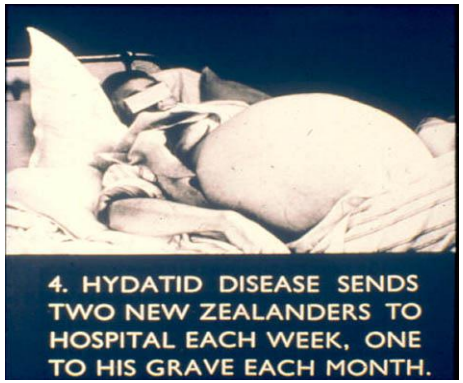
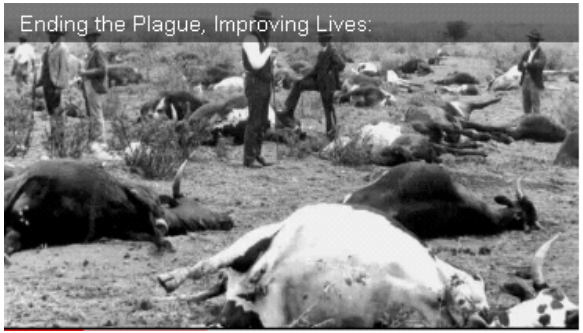
Zoonoses



Nigel French



IDReC | Infectious Disease Research Centre

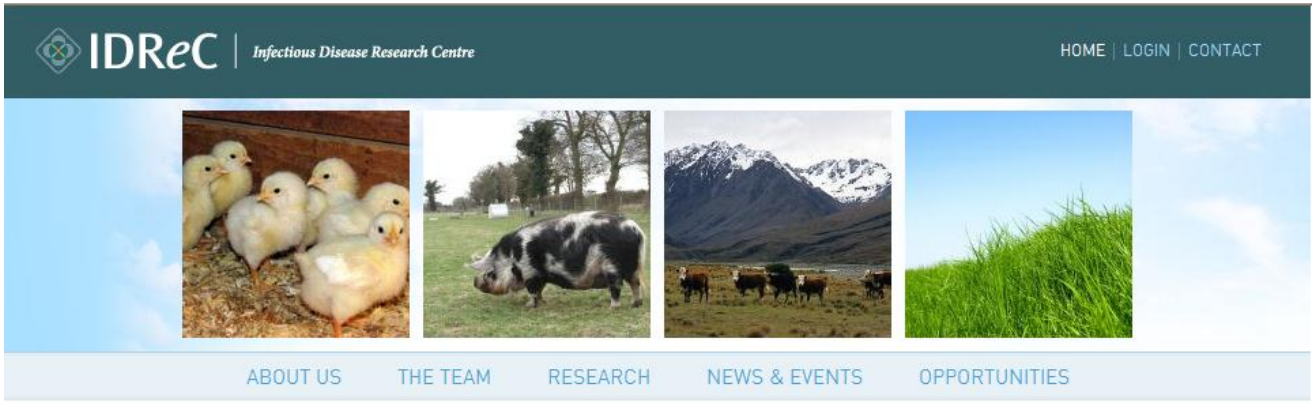
ALLAN WILSON CENTRE

Forever discovering

THE ENGINE OF THE NEW NEW ZEALAND

Te Kunenga ki Pūrehuroa

MASSEY UNIVERSITY



IDReC

- Food and water safety
- Environmental and ecosystem health
- Controlling epidemics

www.idrec.ac.nz/

Kunenga rehuroa

MASSEY UNIVERSITY

*m*EpiLab: Molecular Epidemiology and Public Health Laboratory

We work on:

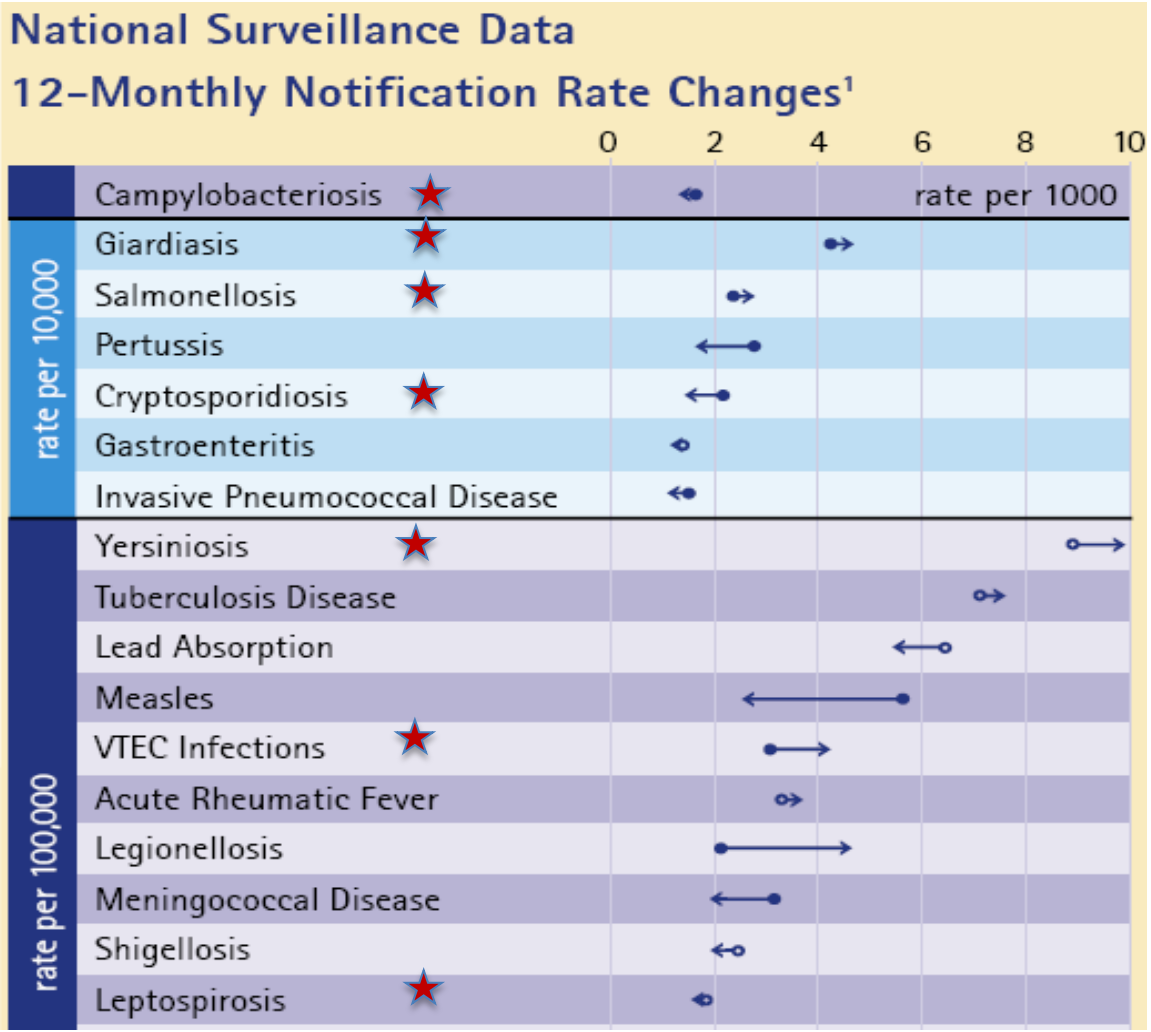
- Food safety
- (Veterinary) Public Health
- Surveillance
- Molecular epidemiology of zoonoses
  - *Campylobacter*
  - VTEC (*E. coli* O157)
  - *Cryptosporidium, Giardia*
  - *Leptospira*
  - *Salmonella*
  - *...others*

http://mepilab.massey.ac.nz

Veterinary Public Health

- ..”the sum of all contributions to the physical, mental and social well-being of humans through an understanding and application of veterinary science” (WHO 2002)

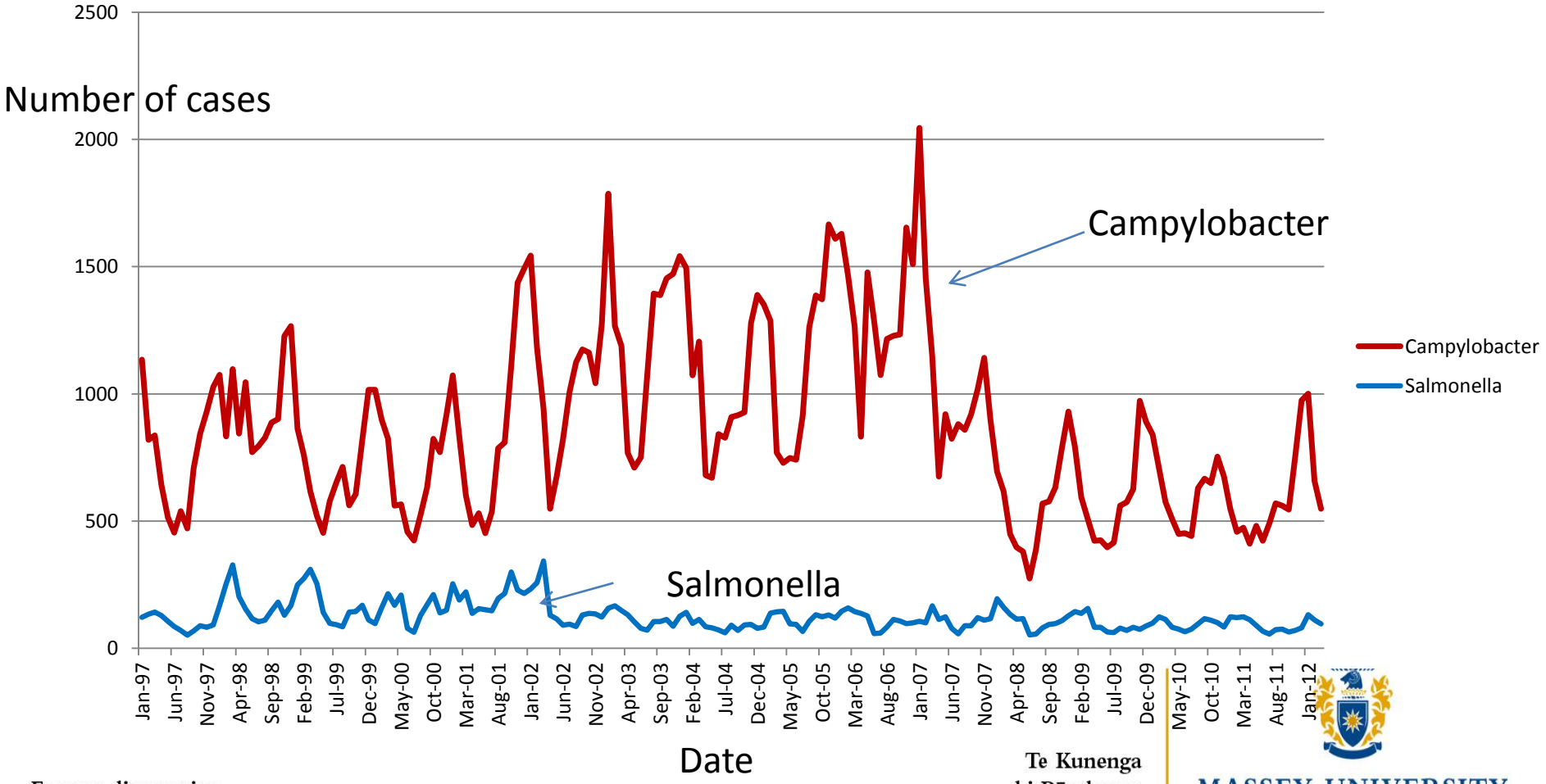
- Zoonotic disease
- Food safety
- Wider context....



Zoonoses figure very prominently in New Zealand.

Source: ESR Ltd

Recent trends in notified cases



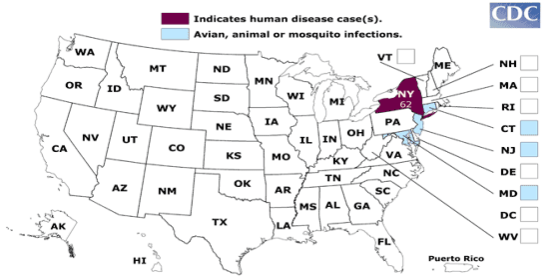
Key facts

- ~60% of ~1500 human infectious diseases are zoonotic
- ~75% of human emerging infectious diseases are zoonotic
- 33% of zoonoses are transmissible between humans
- Many zoonoses don't affect their animal host

Single and multi-host pathogens

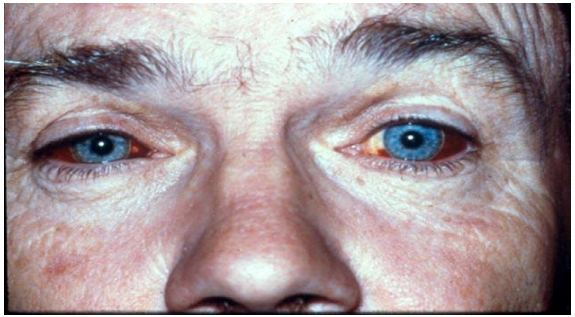
- Most infectious agents are multi-host
  - Particularly emerging ones
  - Subset of these are the zoonoses
- Single host agents relatively rare
  - Subset of these are the solely human to human spread agents (anthroponoses)
  - Evolved once population reached critical size

