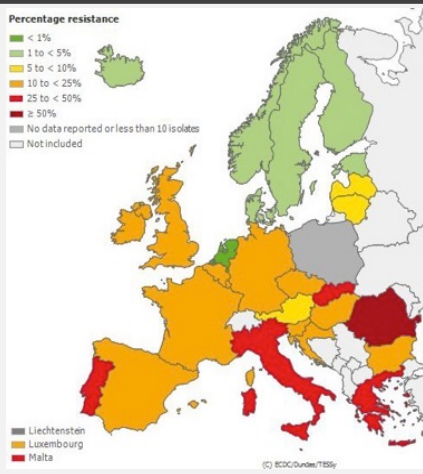
PICTURES WORTH 1,000 WORDS?

CPE

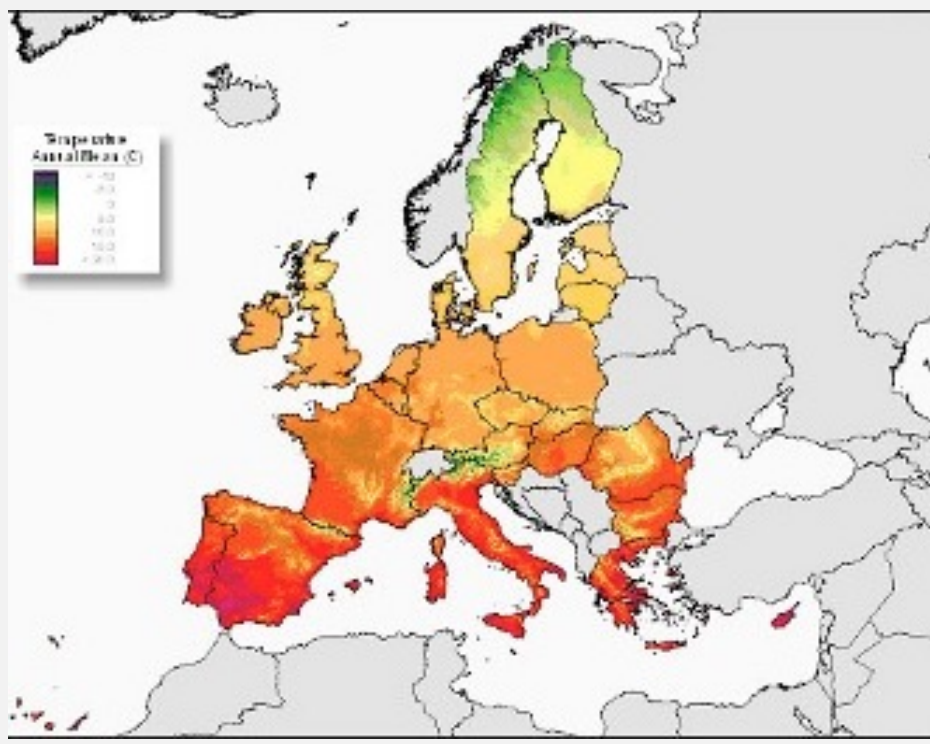
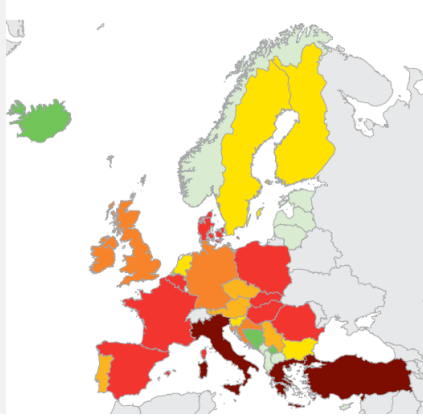


PICTURES WORTH 1,000 WORDS?

