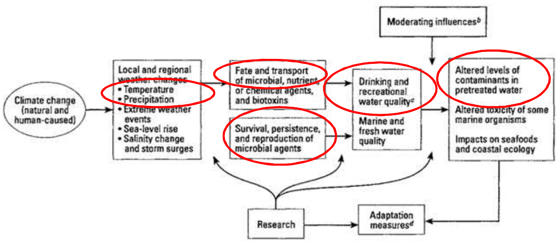
Stochastic modelling of environmental survival of *E. coli* and changes in public health risk

Tom Ross and Mark Tamplin
Food Safety Centre
Tasmanian Institute of Agricultural Science
University of Tasmania

Faecal pathogens and water

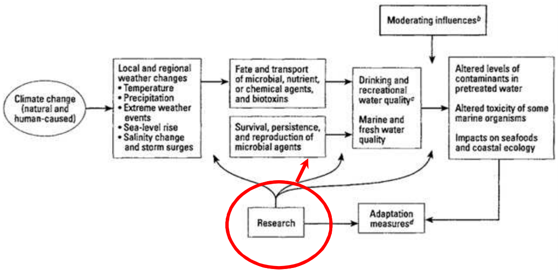
- waterborne diseases are caused by pathogens spread through contaminated drinking, recreational, irrigation or fish-harvesting waters
- cattle harbour pathogens and shed them in their faeces
- water quality depends on land use and how water resources are managed and protected
- factors affecting pathogen survival include temperature and water activity (related to dryness)
- weather conditions affect pathogen survival in manure in fields, and in waters

Factors affecting potential water-borne disease



reproduced from Rose *et al.* (2001) *Environmental Health Perspectives*, **109:** 211-221

Factors affecting potential water-borne disease



E. coli risk in water

"knowledge about transport processes and the fate of microbial pollutants ... is key to predicting risks from a change in weather variability"

"recent studies identified links between climate variability and the occurrence between microbial agents in water, the relationships need further clarification … "

Rose *et al*. (2001)

Escherichia coli

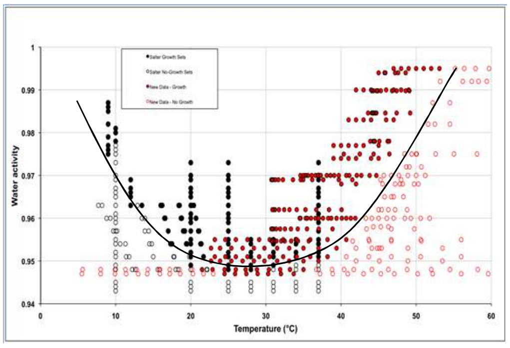
- normal commensal gut microbiota
- usually beneficial (Vit K metabolism)
- some strains pathogenic
  - cause diarrhoea
  - enterohaemorrhagic colitis
  - thrombocytopaenic pupura
  - potentially fatal for YOPI
- carried in cattle, passed out in faeces
- can contaminate natural waters and cause illness

E. coli - ecology

- growth
  - from ~6°C to 50°C (usually 7.5°C to 50°C)
  - from a_w 0.95 to 0.999
- if growth not possible, death ensues

E. coli interaction of a_w and temperature on growth limits

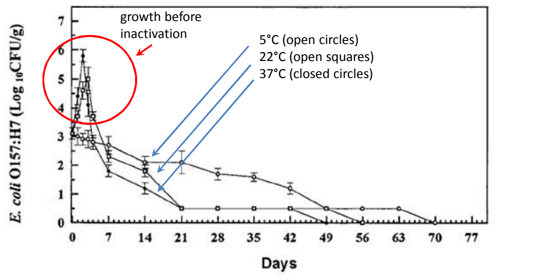
(data of Salter *et al.*, 2000 for *E. coli;* augmented 2002)



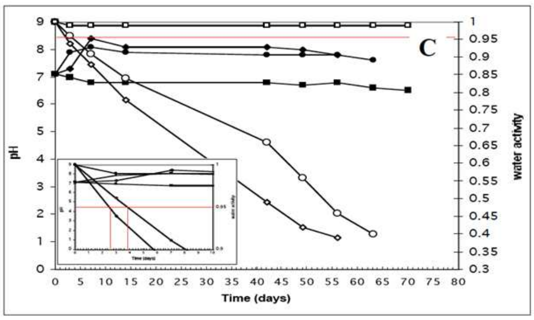
E. coli fate in cow-pats

- *grow* if moisture (water activity > 0.95) allows
- *die* if water activity decreases below growth limit
- numerous studies conducted,
  - *e.g.*, Wang *et al.*, 1996
- inactivation is faster at higher temperatures
- same is observed in foods

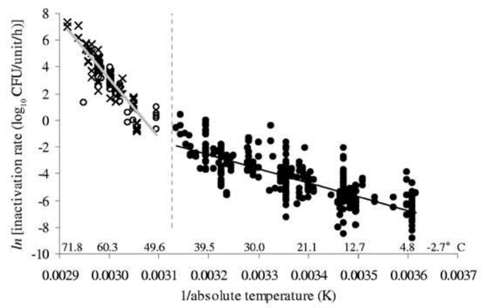
population dynamics of *E. coli* O157:H7 in bovine faeces in relation to temperature (Wang *et al*., 1996)