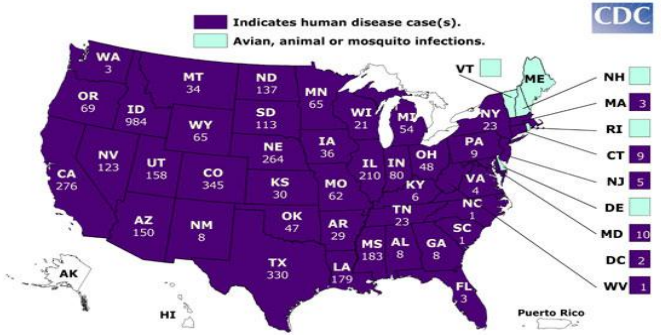
Zoonoses - quiz



1999

20008





Case

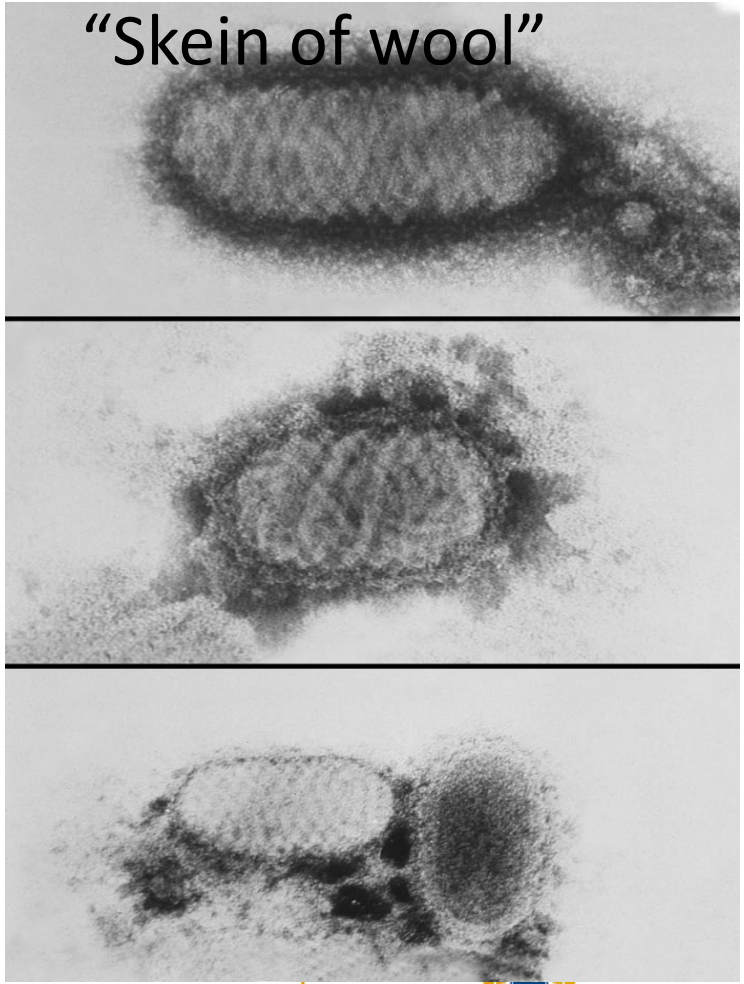
- An adolescent boy aged 16 years was bitten on the left hand by a healthy-appearing sheep that he was grooming for a county fair. Three weeks after he sustained the bite, the patient went to his doctor with three nonpruritic, painless vesicular lesions on his left thumb, the largest of which was 1.5 cm in diameter. Two lesions were eroded vesicles with an erythematous base and white halo; the remaining periungual lesion around the nail was still intact. The patient reported no constitutional symptoms, and the rest of his physical examination was unremarkable. No treatment was administered, and the lesions healed spontaneously after 2 months.

Orf

Aka

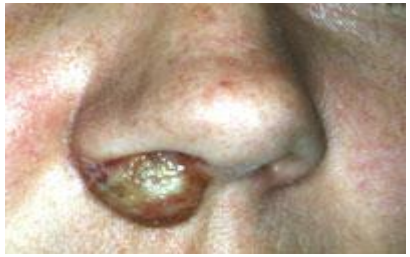
- Contagious ecthyma
- Scabby mouth
- Contagious pustular dermatitis

Agent: Parapox virus
DNA virus
Family poxviridae



Orf: Disease in man

- Incubation period 5 or 6 days
- Small, firm, red or reddish-blue lump enlarges to form flat-topped, blood-tinged pustule or blister.
- Lesion usually 2 - 3 cm but may be 5 cm.
- “Characteristically, although there appears to be pus under the white skin, incising this will reveal firm, red tissue underneath.”
- Sometimes irritable, often tender.
- Generally solitary or few in number.
- Fingers, hands or forearms, occasionally face.
- Occasionally red streaks up lymph channels, enlargement of lymph glands on the inner side of elbow and/or under the arm.
- May be a mild fever.



More severe

Can be severe fever and multiple lesions on face, arms and trunk

Immunocompromised individuals

Bullous pemphigoid

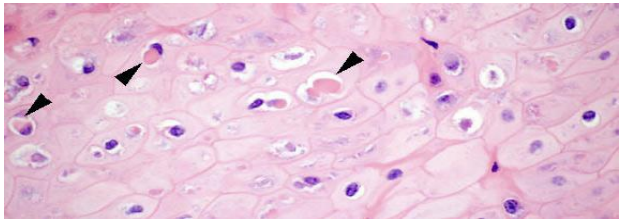
Erythema multiforme

Stevens-Johnson syndrome

Clinical signs in sheep

- Pustular and scabby lesions on the non-woolly areas of the skin
- Occasionally in the mouth and oesophagus
- Can lead to starvation and death
- In ewes, lesions usually found on the udder and teats
- With dermatophilus: Strawberry foot rot
- Venereal lesions
- Poor immunity – repeat infections

Clinical signs



- EM – large numbers
- Acidophilic, intracytoplasmic inclusions
- Real-time PCR genus- and species-specific primers
- Standard PCR assays

Epidemic/endemic status

Animals

- Highly prevalent
- Sheep and goats
- Globally important
- Prevalence 12% in lambs at slaughter
- Mortality <1% (can be higher)

Risk factors

- 3-6 months age
- Rough grazing – thistles and gorse

High risk groups

Man – occupational exposure

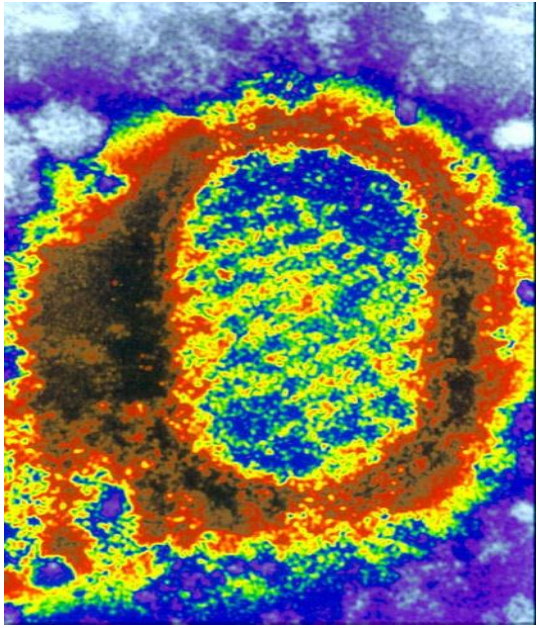
- Meatworkers
- Farmers
- Vets
- Shearers
- Underdiagnosed

Vaccination

Animals

- Vaccination
- Scabine
- Live vaccines: ‘mild field strain’ of the orf virus .
- Given to lambs at docking
  - Usually if history of infection on farm
  - Immunity lasts ~8 months, but often rechallenged naturally
- Vaccine can cause disease in man

Pseudocowpox



- Milker's nodule, Papular stomatitis, Paravaccinia
- Agent: Parapox virus
  - very similar to Orf virus
  - DNA virus
  - Family poxviridae
- Variants of same virus
- Not true cowpox – not endemic in NZ

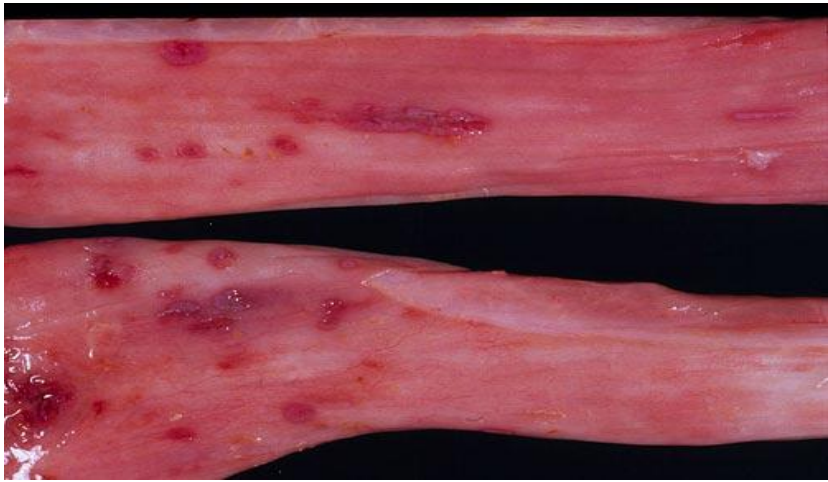
Disease in man

Clinical signs

- Teats and udders of cattle
- Raised firm, erythematous lesions
- Necrotic centres
- Bleed if scabs removed

- Papular stomatitis
- Oral mucosa, lips, hard palate, dental pad, muzzle, nostrils, tongue and oesophagus
- Up to 2cm diameter
- 2^{O} infection – candida, aspiration pneumonia

Clinical signs



The mass slaughter 'must go on'

New cases

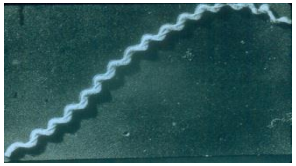
UK cases

● Cases confirmed yesterday	2
+ Existing cases	1,637
Total to May 24	1,639
Animals slaughtered to **May 23**	3,028,000
Animals awaiting slaughter	73,000
Carcasses awaiting disposal	15,000

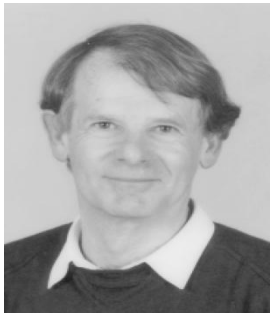
By Roger Highfield
Paul Stokes and
Charles Clover

THE outbreak of foot and mouth in the Yorkshire Dales has ruled out any prospect of an imminent relaxation of the current slaughter policy, Government advisers said yesterday as the 19th case was confirmed in the

AP

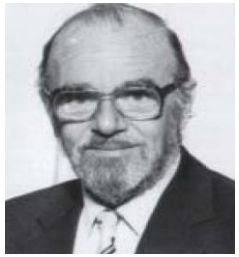


Leptospirosis



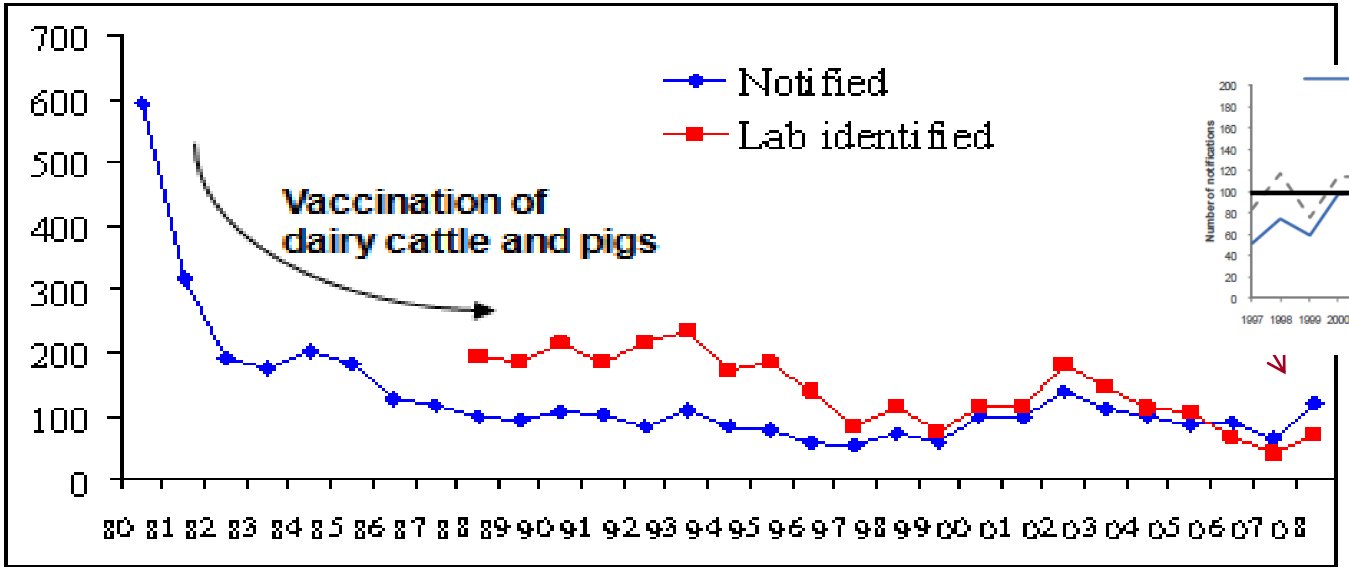
Roger Marshall

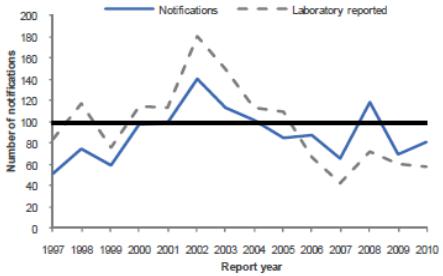
- Arrived? First confirmed in a calf in 1950
- Late 1950s early vaccines
- Bivalent vaccine introduced in 1979
- Improved diagnostics in 1980s
- *“The photophobic dairy farmer retiring to bed with aching muscles, fever and nausea is now almost a thing of the past. This must mark as one of the major recent advances in (veterinary) public health in New Zealand.”*



David Blackmore

Notified human cases since 1980





Environmental Science and Research Limited; Surveillance Report 2009

Leptosure®

Te Kunenga ki Pūrehuroa

MASSEY UNIVERSITY

Leptospirosis continues to place a burden on rural New Zealanders

- Our ruminant livestock are highly exposed and maintain the bacteria in kidneys
- People infected through animal urine contact
- 2010 81 notified cases
  - 75 reported occupation
    - **41 farmers**
    - 14 meat industry
  - Half hospitalised

RWNZ, Massey and leptospirosis

$87,500 raised for Lepto!

Rural Women New Zealand presented a jumbo-sized cheque to the value of $87,500 to Massey University at our national conference in Blenheim on 19 May for further research into Leptospirosis, New Zealand's most important occupationally-acquired disease.