MRSA



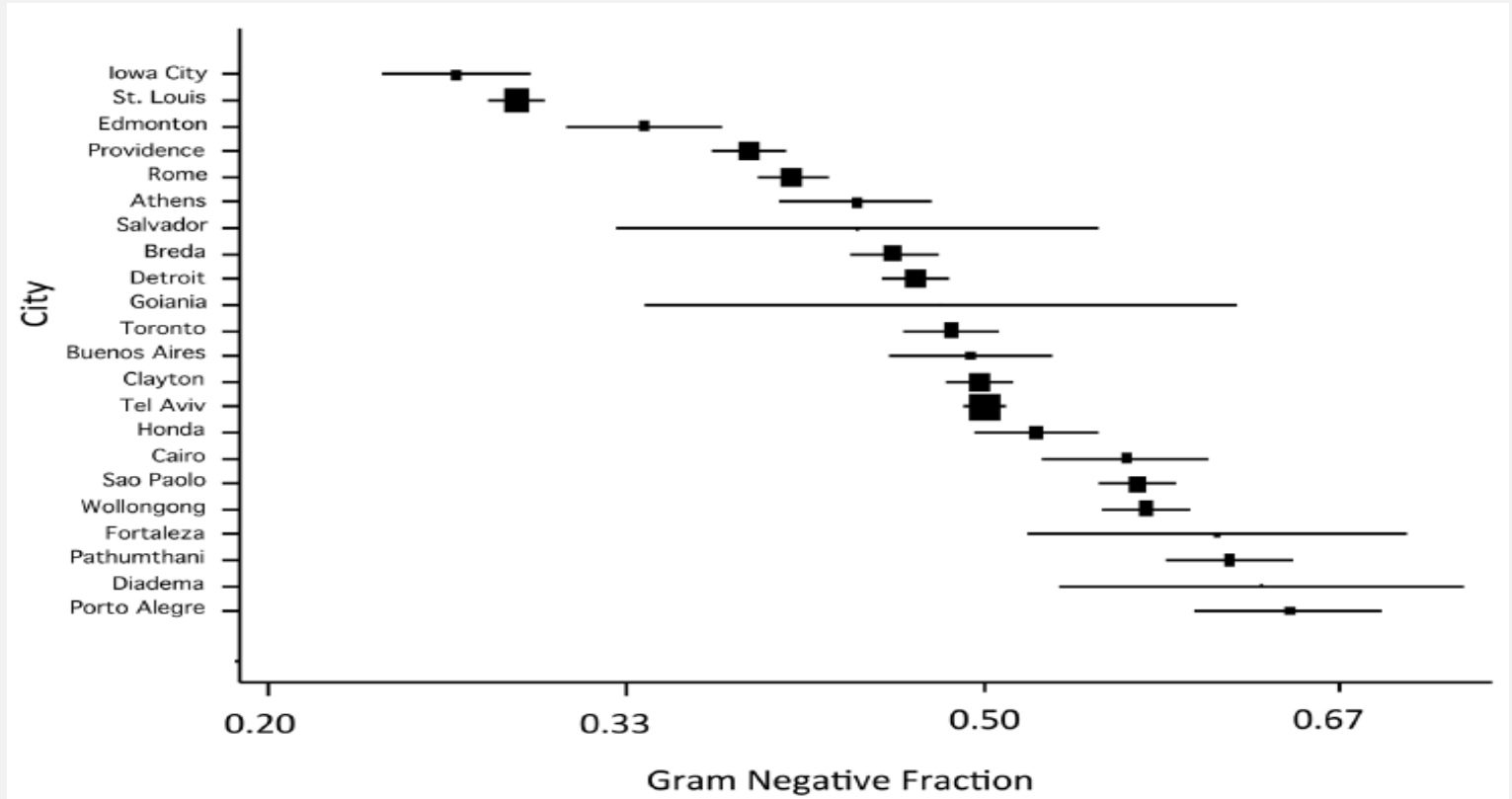
CPE



GRAM-NEGATIVE BSI AND PROXIMITY TO THE EQUATOR

- Retrospective study with 23 international centres in 22 cities
- Identified geographical, climatic and social factors associated with increases in Gram-negative BSI
 - In univariate meta-regression models, temperature, latitude, latitude squared, longitude, per capita gross domestic product (GDP) and % GDP spent on healthcare were all associated with GN BSI
 - In multivariable models, only GDP spent on healthcare and distance from the equator were significantly associated
 - Fisman D, et al. (2014) PLoS ONE 9(12): e114548

PROPORTION OF BSI CAUSED BY GNB FISMAN D, ET AL. (2014) PLOS ONE 9(12): E114548



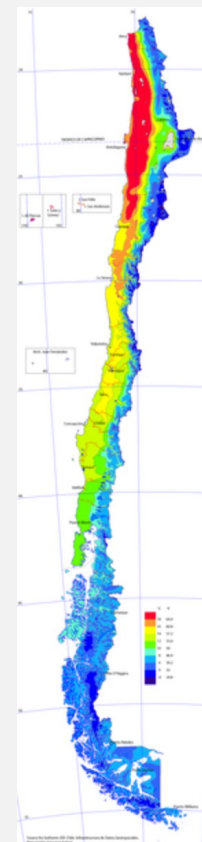
RETROSPECTIVE STUDIES

- There are no RCTs on the effect of climate or weather on HCAI
- Retrospective studies have caveats
 - rely on existing data, so may be incomplete, inconsistent, or inaccurate
 - limited control over confounding variables leading to spurious associations
 - establishing a clear temporal relationship between exposure and outcome is problematic
 - data may be based on sources not designed for research
 - lack of generalisability



SEASONAL VARIATION

- For some infections this is well-recognised
 - RSV, Influenza, Legionella, Strep pneumoniae
 - Enteric bacterial pathogens
- Is this true of pathogens responsible for HCAI?
 - Some studies do not look at effect of temperature/humidity, just 'season'
 - National rates are not useful due to data combination
 - USA a case in point (Alaska + Arizona)
 - Chile



SEASONAL PEAKS IN GRAM-NEGATIVES

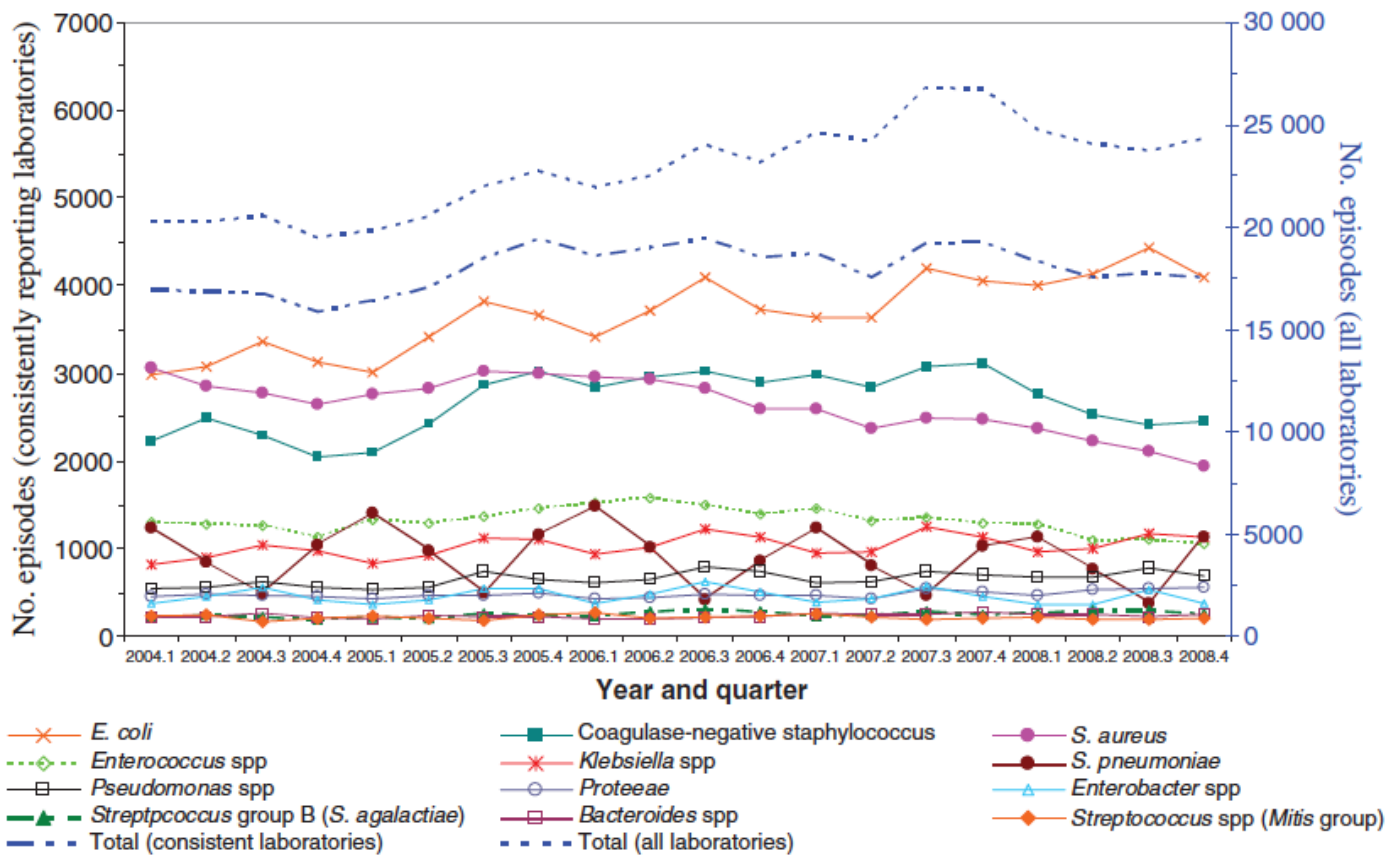
- Retrospective study 1998-2007
 - Al-Hasan M, et al. Clin Microbiol Infect 2009; 15
- E. coli incidence rate of BSI increased by 35% per month during 4 summer months in Minnesota compared with the other 8 months
 - 59% 'Community', 80% associated with UTI