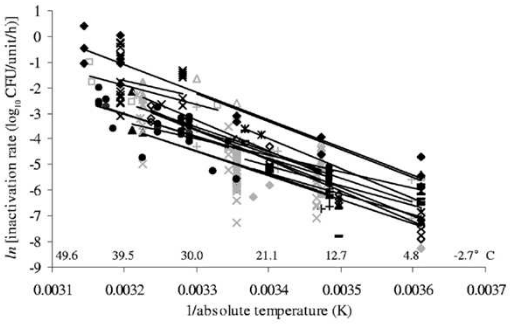
inactivation begins when water activity reduction prevents growth



effect of temperature on passive inactivation of *E. coli* (McQuestin *et al*., 2009)



effect of temperature on passive inactivation
(relationship consistent between strains)



passive inactivation

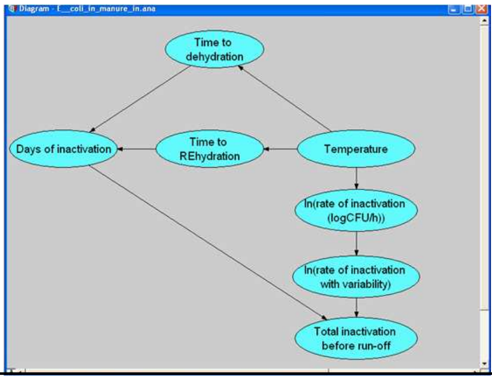
- predictable
- between strain *variability* appears to be large
- commencement of inactivation depends on drying
- rate of inactivation almost completely explained by temperature alone

- a simple stochastic model developed to illustrate potential affects of temperature and rainfall change on public health risk *via* exposure to water borne faecal pathogens

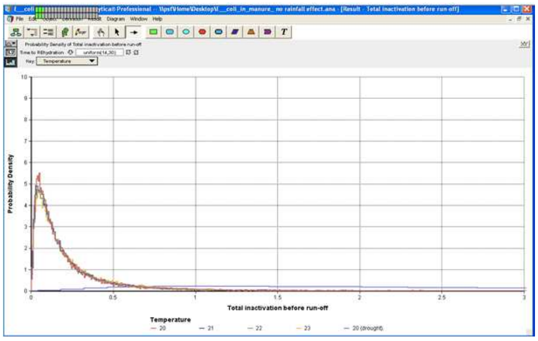
stochastic model

- increase in inactivation rate due to mean temperature increase from 20°C to 23°C
- concomitant effect of increased rainfall modelled as
  - i) longer time to desiccation (from 5 – 7 @ 20°C to 8-10 days @23°C)
  - ii) increased frequency of rehdyration (from 14 - 30 @ 20°C to 8 - 24 days @23°C)
  - iii) drought (no rain for 365 days)
- inactivation rate modelled from McQuestin *et al*.(2009) taking variability in inactivation rate into account

influence diagram



results: increased temperature only



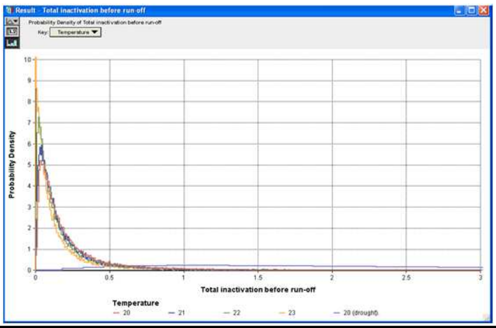
results: increased temperature only

Result - Total inactivation before run-off

Statistics of Total inactivation before run-off

	20	21	22	23	'20 (drought)'
Min	1.501m	1.839m	1.829m	1.858m	0.04727
Median	0.1284	0.1346	0.1414	0.1464	3
Mean	0.2207	0.2333	0.2463	0.2566	4.946
Max	12.51	8.054	14.35	9.74	190
Std. Dev.	0.3093	0.331	0.3537	0.3692	6.456

results – increased temperature and rain frequency



results – increased temperature and rain frequency

Result - Total inactivation before run-off

Statistics of Total inactivation before run-off

Statistics ☐ Totals

Temperature ☐ Totals

	20	21	22	23	'20 (drought)'
Min	1.699m	1.779m	729u	0	0.04727
Median	0.1278	0.1148	0.09444	0.06782	3
Mean	0.2212	0.2015	0.1752	0.1395	4.946
Max	9.959	9.876	6.116	9.955	190
Std. Dev.	0.3136	0.2869	0.2591	0.2448	6.456

Conclusions

- climate change can be expected to impact run-off of faecal pathogens from animal manures into recreational, irrigation and fish harvesting waters
- higher temperatures and increased rainfall will have opposing effects
- increased rainfall frequency is likely to be a more dominant effect, reducing pathogen die-off, with increased public health risk
- microbial ecology in natural ecosystems could benefit from existing knowledge of microbial ecology of foods