Assoc Prof Cord Heuer and Dr Jackie Benschop of Massey University with RWNZ national president Margaret Chapman

Drs. John Kerr, Anita Bell, Chris Mansell, Keith Buswell

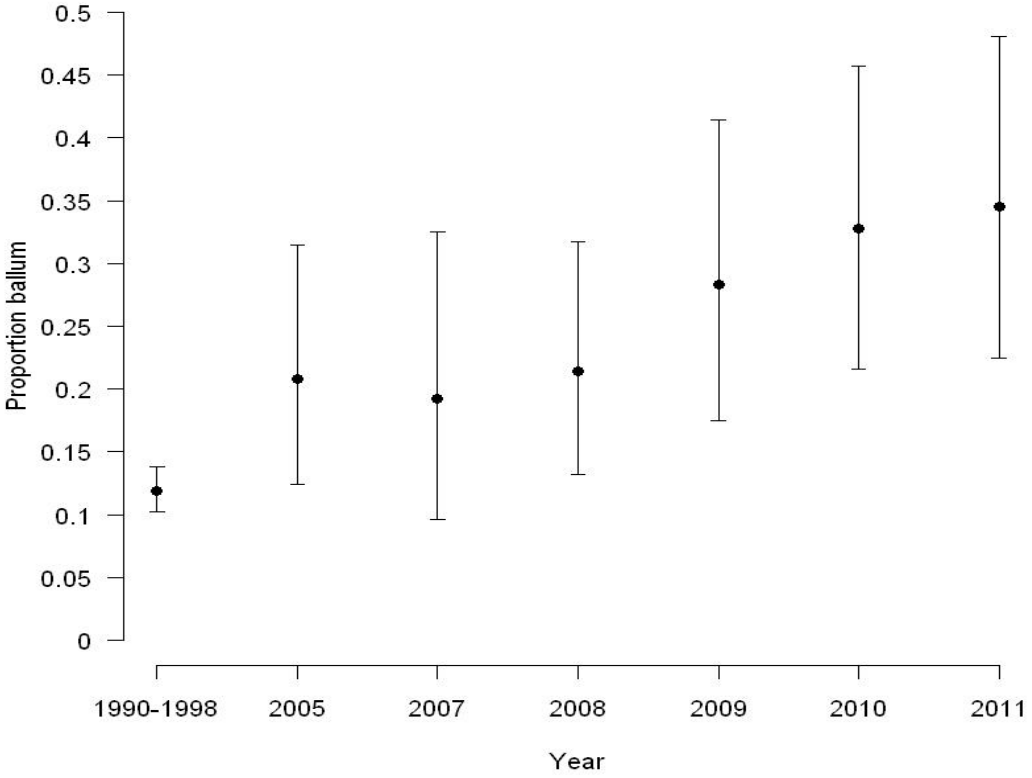
Fang Fang, Anou Dreyfus, Emilie Vallee, Alison Harland

Known endemic serovars and maintenance hosts in NZ

Genomospecies	Serovar	Maintenance host
L. interrogans	Pomona	Pig
L. interrogans	Copenhageni	Brown Rat
L. borgpetersenii	Ballum	Mouse, Black Rat, Hedgehog
L. borgpetersenii	Hardjobovis	Cattle, Deer, sheep???
L. borgpetersenii	Tarassovi	Pig
L. borgpetersenii	Balcanica (possum strain)	Possum

>180 serovars worldwide

• Human		Ballum, Hardjo, Pomona, Tarassovi, Canicola, Copenhageni
• Cattle, sheep, deer	(>50%)	Hardjo, Pomona, (Copenhageni, Ballum)
• Dog	(14.2%)	Copenhageni, Hardjo, Pomona, Ballum, Tarassovi, Canicola
• Pig		Pomona, Tarassovi
• Rodents		Ballum, Copenhageni
• Wildlife		Possum, hedgehog (Balcanica) Feral goat (Harjo, Balcanica)



Human lepto trends 2007-2011

Increasing predominance of Ballum at expense of Hardjo-bovis and Pomona

Relatively more farmers compared to meatworkers in recent years

Data source: Thornley *et al* 2002 and ESR

Feral animals

Mouse, rat
Possum
Hedgehog
Rabbit
Deer
Goat
Pig

Reservoirs

Beef cattle
Sheep
Deer
Dairy cattle
Dog, pig

Vectors

Environment

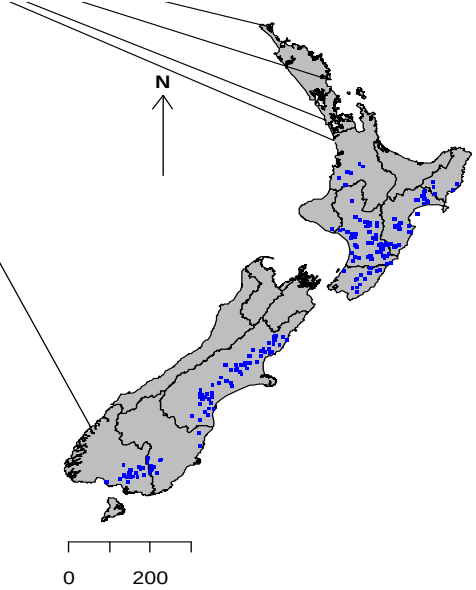
Floods on pasture
Ponds
Drains
Rivers

Co-factors

[+ Rain + temperature + fencing]

People
[occupation, behaviour]

Livestock prevalence



- Previous: slaughter stock
  - 44% lamb slaughter lines
  - 85% deer slaughter lines
  - 71% beef breeding herds
- Urine shedding at slaughter: 31% for sheep, 21% for cattle
- New data adult breeding stock (238 farms, 20 animals/mob):

Dreyfus et al. unpublished

	Farms	Hard	Pom	H or P	Animals	Hard	Pom	H or P
Beef	116	92%	72%	97%	2,308	50%	25%	58%
Deer	98	60%	49%	76%	1,992	26%	10%	34%
Sheep	161	91%	74%	97%	3,361	43%	14%	51%
Total	375	83%	67%	92%	7,661	41%	16%	49%

Dairy cattle prevalence

Parramore et al. 2011, unpublished

	# Sampled	# Shedding	%
Herds	44	13	30%
Cows	445	18	4%
Cows in pos herds	134	18	13%

Production effects: Beef cattle

- Linked to willingness to vaccinate...
- Clinical disease: rare (jaundice, haemoglobinuria)
  - Outbreaks: 22 / 1,061 (2.1%)
- Growth and weaning rates
  - ?? Current study
- Foetal loss
  - Associated with both Hardjo and Pomona
  - 9.1% of all foetal loss attributable to Hardjo or Pomona

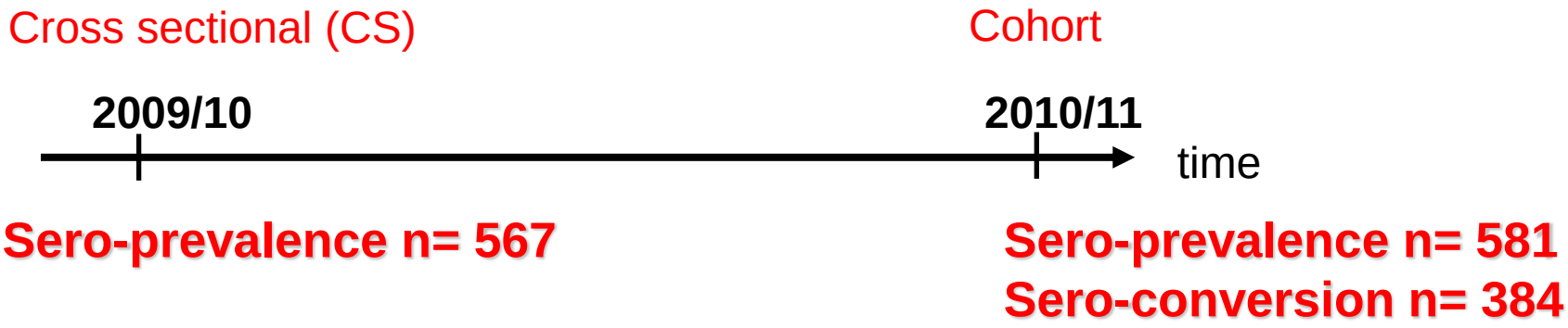
(Sanhueza et al, 2012)

Meat worker study design

Bi-annual interview & blood sampling

of ≈ 600 meat workers

8 meat plants (sheep, deer, cattle)



Key findings meat worker study (current and new infections)

Worker position a risk factor

PPE may not protect

12% new infection risk over one year

- 384 were negative 2010
- 47 of these had became positive by 2011
  - Of these 47, 1 was diagnosed with lepto
  - However half of these 47 (22) reported a flu-like illness and had a median of 4.4 days off work
  - Can quantify under-reporting and disease burden

Sheep:

Lambs (13%)

Ewes (56%)

??

H or P 12.2%
Har (3.6%)
Pom (9.4%)

384 workers

New infection	non-infected
47 (12.2%)	337

Flu-like disease

22 (46.8%)	82 (24.3%)

Risk of disease due to Lepto:
1 in 36 per year (4.4 days ill)

Notified Lepto incidence:
1 in 1,714 per year

→ underreported: x 47

Dreyfus et al. 2012, unpublished

Canine Leptospirosis in NZ

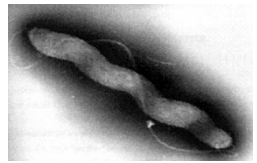
- Exposure to Copenhageni common
- Acute infection usually is infrequent
  - Currently are a number of local cases
  - Vets from Taranaki/Hawkes Bay/Rangitikei and Tararua have reported cases of acute leptospirosis in dogs in the last couple of months – Pomona is the serovar implicated so far.
- Canine vaccination (Icterohaemorrhagia) cross protects for serovar Copenhageni only

Lepto in Context

- High endemic level in sheep, cattle and deer → high human exposure
- Changing ecology → shift in host – serovar balance
- Little knowledge about wildlife reservoirs
- Uncertainties about vaccination of animals → NZVA review of best practice recommendations
- Real impact on human disease underestimated
- Prevalence data required for farmers, vets etc → identification of infection sources

Campylobacter

- Diarrhoea (98%), abdominal pain (92%), fever (85%), vomiting (39%), bloody diarrhoea (33%)
- 7.6% cases hospitalised (2004)
- Complications
  - Guillain Barré / Miller Fischer/ RA



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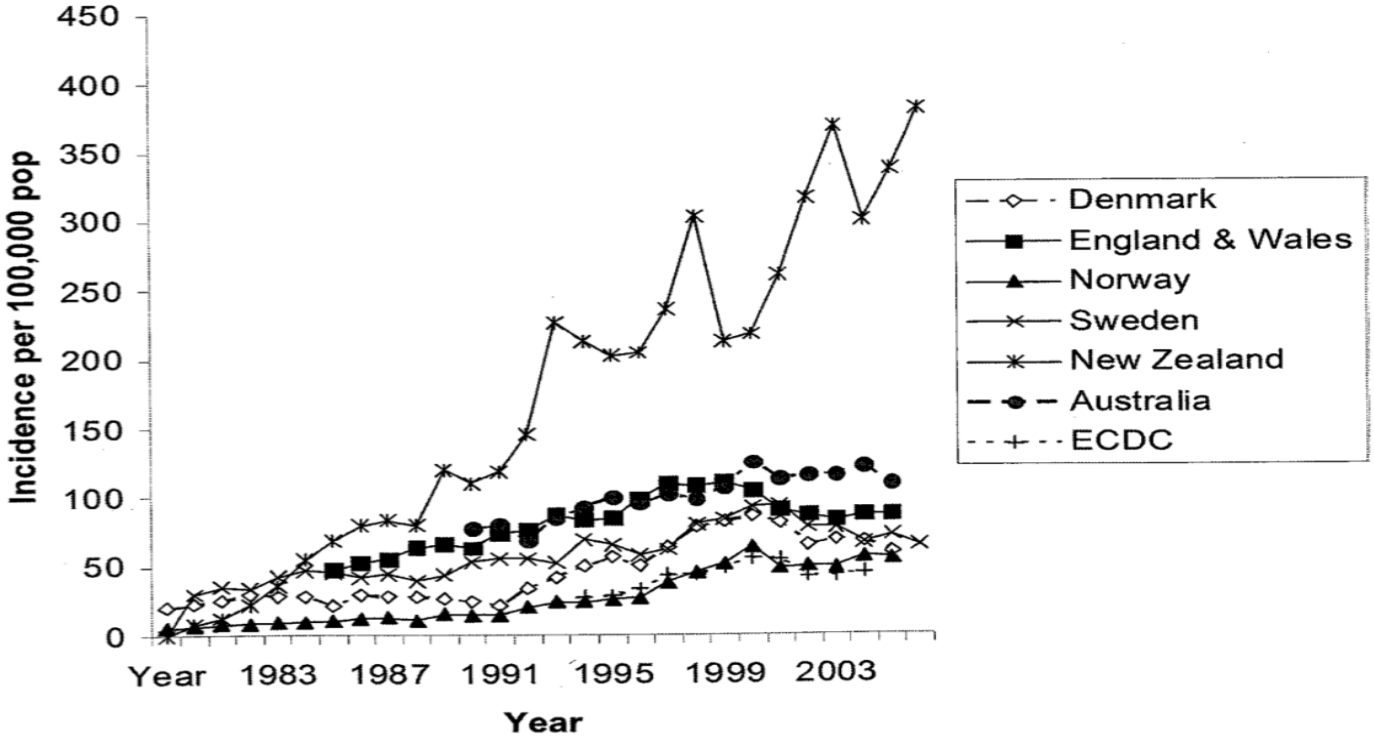
Campylobacteriosis



Source: Olsen et al Campylobacter. 3rd ed. Washington DC: ASM Press; 2008 .