DISCUSSION

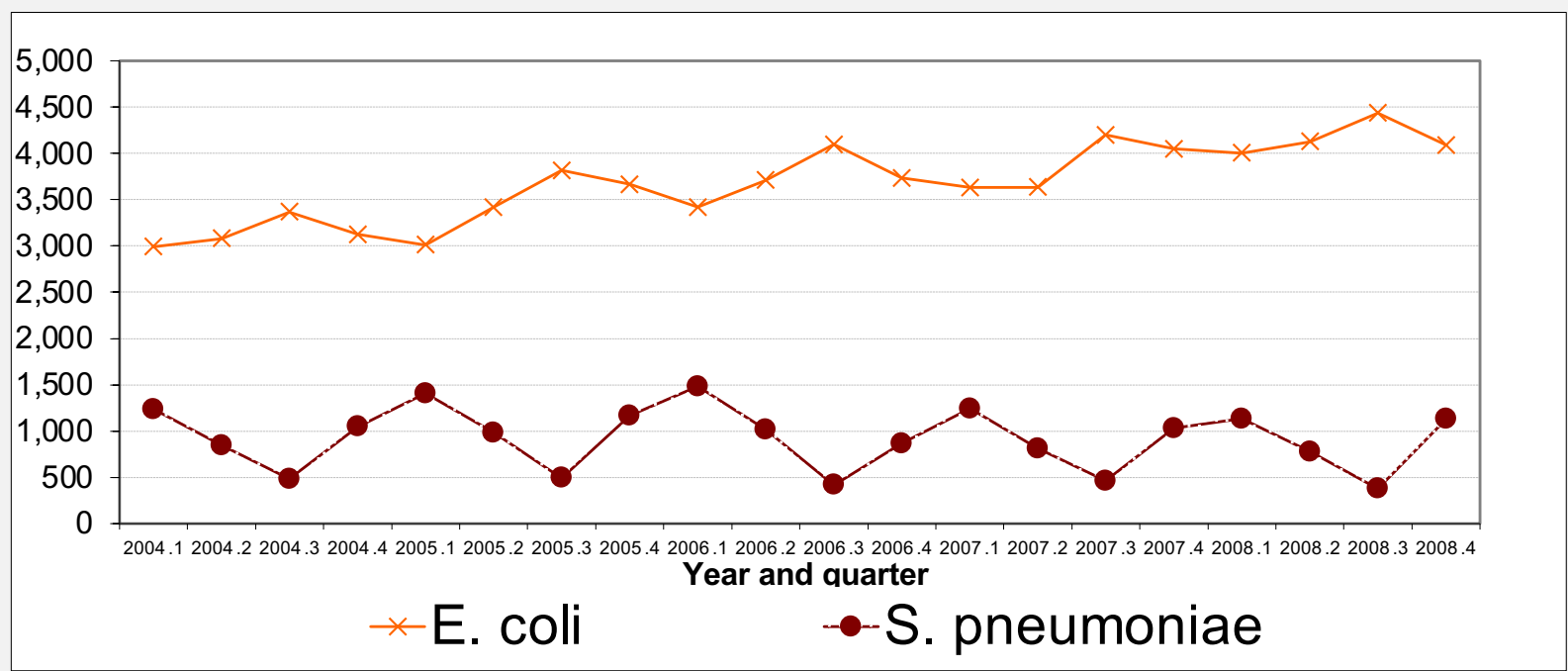
- Doubling rate of *E. coli* increases with increasing temperature until an optimal growth temperature of 35–36C is reached
 - Bronikowski AM, Bennett AF, Lenski RE. Evolutionary adaptation to temperature.VIII. Effects of temperature on growth rate in natural isolates of *Escherichia coli* and *Salmonella enterica* from different thermal environments. *Evolution* 2001; 55: 33–40.
- Higher density of *E. coli* in temperate soils from Lake Superior watersheds in Northern Minnesota during the warmest months compared with the remainder of the year
 - Ishii S, et al. Presence and growth of naturalized *Escherichia coli* in temperate soils from Lake Superior watersheds. *Appl Environ Microbiol* 2006; 72: 612–621

UK DATA SUPPORT

WILSON J. ET AL CLINICAL MICRO INFECT, SEPT 2010

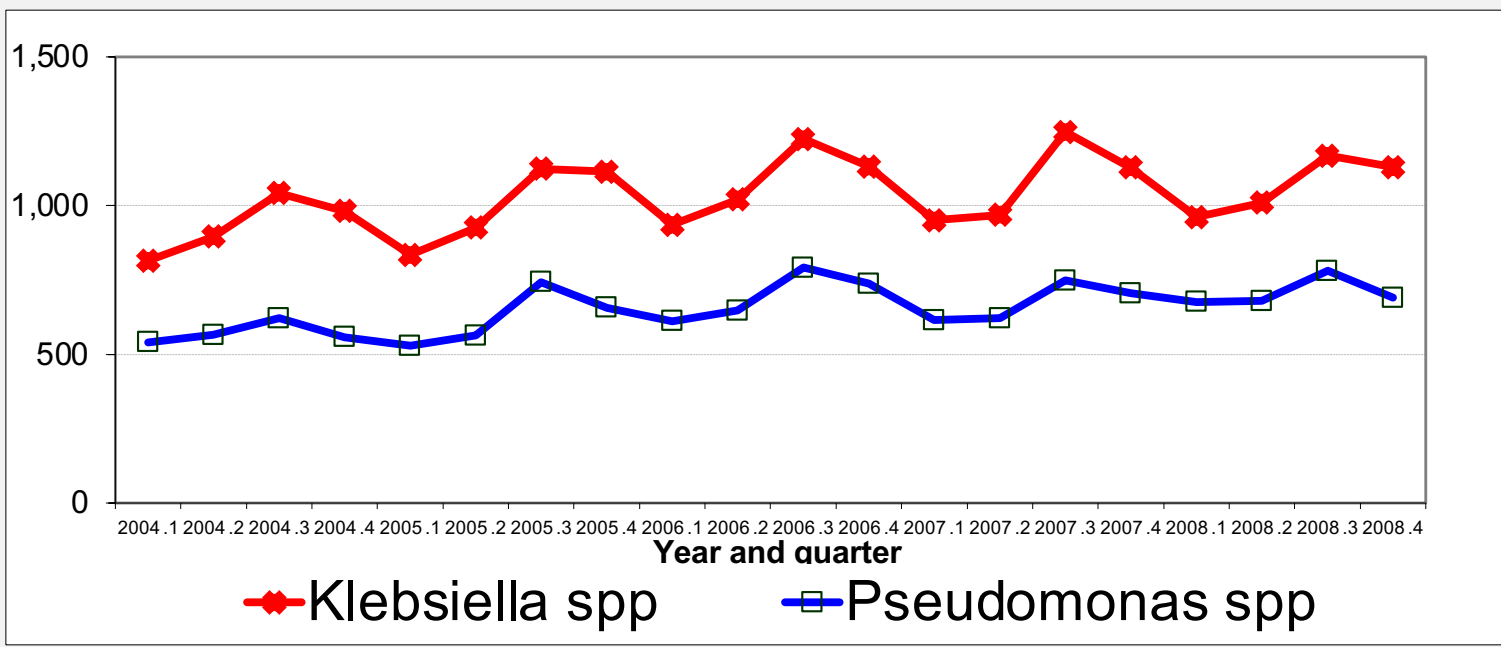


SEASONAL TRENDS IN CAUSE OF BACTERAEMIA: 2004-2008



Wilson *et al* Clinical Micro Infect, Sept 2010

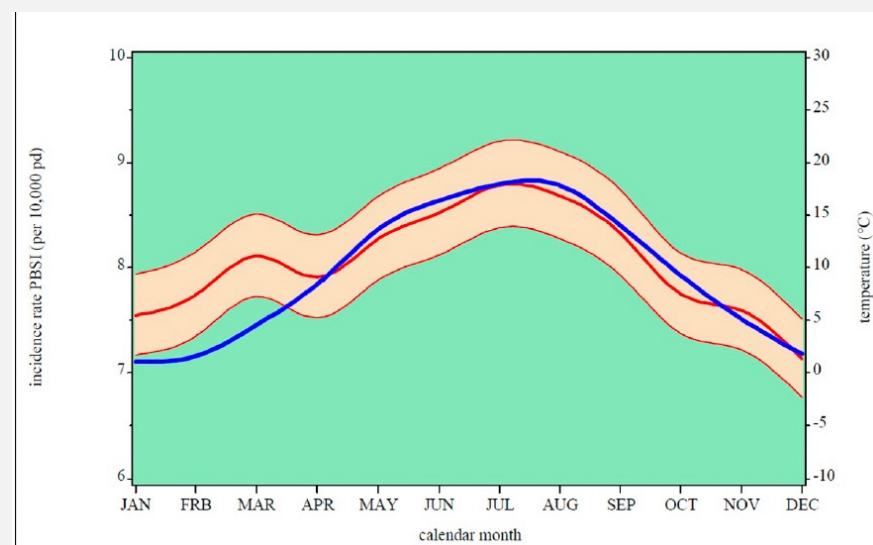
SEASONAL TRENDS IN CAUSE OF BACTERAEMIA: 2004-2008



Wilson *et al* Clinical Micro Infect, Sept 2010

BLOODSTREAM INFECTIONS IN GERMAN ICUS 2001-15

- Incidence rate of BSI was 17% (IRR 1.169, 95%CI (1.077–1.269)) higher in months with high temperatures ($>20^{\circ}\text{C}$) when compared to low temperatures ($<5^{\circ}\text{C}$)
- Effect most prominent for gram-negatives with more than one third (38%) higher followed by gram-positives (13%)
 - Schwab F, et al Summer, sun and sepsis-The influence of outside temperature on nosocomial bloodstream infections: A cohort study and review of the literature. PLoS One. 2020;15:e0234656.



SEASONALITY IN NEONATAL ICU

SHAH PS ET AL, ARCH DIS CHILD 2013; 98 F65-69

- Retrospective study of 25 NICU in Canada
 - HCAI = Positive BSI or CSF
 - No data on temperatures, humidity etc., but not explained by clinical factors, including severity of illness size etc., etc.
 - NICU babies are normally in a temperature-controlled physical environment
 - Relative carriage, staff stress and shortage?

Comparison	IR (95% CI)		IRR (95% CI)
	June–September	Rest of the year	IR (summer)/IR (the rest)
Overall	4.02 (3.85 to 4.20)	3.83 (3.70 to 3.95)	1.05 (1.00 to 1.11)
Stratified analyses by type of organisms			
Gram positive	3.20 (3.04 to 3.36)	3.13 (3.02 to 3.25)	1.02 (0.96 to 1.09)
Gram negative	0.65 (0.58 to 0.72)	0.54 (0.49 to 0.59)	1.20 (1.04 to 1.39)

DEVICE-RELATED INFECTIONS

- Significant doubling in the incidence of central venous catheter-associated bacteraemia due to non-endogenous gram-negative organisms (*Pseudomonas* spp.) in paediatric oncology patients during the summer
 - Smith TL, et al. ICHE 2002; 23:239-243.
- Why?
 - Water-related recreational activity?