The economic cost of foodborne disease in New Zealand

Prepared for:
NEW ZEALAND FOOD SAFETY AUTHORITY

November 2010

Applied Economics

Table 6: Central estimates of the treatment cost of incident cases of foodborne disease, 2009 incident cases

Disease	No incident cases	Cost during 2009, $m	Cost after 2009 $m[1,2]	Unit treatment cost per case, $[1,2]	Total lifetime treatment cost, $m[2]
Campylobacteriosis	41,262	2.13	0.04	52.69	2.17
Salmonellosis	2,741	0.19	0.00	71.23	0.20
Norovirus	138,204	1.45	0.00	10.49	1.45
Yersiniosis	4,699	0.12	0.00	24.53	0.12
STEC	210	0.38	1.17	7,202.38	1.51
Listeriosis	23	0.74	0.00	32,313.38	0.74
TOTAL	187,139	5.01	1.18	33.08	6.19

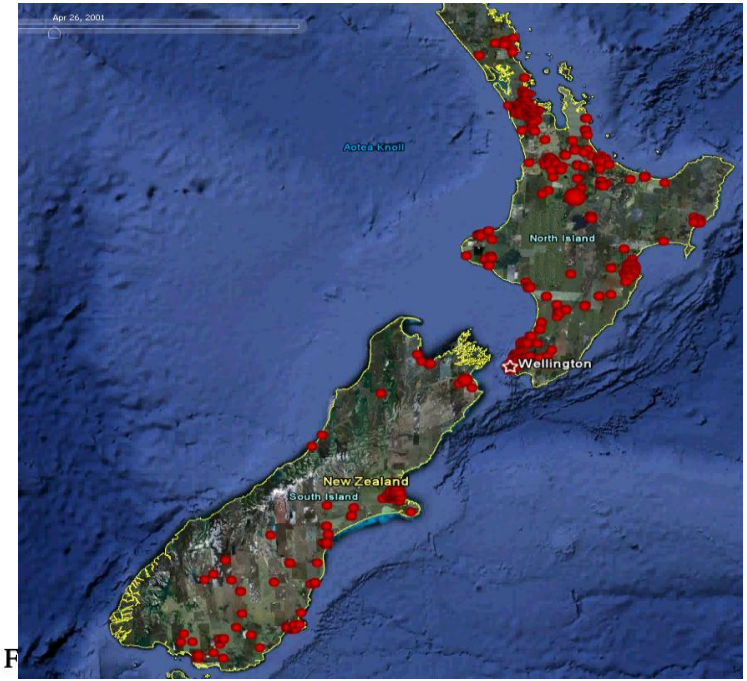
Campylobacter $36 million or 27% of all disease-specific costs—followed by salmonellosis ($15.4 million, 12%).

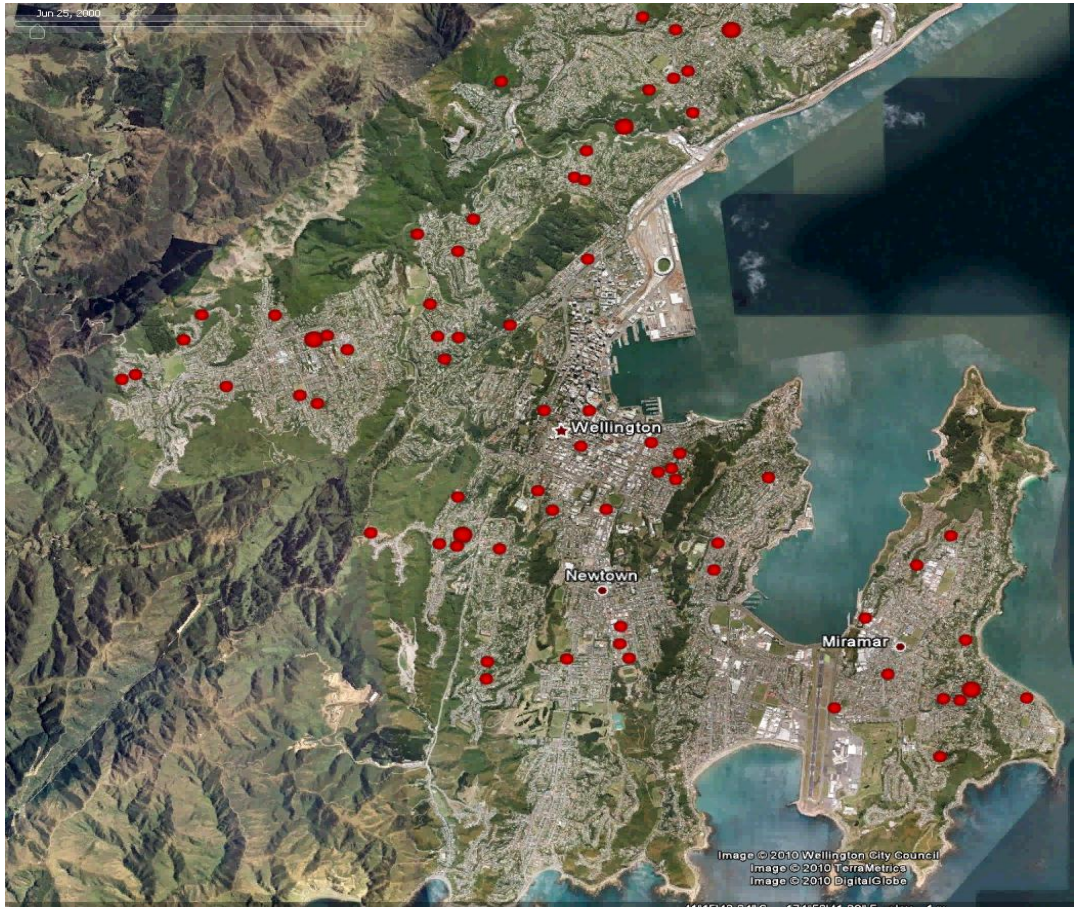
STEC, although rare, accounted for $14.6 million (11%) of total cost of food borne disease

Campylobacter from space...

Google Earth 2000-10

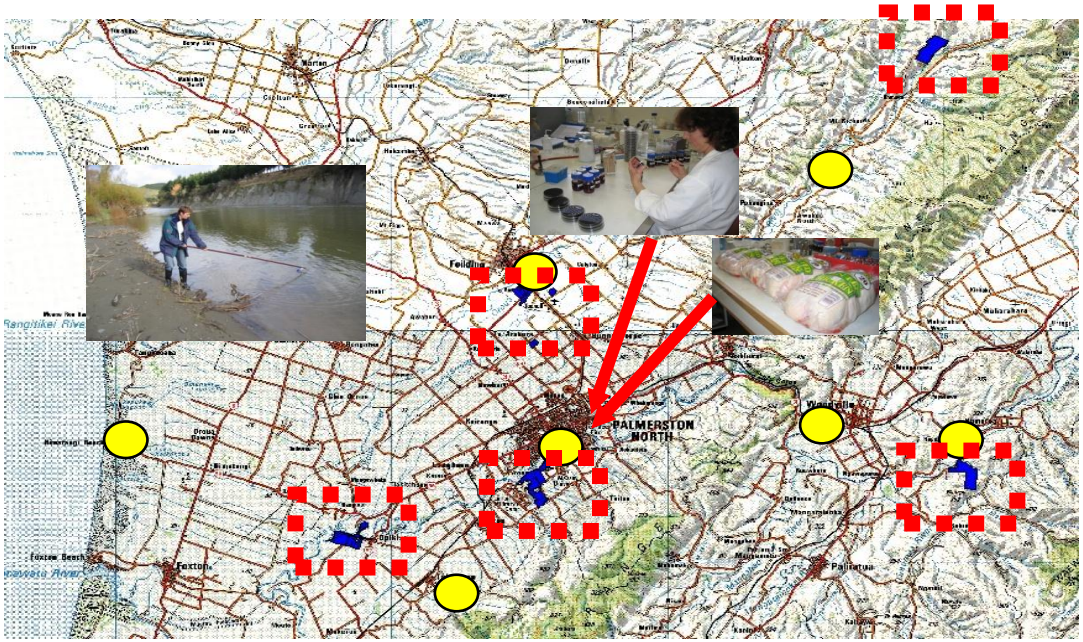
110,000 cases





Setting up a sentinel site

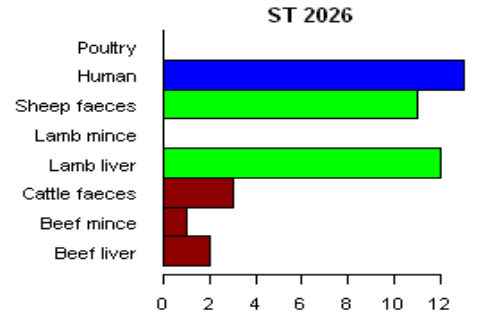
- Collaboration
  - MedLab Central
  - MidCentral Public Health Unit
  - Human health surveillance unit: ESR
  - Industry bodies
  - Dairy and sheep farmers
  - Regional council
  - Institutes at Massey
  - Regulator: NZFSA

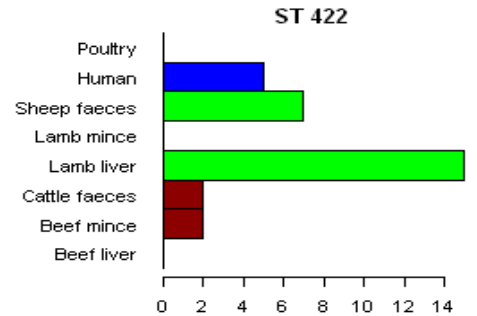


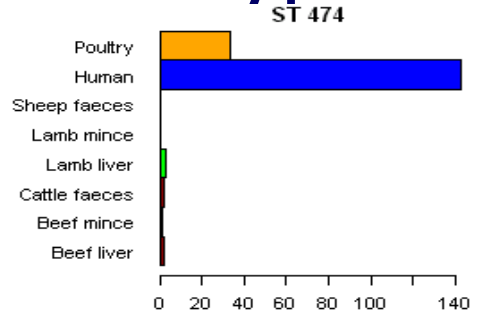
Manawatu study 2005-2012

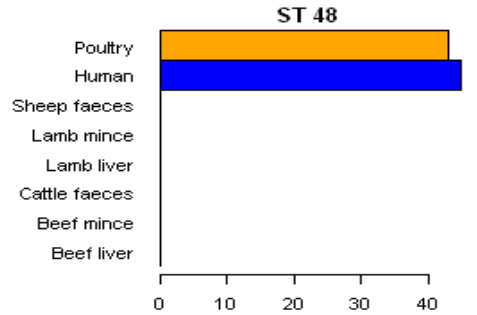
Host associated sequence types in NZ

Ruminant associated





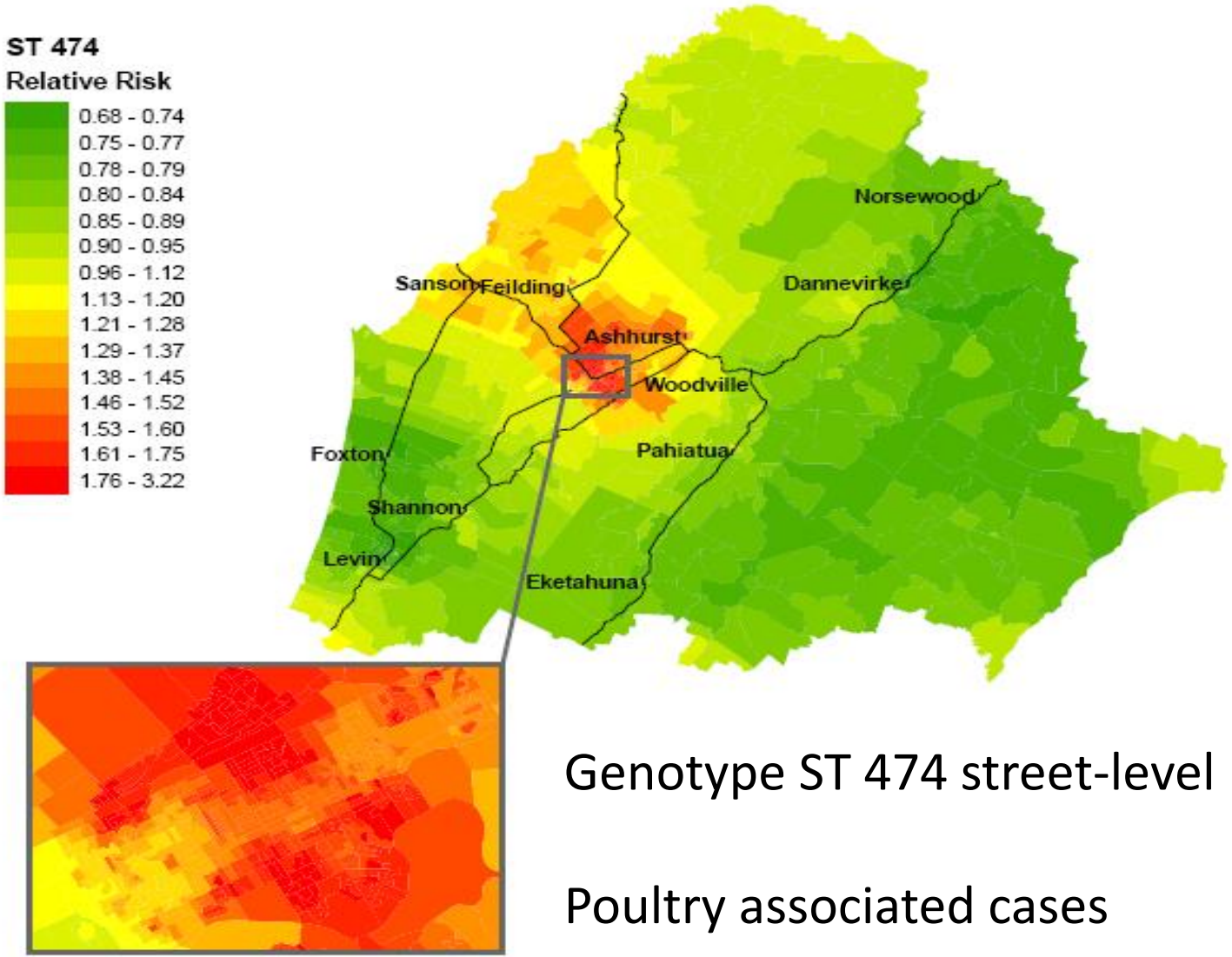




Poultry associated

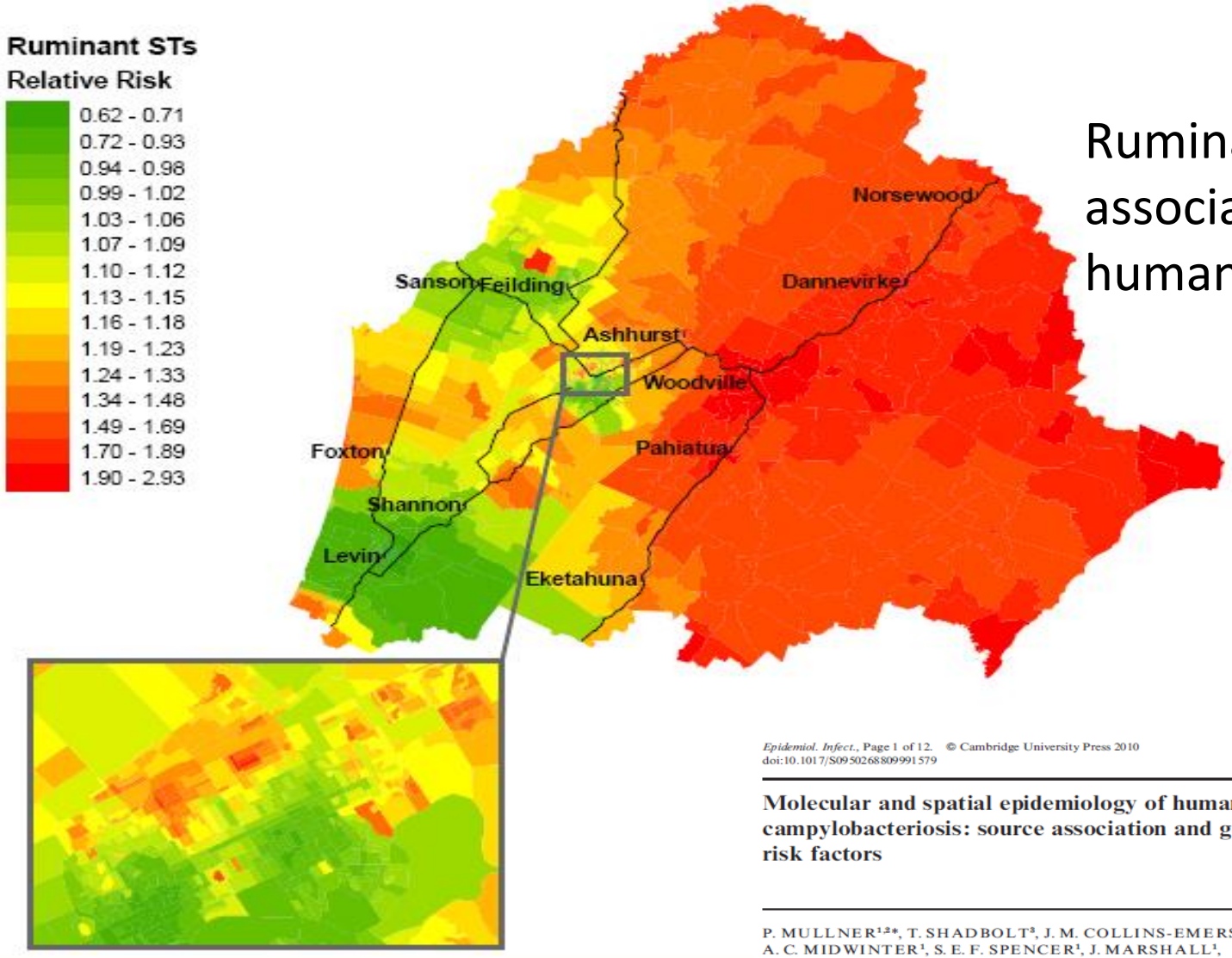
Forever dis

UNIVERSITY



Genotype ST 474 street-level pattern

Poultry associated cases



Ruminant-associated human cases

Epidemiol. Infect., Page 1 of 12. © Cambridge University Press 2010
doi:10.1017/S0950268809991579

Molecular and spatial epidemiology of human campylobacteriosis: source association and genotype-related risk factors

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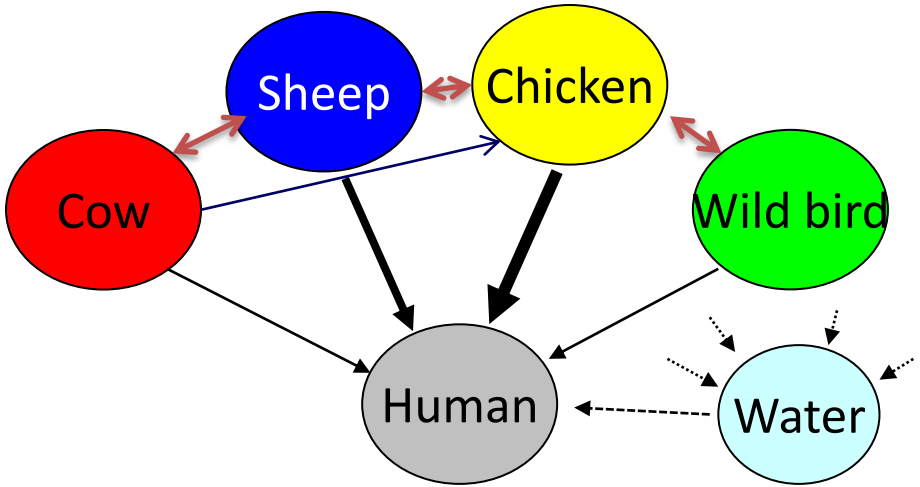
Evolutionary modelling

- Population genetics approach
- Used to find out source of human infections



OPEN ACCESS Freely available online

PLoS GENETICS

Tracing the Source of Campylobacteriosis

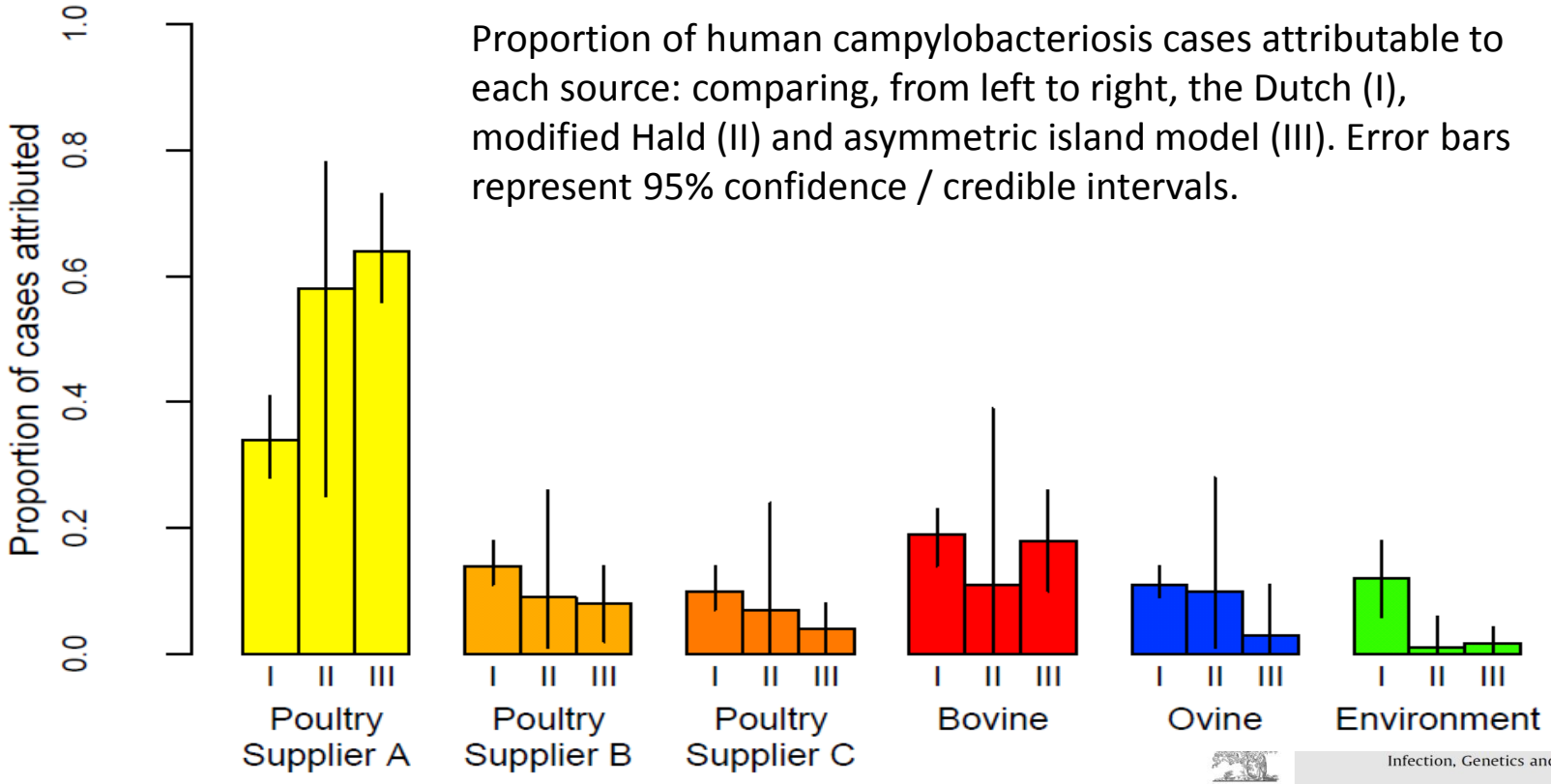
Daniel J. Wilson[1¤a*], Edith Gabriel[2¤b], Andrew J. H. Leatherbarrow[3], John Cheesbrough[4], Steven Gee[4], Eric Bolton[5], Andrew Fox[4,5], Paul Fearnhead[1], C. Anthony Hart[6†], Peter J. Diggle[2]

Forever discovering

Ki Purehuroa

MASSEY UNIVERSITY

Source attribution (Mullner et al)



Proportion of human campylobacteriosis cases attributable to each source: comparing, from left to right, the Dutch (I), modified Hald (II) and asymmetric island model (III). Error bars represent 95% confidence / credible intervals.

Infection, Genetics and Evolution
journal homepage: www.elsevier.com/locate/meegid

Assigning the source of human campylobacteriosis in New Zealand: A comparative genetic and epidemiological approach

Petra Mullner[a,b,*], Simon E.F. Spencer[a,1], Daniel J. Wilson[c], Geoff Jones[d], Alasdair D. Noble[d], Anne C. Midwinter[a], Julie M. Collins-Emerson[a], Philip Carter[e], Steve Hathaway[b], Nigel P. French[a]

Marked Campylobacteriosis Decline after Interventions Aimed at Poultry, New Zealand

Ann Sears, Michael G. Baker, Nick Wilson, Jonathan Marshall, Petra Muellner, Donald M. Campbell, Robin J. Lake, and Nigel P. French

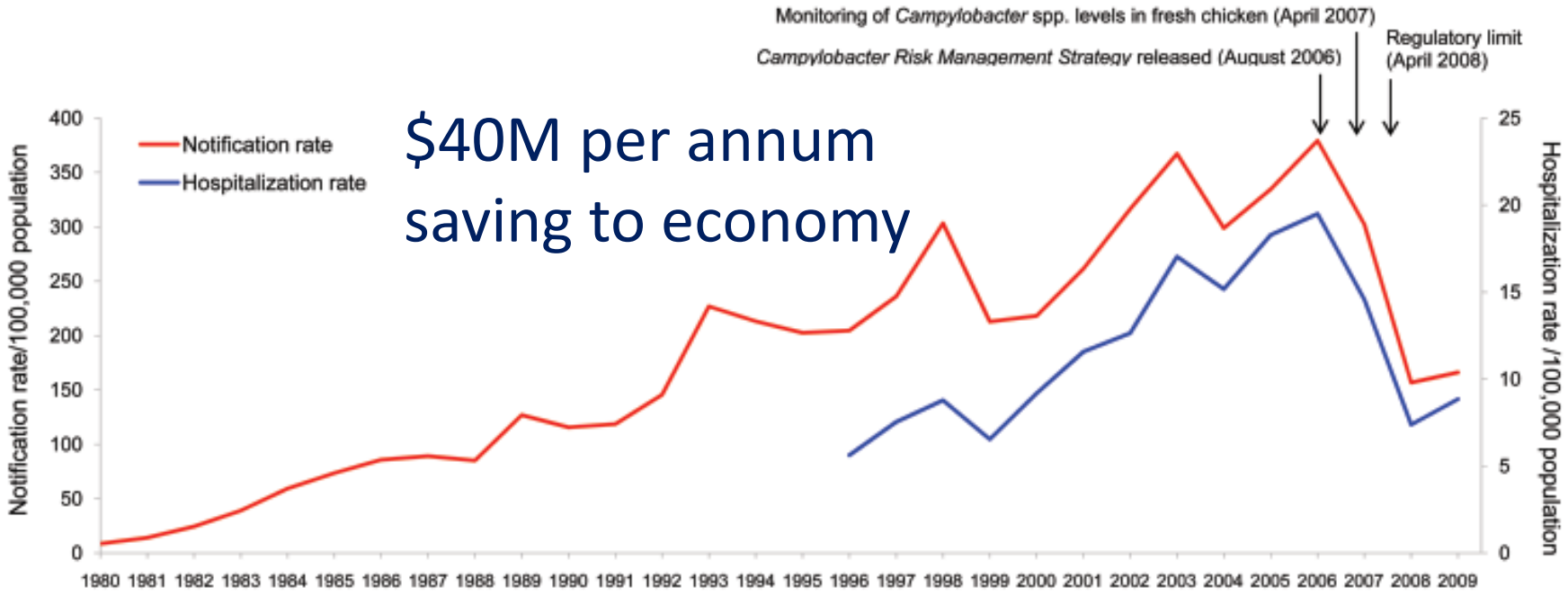
Emerging Infectious Diseases • www.cdc.gov/eid • Vol. 17, No. 6, June 2011