DIALYSIS

KIM MJ, ET AL. ADV PERIT DIAL 2000; 16:243–247.

- Incidence of continuous ambulatory peritoneal dialysis peritonitis (CAPD) according to temperature and relative humidity was analysed
 - Highest incidence in July and the lowest in November
 - Significant positive correlation observed between monthly frequency of CAPD peritonitis, temperature, and relative humidity
 - Not for Gram positives
- Findings echoed
 - Cho Y, et al. Nephrol Dial Transplant 2011; 4: 7–9

SEASONAL PEAKS IN GRAM-NEGATIVES

- Increases in the mean monthly rates of infection caused by Gram-negatives
 - *P. aeruginosa*, *E. cloacae*, *E. coli*, and *A. baumannii*
 - Perencevich EN et al. ICHE 2008;29(12):1124-31
- Higher temperatures associated with higher infection rates, independent of seasonality
 - For each 10°F increase, observed a 17% increase in the monthly rates of infection caused by *P. aeruginosa* ($P < 0.01$) and *A. baumannii* ($P < 0.05$)
 - Hottest month also the wettest, so effect of humidity?



EFFECT OF TEMPERATURE AND HUMIDITY ON NON-FERMENTERS

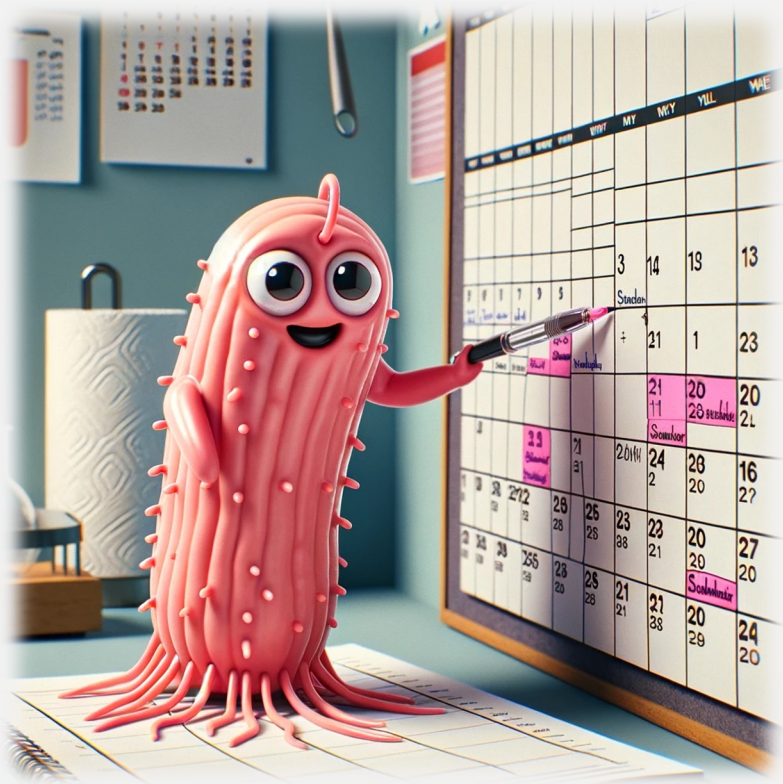
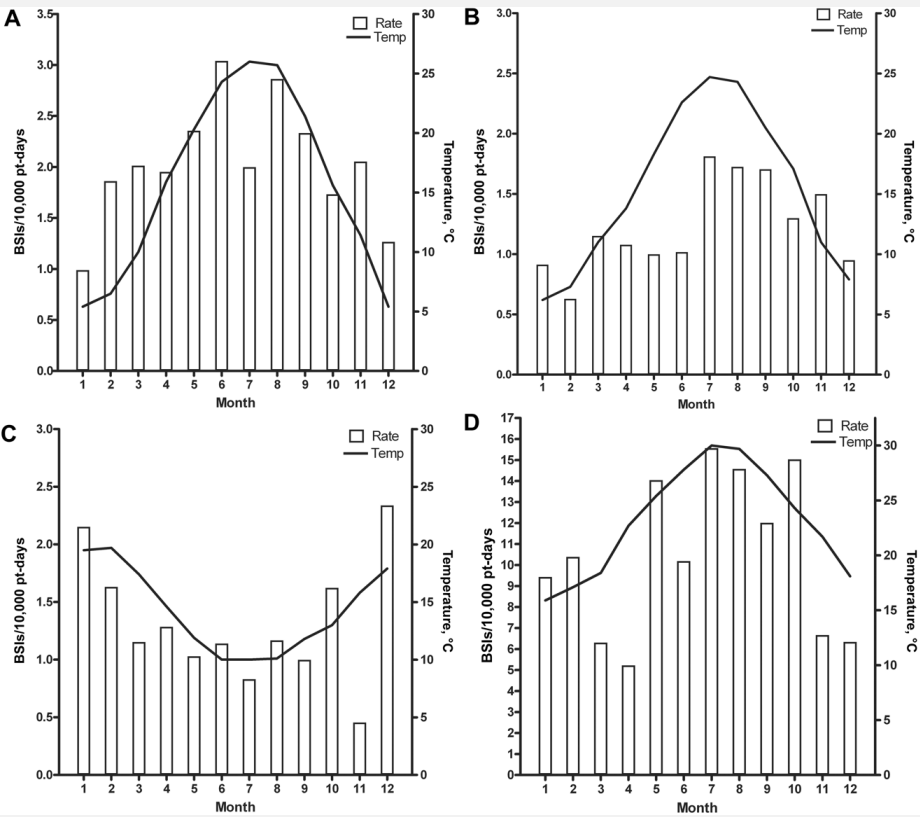
- Healthcare infections caused by *Pseudomonas aeruginosa* (5 yr study, retrospective)
 - Mean temperature $18.2 \pm 2.8^{\circ}\text{C}$; relative humidity $80.3 \pm 3.6\%$; precipitation 104.7 ± 64.38 mm
 - Significant correlation for UTI between
 - temperature ($R = 0.29$; $p = 0.021$); precipitation ($R = 0.27$; $p = 0.036$)
 - Significant correlation for HAP between
 - precipitation ($R = 0.29$; $p = 0.022$); relative humidity ($R = 0.31$; $p = 0.013$)
 - Relative humidity associated with higher infection rate of other infections
 - Ramos et al, Int J Inf Dis 2013: 17 e757-761