NEW ZEALAND FOOD SAFETY AUTHORITY

Campylobacter in Poultry – Risk Management Strategy 2007 - 2010

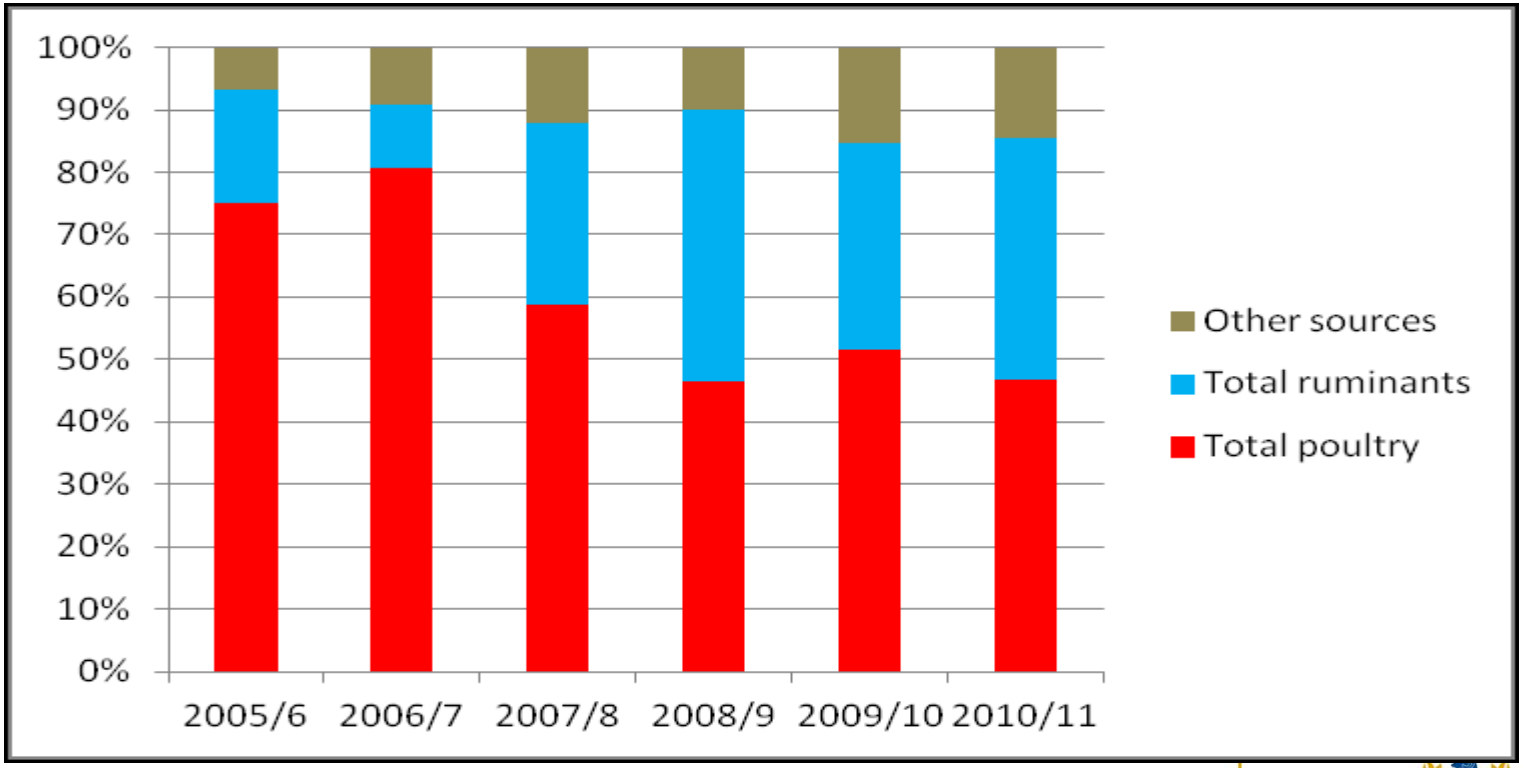
…2006-2009, now 2010-2012

Relationship between campylobacteriosis notifications and hospitalisations (A. Sears)



Data Sources: ESR Ltd notification data; NZHIS hospitalisation data (filtered)

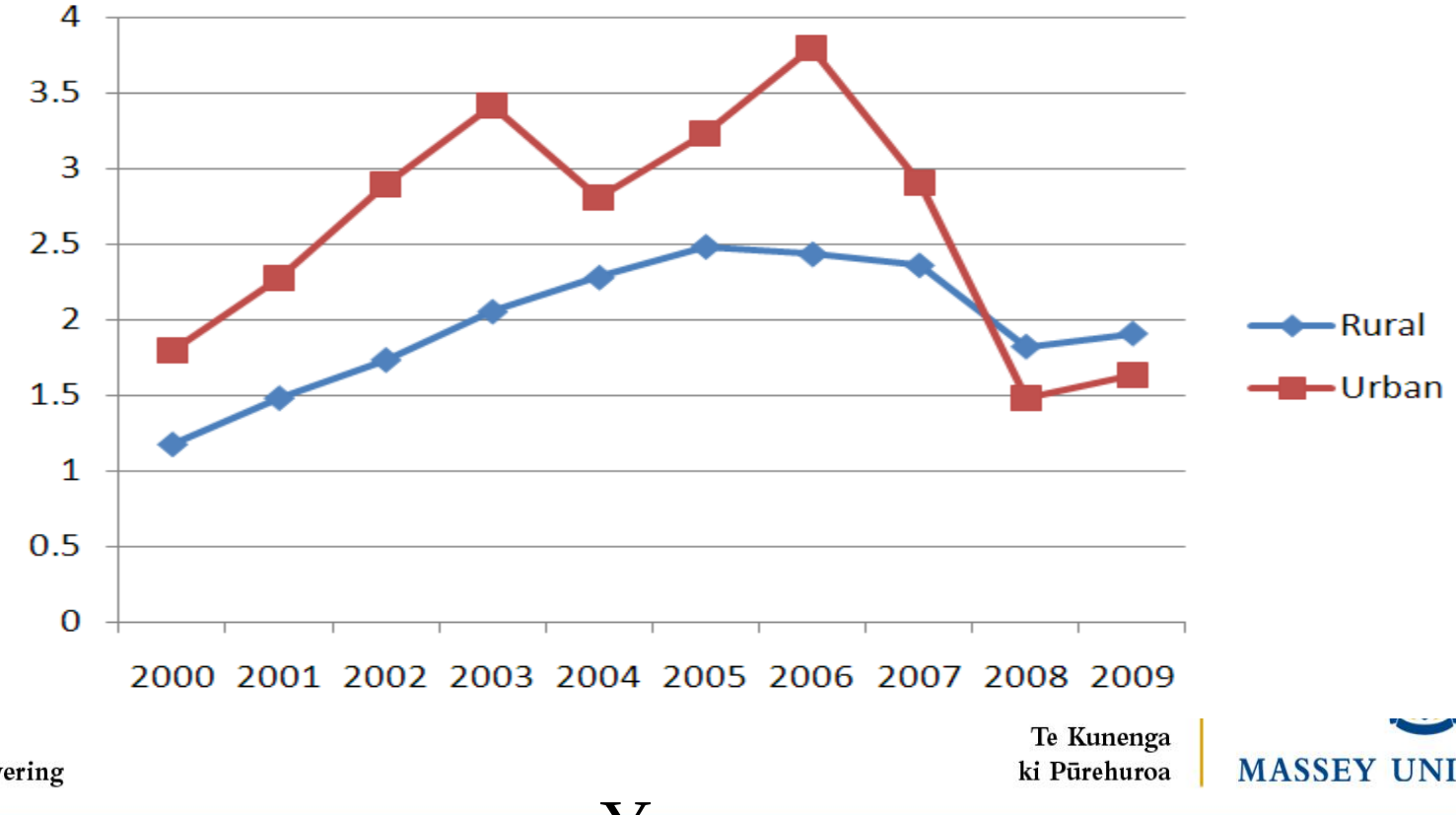
Change in source of infection



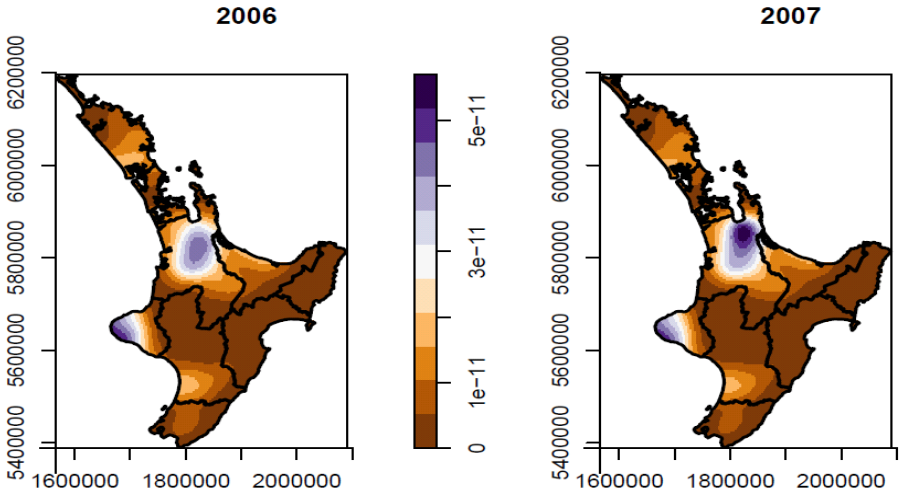
Time in years

Changing epidemiology presents new challenges

Rates: Number of cases per 1000 people



Why different epidemiology in rural areas?



	Rural	
Variable	Coeff	P value
Sheep density	-0.028	0.88
Dairy density	6.216	<0.0001
Social Deprivation Index	-0.07956	<0.0001

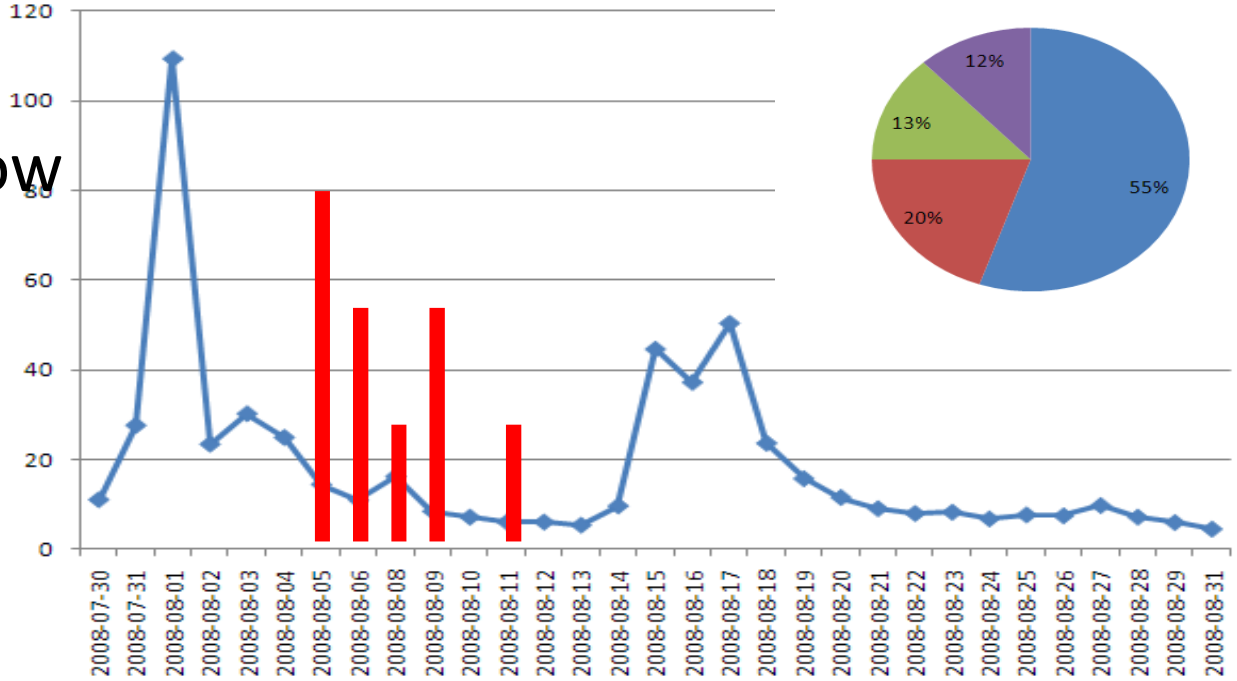
Models showed strong correlation with density of dairy cattle in rural areas

Raw milk cluster

Sampled Date	ST	Sex	Age Group	Ethnicity Grouping	Occupation	Probable food source
18-Aug-10	520	Male	0-5	European only	Toddler	
27-May-11	520	Male	20-29	European only	Maintenance Worker	Unpasteurised milk
23-May-11	520	Male	70+	European only	Resthome Resident	Unpasteurised milk
26-May-11	520	Female	70+	European only	Retired	Unpasteurised milk
27-May-11	520	Female	50-59	European only	Unknown	Unpasteurised milk
02-Jun-11	520	Male	50-59	European only	Truck Driver	Unpasteurised milk
02-Jun-11	520	Female	40-49	Maori only	Shop Assistant	Unpasteurised milk
02-Jun-11	520	Male	40-49	European only	Mechanic	Unpasteurised milk
07-Jun-11	520	Female	20-29	European only	Student	Unpasteurised milk