WORLDWIDE SEASONALITY OF KLEBSIELLA PNEUMONIAE

- Analysis of 5 yrs surveillance data from hospitals in 4 continents
 - Anderson DJ, et al. J Infect Dis. 2008;197(5):752-6.
- Risk of *K. pneumoniae* BSI during the 4 warmest months of the year IRR 2.23/10,000 patient-days
 - other 8 months was 1.55/10,000 patient-days (IRR, 1.46 [95% CI 1.04 –2.06]; P<.03)
- Poisson regression showed temperature (P<.0001) and dewpoint (marker for relative humidity; P <.0001) were both linearly predictive of increasing rates of *K. pneumoniae* BSI

MIRRORED ON ALL CONTINENTS

ANDERSON DJ, ET AL. J INFECT DIS. 2008;197(5):752-6



ADDITIONALLY

- Density of *K. pneumoniae* in the environment (e.g., in freshwater ponds) is higher during warm months
 - Al-Harbi AH. *Aquaculture Res* 2003; 34:517–24
- Higher in cow faeces during the summer
 - Munoz MA et al. *J Dairy Sci* 2006; 89:3425–30
- Do humans also have higher levels of colonisation with *K. pneumoniae* during warm months?



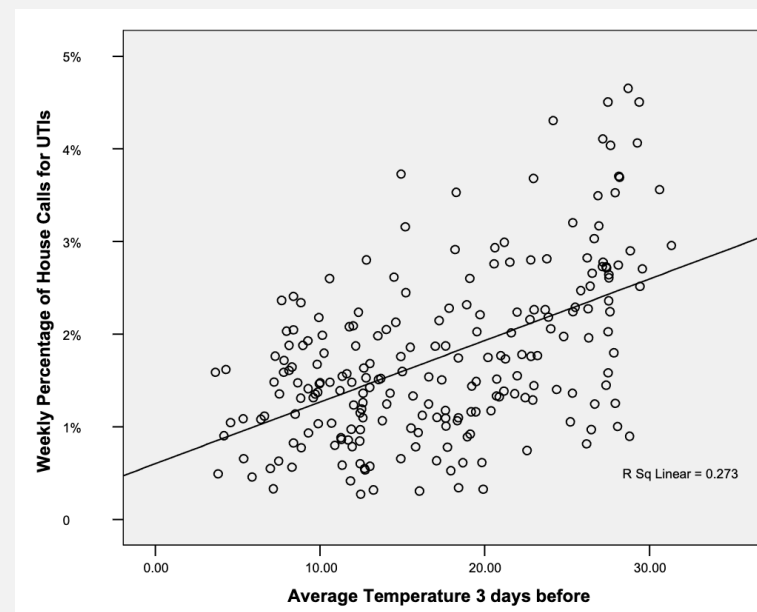
DOES TEMPERATURE AFFECT PATHOGENICITY?

- Elevated temperatures may be associated with increased virulence of Gram-negatives
- Lipid A part of lipopolysaccharide, which forms the outer monolayer of the outermost membrane of most Gram-negatives, is regulated by environmental conditions and modulates virulence
 - Raetz CR, et al (2007) Annu Rev Biochem 76: 295–329



SEASONALITY OF URINARY TRACT INFECTIONS

- Retrospective evaluation of potential for lower UTIs being associated with meteorological parameters
 - Falagas ME, et al Eur J Clin Microbiol Infect Dis 2009; 28: 709–712
- Reviewed weekly percentage of house call visits for lower UTIs (2000 to 2005) and average weekly temperature and humidity recorded in the same area 3 days earlier
- 3221 visits for lower UTIs in patients 62.9 ± 21.0 years of age
- Significant correlation between visits for UTIs and average higher weekly temperature and decreased relative humidity



HYDRATION AND UTI

- Poor fluid intake or low urine output are host-mediated predisposing factors
 - Beetz R Eur J Clin Nutr 57 (Suppl 2):S52–S58, 2003
- Two years after health education and seasonal on-the-job training in female clean room workers, number of drinks and urine voids increased and UTI prevalence decreased from 9.8% to 1.6%
 - Su S. et al., J Womens Health (2006) 15(7) pp870–876