Tararua outbreak in 2008

Water flow



ST 190

Episury

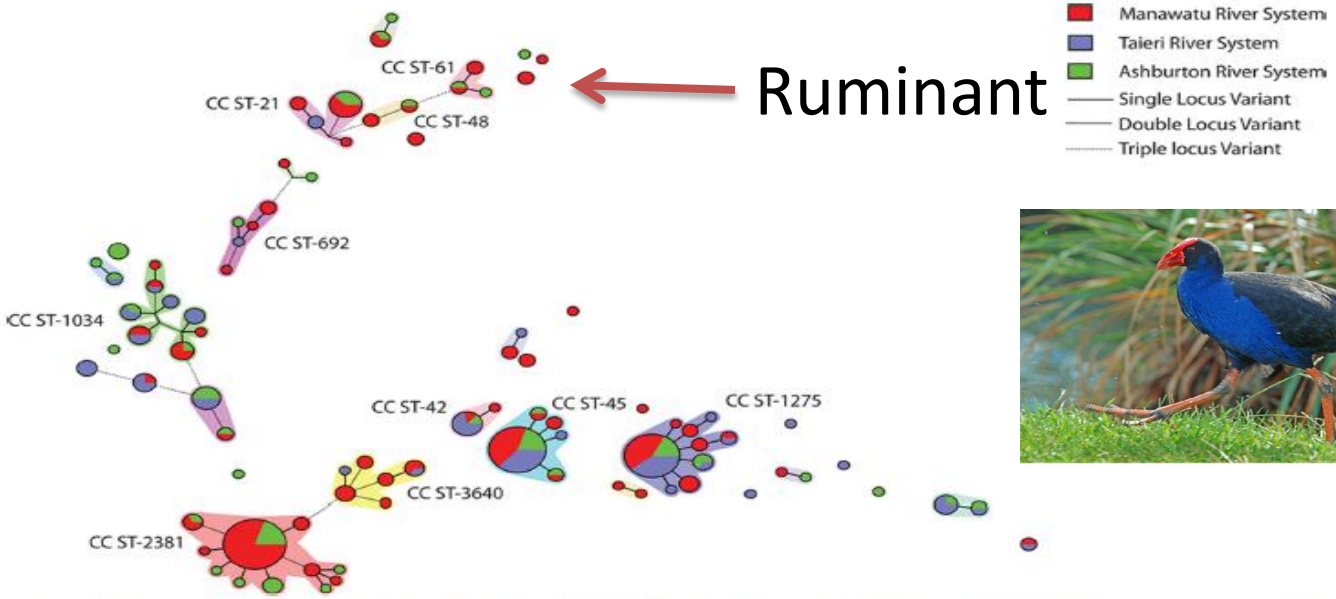
Lab ID	ource Typ	ST	OnsetDt	Outbrk	CurrWSCode	CurrWSSpec
H775	Human	61	20/07/200	No	PAH001PA	
H791	Human	190	5/08/2008	No	PAH001PA	Muddier than usual"toxic in it's self"
H787	Human	190	5/08/2008	No	PAH001PA	smells of dirt, brown
H788	Human	190	5/08/2008	No	PAH001PA	water been brown, "crap"
H804	Human	3793	6/08/2008	Yes	PAH001PA	
H803 D	Human	50	6/08/2008	No	PAH001PA	
H795	Human	190	7/08/2008	No	PAH001PA	
H798	Human	50	9/08/2008	Yes	PAH001PA	
H801	Human	61	9/08/2008	Yes	PAH001PA	

Manawatū River

APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Oct. 2009, p. 6038–6046 Vol. 75, No. 19
0099-2240/09/$08.00+0 doi:10.1128/AEM.01039-09

Novel Clonal Complexes with an Unknown Animal Reservoir Dominate *Campylobacter jejuni* Isolates from River Water in New Zealand[▽]

P. E. Carter,[1]* S. M. McTavish,[1]† H. J. L. Brooks,[2] D. Campbell,[3] J. M. Collins-Emerson,[4] A. C. Midwinter,[4] and N. P. French[4]

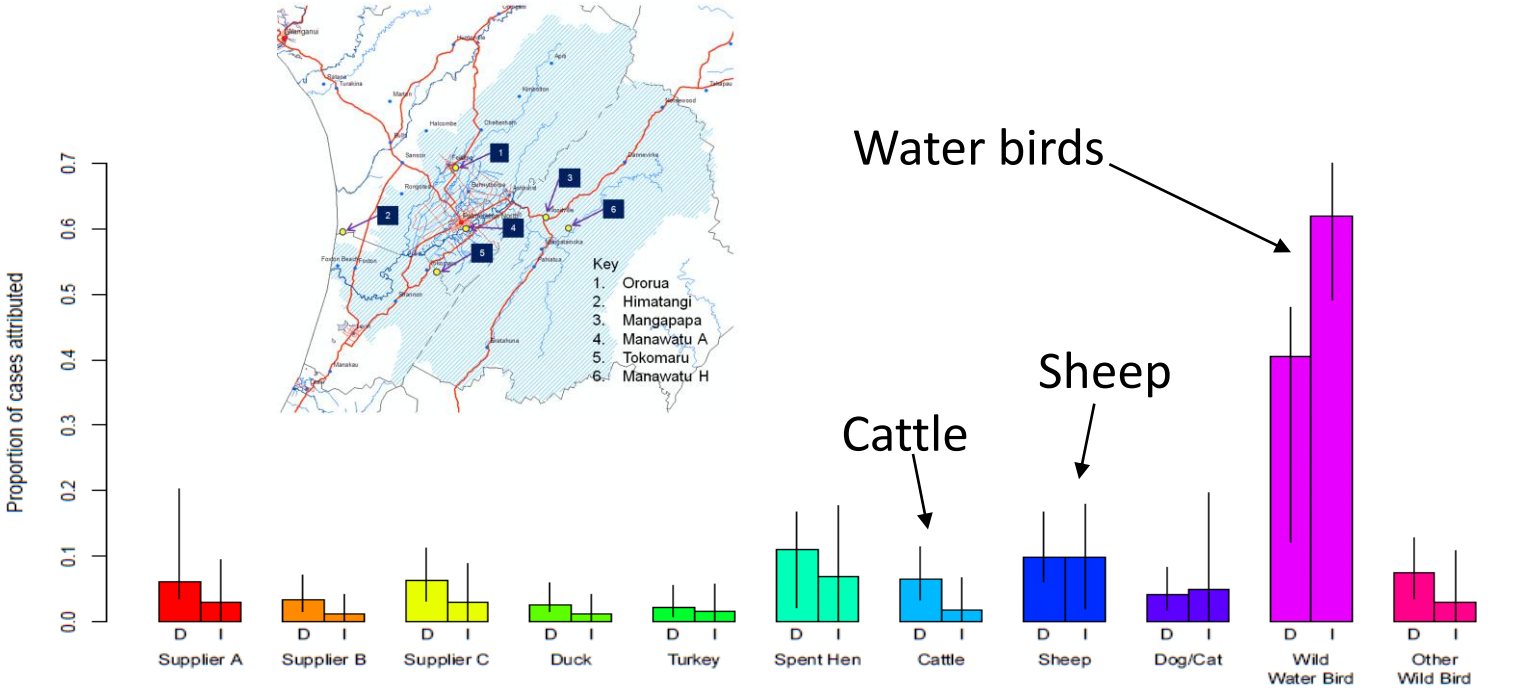


Ruminant

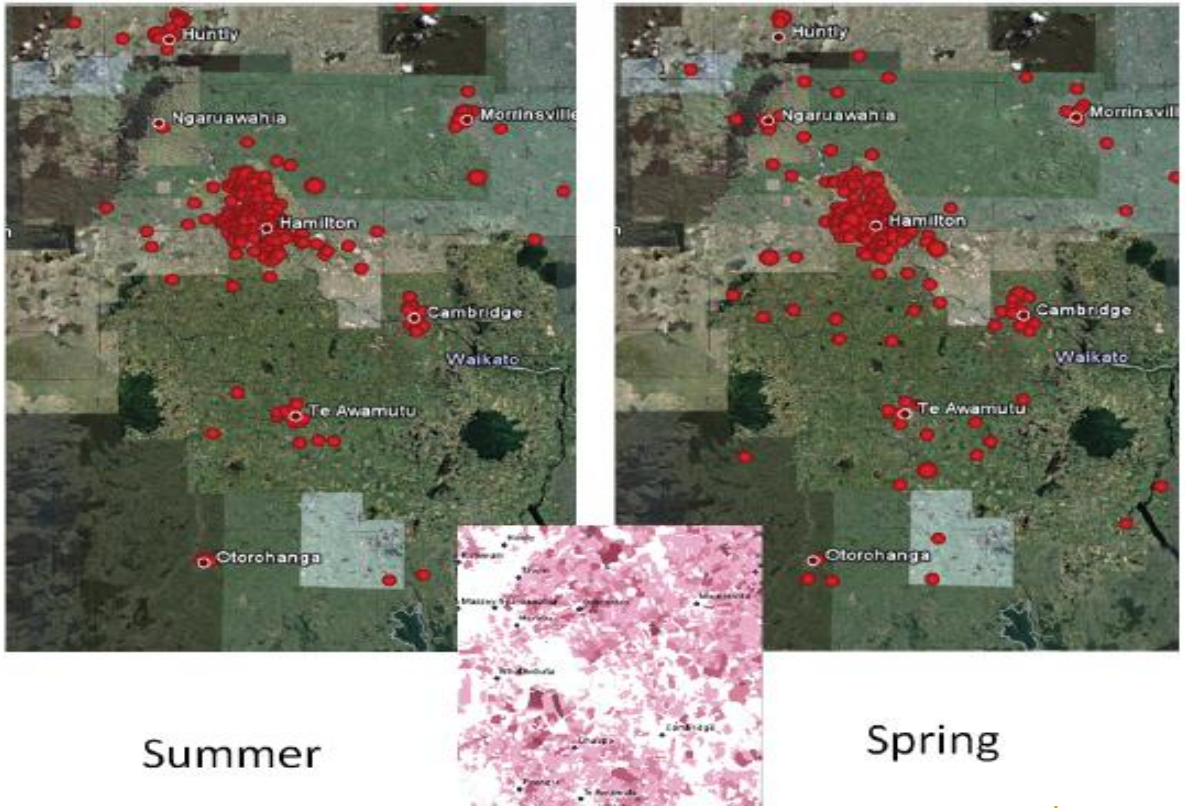
FIG. 1. Minimum spanning tree of New Zealand water isolates based on sequence types. Clusters are identified by the clonal complex number sociated with the sequence types in the cluster.

Campylobacter source attribution: water

Most bacteria from water in Manawatu associated with wildlife – even in dairy catchments

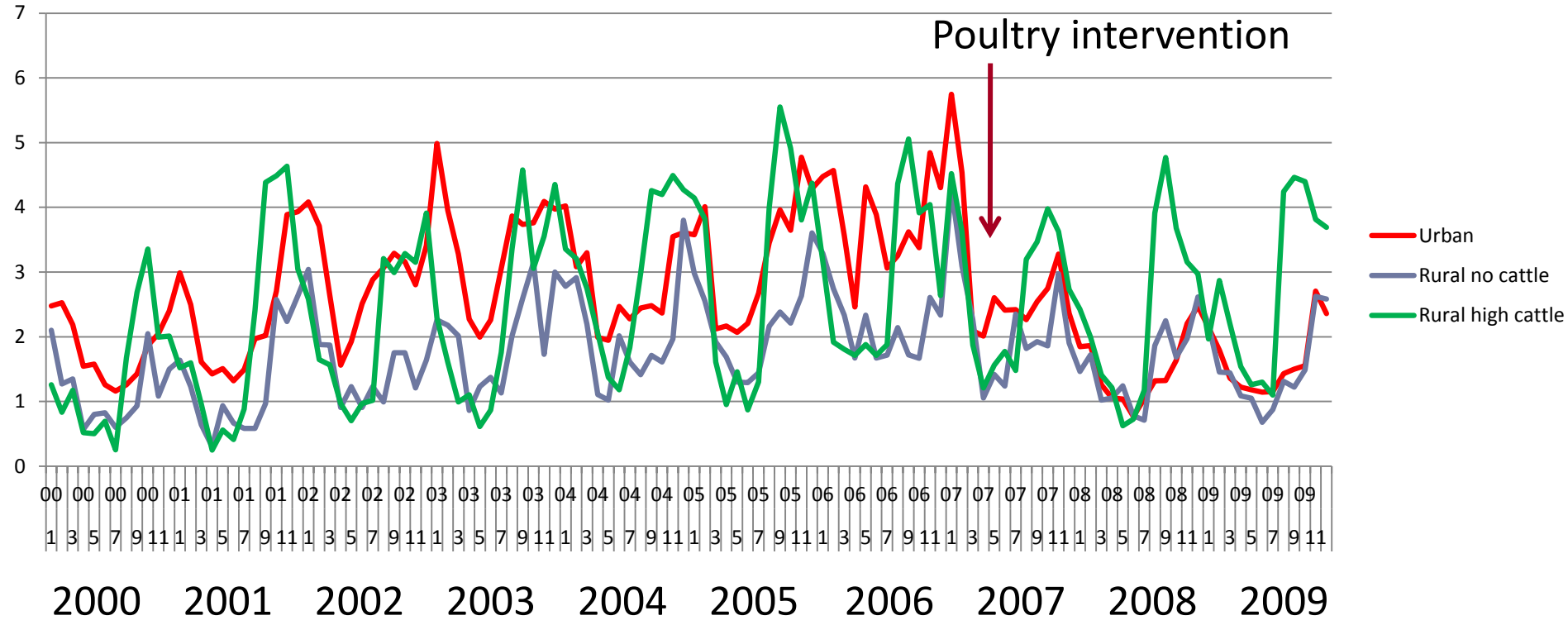


Waikato human cases 2000-2009

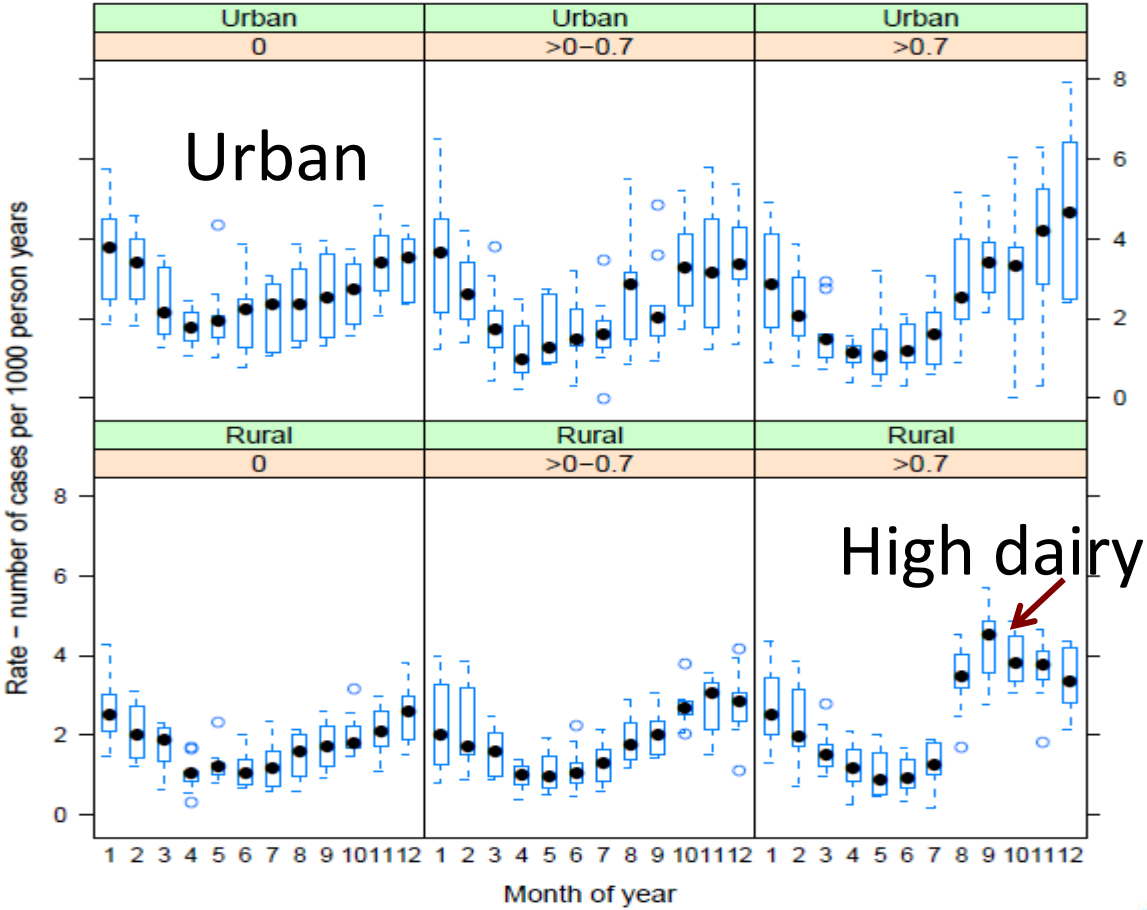


Summer

Spring


Poultry intervention
Urban
Rural no cattle
Rural high cattle
0
1
2
3
4
5
6
7
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009