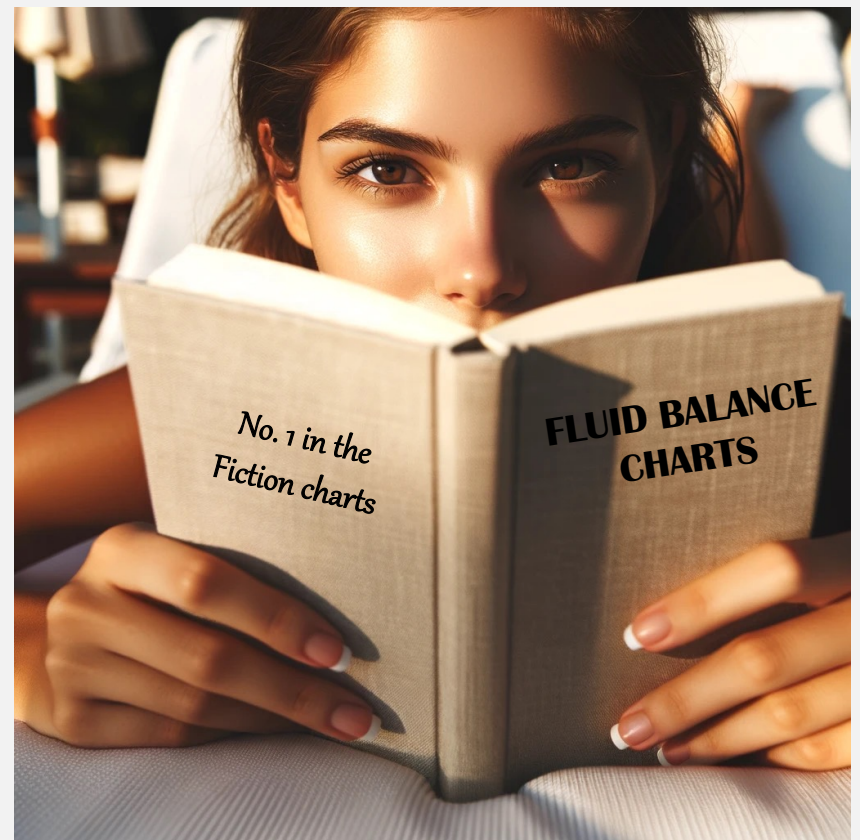
HYDRATION, UTI AND INCONTINENCE

- Study in 1492 teachers (16% reported UTI in a year)
 - half made a conscious effort to drink less while working to avoid using the toilet
 - those who drank less had a 2.21-fold risk of UTI
 - 1 in 20 had >3 UTIs per year
 - Nygaard I, Linder M. Thirst at work - An occupational hazard? Int Urogynecol J Pelvic Floor Dysfunction 1997;8:340.
- Other studies have shown the same in nurses
 - Bendtsen AL. et al., Infrequent voiders syndrome (nurses bladder). Scand J Urol Nephrot 199t;25:201-204



CAN WE IMPROVE HYDRATION IN HOSPITAL

- Survey of patients in University College Hospital, London
 - Omar F, et al. Preventing Escherichia coli bacteraemia through optimized hospital hydration: an inpatient survey on drinks consumption on care of elderly wards. J Hosp Infect. 2019;103:170-1
- 70% rated hydration as 'very important' for health
- only 11% (3/27) met the minimum recommended fluid intake of 1500 mL/day (about eight small cups); 67% drank half the recommended fluid intake or less



CAN WE IMPROVE HYDRATION IN HOSPITAL

- 59% reported that water jugs were changed once a day or less
- Barriers included lack of thirst (18.5%), inability to reach jug or drink due to physical impairment (22.5%), and polystyrene cups, described as hard to grasp and liable to spill
- Two patients in single rooms reported jug changes of only once and less than once a day, and had the lowest total fluid consumption of one to three cups/day (0.3-0.6 L)



WHEN TO HAVE SURGERY?

- Summer is the time for holidays, not surgery
 - Durkin MJ, et al. ICHE 2015:1-6.
- 2007-2012 (Duke, DICON); 20 Hospitals
 - 441,428 procedures, 4543 SSI
- 11% more in summer
 - 1.11 [95% CI, 1.04–1.19]; P= .002
 - Gram-positive: 1.08 (1.00–1.19) p=0.04
 - Gram-negative: 1.26 (1.10–1.40) p<.001



SSI AND TEMPERATURE

- Each additional 1° C, a 6% increase in SSI for Acinetobacter spp and 4% for Enterobacter spp.
- Superficial SSIs with Acinetobacter spp 10x more likely when comparing months with mean temperatures of ≥ 20 degrees C to < 5 oC
 - Aghdassi SJS, et al Increase in surgical site infections caused by gram-negative bacteria in warmer temperatures: Results from a retrospective observational study. Infect Control Hosp Epidemiol. 2021;42:417-24
- Not the OR itself though
 - Hammond JB, Madura GM, Chang YH, Lim ES, Habermann E, Cima R, et al. The influence of operating room temperature and humidity on surgical site infection: A multisite ACS-NSQIP analysis. Am J Surg. 2023;226:840-4



WHY MORE SSI IN SUMMER?

- Patient factors
 - Skin colonisation, perspiration?
- Intraoperative
 - Skill and experience of the surgeon
 - Does not explain seasonality in non-teaching hospitals
 - Sweaty surgeons/theatre staff?
 - Lead surgeons on holiday?
- Postoperative
 - Same as preoperative



SWEAT

- Sweat is as good as a nutrient broth in promoting growth
 - Watson, F., et al., Artificial Human Sweat as a Novel Growth Condition for Clinically Relevant Pathogens on Hospital Surfaces. Microbiology Spectrum, 2022. 10(2).



Species	Artificial human sweat		Nutrient broth	
	Mean (log ₁₀ CFU/mL)	SD	Mean (log ₁₀ CFU/mL)	SD
<i>A. baumannii</i>	7.97	0.80	7.23	0.58
<i>S. aureus</i>	6.07	0.63	7.06	0.36
<i>E. faecalis</i>	6.75	0.27	7.14	0.58
<i>P. aeruginosa</i>	8.04	0.79	7.47	0.55

IS IT THE MICROBIOME?

- How does the skin and gut microbiome vary in different climactic conditions?
 - Optimal temperature for survival and growth of skin bacteria (i.e., *Staphylococcus*, *Corynebacterium*, and *Acinetobacter*) is 33.2 - 35.0°C
 - these species demonstrate an increased tolerance for warmer temperatures and higher salt conditions compared to other, non-commensal bacteria
 - Bewick S, et al. Trait-based analysis of the human skin microbiome. *Microbiome* 2019 5(7): 101

SEASONALITY OF C. DIFFICILE

FURUYA-KANAMORI L. ET AL. (2015) PLOS ONE 10(3): E0120730

- Similar seasonal pattern in both Hemispheres
 - Spring peak, lower frequencies in summer/autumn with an 8 month lag between hemispheres
 - No difference between seasonal patterns across Europe and North America
- After antibiotic cessation, higher risk of CDI for up to 3 months
 - Hensgens MPM, et al (2012) J Antimicrob Chemother 67: 742–748
- Climate also can affect C. difficile in other ways

WHAT HAPPENS WHEN CROPS FAIL?

SURVEILLANCE AND OUTBREAK REPORTS

Emergence and spread of predominantly community-onset *Clostridium difficile* PCR ribotype 244 infection in Australia, 2010 to 2012

D W Eyre (david.eyre@ndm.ox.ac.uk)^{1,2,3}, L Tracey^{3,4}, B Elliott⁵, C Slimings⁴, P G Huntington⁶, R L Stuart⁷, T M Korman⁷, G Kotsiou⁶, R McCann⁴, D Griffiths¹, W N Fawley⁸, P Armstrong⁴, K E Dingle¹, A S Walker^{1,2}, T E Peto^{1,2}, D W Crook^{1,2}, M H Wilcox⁸, T V Riley^{5,9}

1. Nuffield Department of Clinical Medicine, University of Oxford, John Radcliffe Hospital, Oxford, United Kingdom
2. National Institute for Health Research Oxford Biomedical Research Centre, John Radcliffe Hospital, Oxford, United Kingdom
3. These authors contributed equally to the work
4. Communicable Diseases Control Directorate, Health Department of Western Australia, Shenton Park, Australia
5. Microbiology and Immunology, The University of Western Australia, Nedlands, Australia
6. Microbiology, Pathology North, Royal North Shore Hospital, St Leonards, Australia
7. Monash Infectious Diseases and Monash University, Clayton, Australia
8. Department of Microbiology, Old Medical School, Leeds Teaching Hospitals NHS Trust and University of Leeds, Leeds General Infirmary, Leeds, United Kingdom
9. Microbiology and Infectious Diseases, PathWest Laboratory Medicine, Nedlands, Australia

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Eyre DW, Tracey L, Elliott B, Slimings C, Huntington PG, Stuart RL, Korman TM, Kotsiou G, McCann R, Griffiths D, Fawley WN, Armstrong P, Dingle KE, Walker AS, Peto TE, Crook DW, Wilcox MH, Riley TV. Emergence and spread of predominantly community-onset *Clostridium difficile* PCR ribotype 244 infection in Australia, 2010 to 2012. *Euro Surveill.* 2015;20(10):pii=21059. Available online: <http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=21059>

Article submitted on 18 February 2014 / published on 12 March 2015

FUNGI



EMERGING INFECTIONS

- *C. auris*: five clonally distinct clades on three continents (so far)
 - Possible 'emergence' due to acquisition of virulence factors
 - Fungi generally don't like high temperatures however *C. auris* appears to have developed tolerance
 - Possibly birds involvement in dissemination – salt tolerant, found in marshland
 - Garcia-Bustos V, et al Climate change, animals, and *Candida auris*: insights into the ecological niche of a new species from a One Health approach. *Clin Microbiol Infect.* 2023;29:858-62



FUNGAL CONCERNS ARE MUSHROOMING

- To date, around 148 000 fungal species have been described
- High-throughput sequencing methods estimate that as many as 5.1 million fungal species exist
 - Blackwell M. The fungi: 1, 2, 3 ... 5.1 million species? Am J Bot 2011;98: 426e38.
<https://doi.org/10.3732/ajb.1000298>.



ZOONOSES

- Threats are increasing
 - Climate change, including extreme weather events
 - Land alteration
 - Biodiversity loss
- More than 60% of human infectious diseases are caused by pathogens shared with wild or domestic animals
 - There are ~2 billion cases of zoonotic disease annually, resulting in >2 million deaths, and >700,000 global deaths each year are due to vector-borne diseases
 - Karesh WB, et al. Ecology of zoonoses: natural and unnatural histories. Lancet. 2012;380:1936-45. <https://www.ncbi.nlm.nih.gov/pubmed/23200502>

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● This article is more than 1 month old

'A first in Paris': city fumigates for tiger mosquitoes as tropical pests spread, bringing disease

Parisian health authorities treat French capital for the first time as Zika and dengue-carrying tiger mosquitoes advance through northeastern Europe



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Climate change linked to surge in Japanese encephalitis in North East India

Doctors and health experts blame warmer weather and erratic rainfall for a rising number of cases in Assam and Manipur, with similar evidence emerging across Asia.

By Azera Parveen Rahman, The Third Pole

Wednesday 12 October 2016

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WHEN THE CLIMATE CHANGES

- Animal and bird populations move
 - Takekawa JY et al. Potential Effects of Habitat Change on Migratory Bird Movements and Avian Influenza Transmission in the East Asian-Australasian Flyway. *Diversity*. 2023;15



OTHER THINGS FLY

- Moving bats won't be good either..
- More than 4,100 bat-associated animal viruses detected from 196 bat species in 69 countries worldwide
 - Liu Z, Liu Q, Wang H, Yao X. Severe zoonotic viruses carried by different species of bats and their regional distribution. Clin Microbiol Infect. 2023.
<https://www.ncbi.nlm.nih.gov/pubmed/37805032>



IT'S JUST ALL SUCH BAD NEWS..

- Mozny M, et al. Climate-induced decline in the quality and quantity of European hops calls for immediate adaptation measures. Nat Commun. 2023;14:6028.<https://www.ncbi.nlm.nih.gov/pubmed/37816707>



CONCLUDING

- Weather, climate and seasonality affect HCAI
 - Climate change will affect this over a long period
- We will need to plan for this with better hospital design to mitigate the increasing risk
 - Controlling temperature, humidity and ventilation
- Staff need to be aware that there are things that they can do too
- If you are planning a 12-month study targeting gram-negatives, collect baseline data in the winter, intervention to start in spring/summer



www.webbertraining.com/schedulep1.php

(Australasian Teleclass)

June 26, 2024

HEALTH CARE WORKERS' EXPERIENCES OF VIDEO-BASED MONITORING OF HAND HYGIENE BEHAVIORS

Speaker: **Prof. Katherine McKay**, University of Sydney, Australia

July 11, 2024

HOW SOCIAL MEDIA MAKES ME A BETTER INFECTION PREVENTIONIST

Speaker: **Rebecca Battjes**, Clinical Advisor, Diversey

July 18, 2024

(FREE Teleclass)

CBIC AND THE FUTURE OF IPC CERTIFICATION

Speaker: **Jessica Dangles**, Certification Board for Infection Prevention and Control

August 8, 2024

(FREE Teleclass)

EPIDEMIOLOGY AND PREVENTION OF CATHETER ASSOCIATED BLOODSTREAM INFECTIONS IN LOW AND MIDDLE-INCOME COUNTRIES

Speaker: **Prof. Victor D. Rosenthal**, University of Miami, International Nosocomial Infection Control Consortium

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