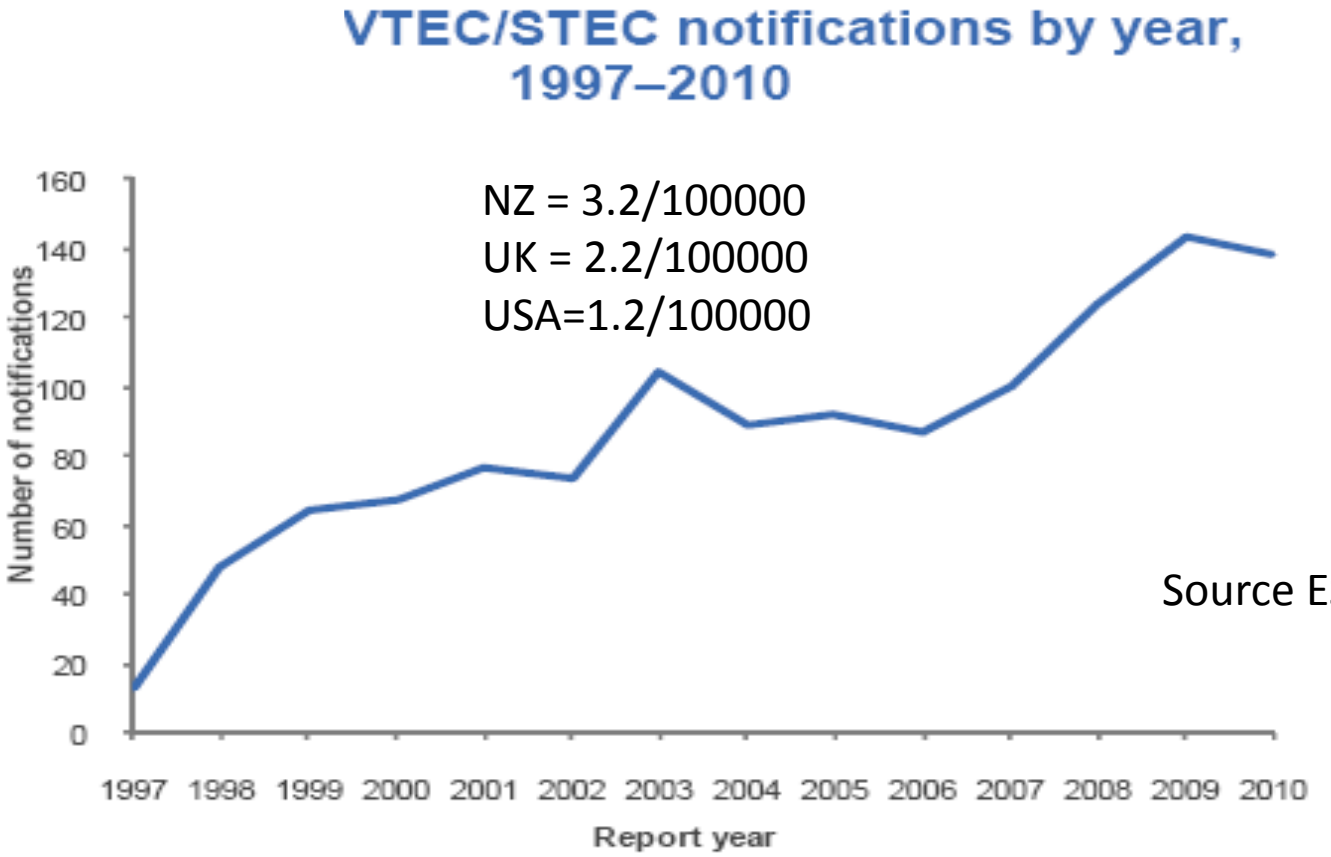
Seasonality and dairy density



Cattle-associated cases

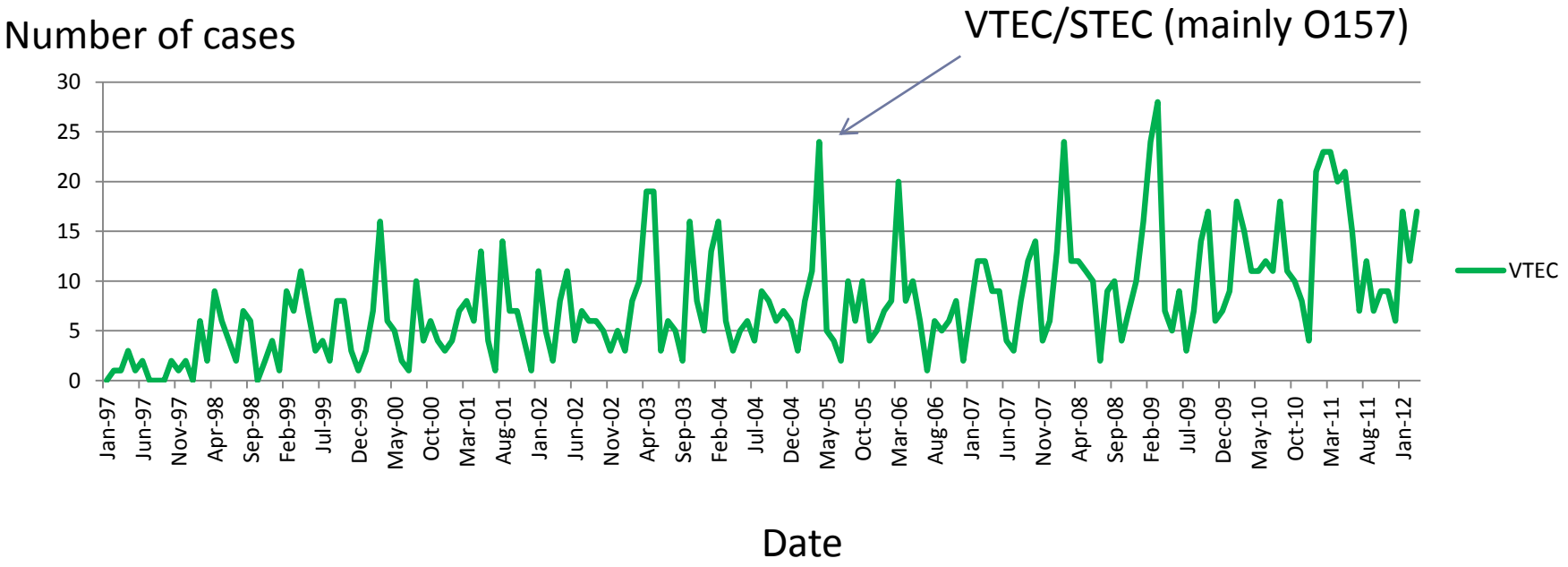
- Young children
- During calving season
- Direct contact?
- Epidemiology changed
  - Different set of policy and decision makers
  - Different stakeholders

Human STEC Cases in NZ / 100,000 population



Source ESR Ltd

Recent trends in notified cases



23/05/2011
Increase in BD/HUS reported to ECDC
Daily reporting of HUS requested

B

10/06/2011
Source "confirmed" as beansprouts (epi and culture)
Public warning issued regarding consumption of sprouts.

C

Decisions made

20/05/2011
Outbreak investigation initiated

25/05/2011
ECDC issue cucumber warning

6/06/2011
Beansprouts suspected from cohort and C-C studies

22/06/2011
HUS/BD outbreak in France
8 cases notified

19/05/2011
RKI informed of 'small' cluster of HUS

1/06/2011
EC lifts warning on Spanish cucumbers

15/07/2011
Total number of deaths revised to 41

Dec 2009

1/05/2011

1/06/2011

1/07/2011

27/07/2011

A

13/05/2011
Peak in exposure

2/05/2011
Onset date for first case in Germany

8/06/2011
O104 buffet at community centre in France

30/05/2011
Development of rapid multiplex PCR and whole genome sequencing begins

26/05/2011
PFGE of 5 isolates confirm linked to one event

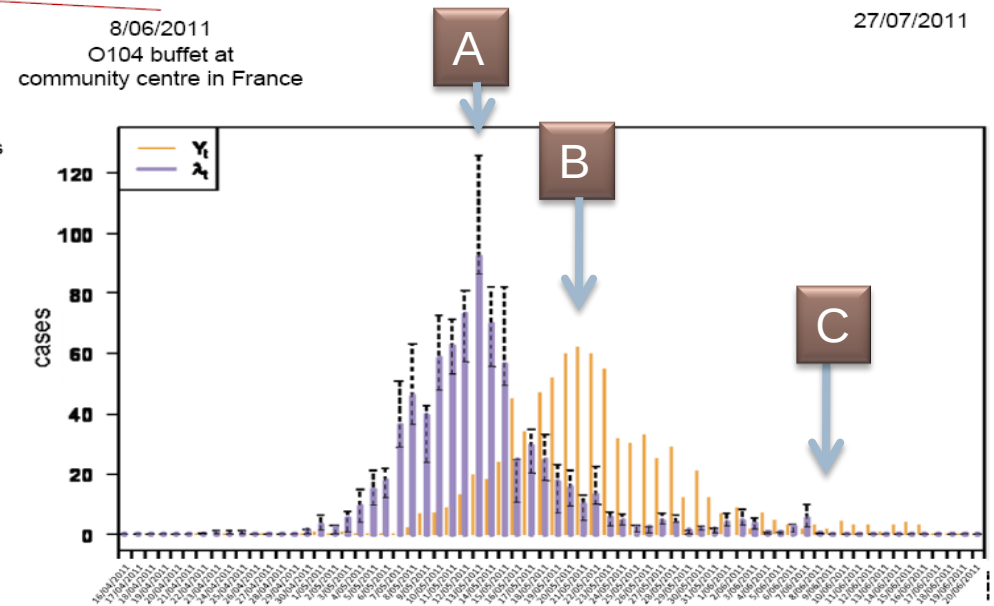
23/05/2011
Peak in epidemic: onset date diarrhoea

2 isolates identified as stx2 +ve eae -ve

B

25/05/2011
Confirmed as O104:H4 stx2a+, eae-,hly-, ESBL MLST 678

24/05/2011
Isolates confirmed as O104 serotype



Epidemiological and microbiological events

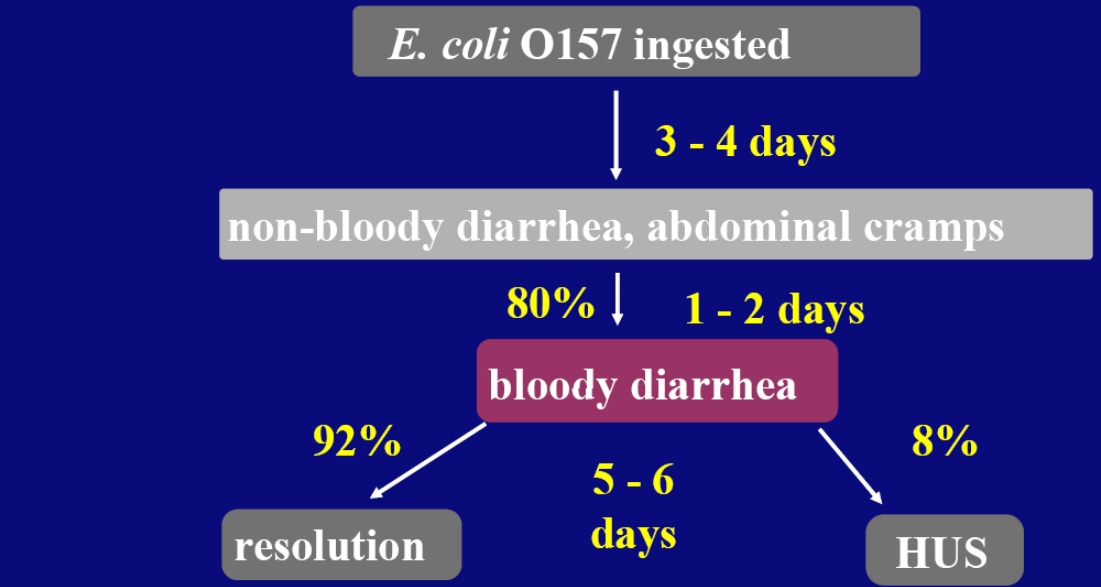
Pathogenesis & Clinical Signs : EHECS

- Humans: O157/H7
  - haemorrhagic colitis (HC)
    - *E. coli* attach to and destroy enterocytes
    - severe & painful haemorrhagic diarrhoea
  - haemolytic-uremic syndrome (HUS)
    - *E. coli* secrete Shiga toxins
    - toxins gain access to blood stream & body tissues → systemic complications
      - renal failure: destruction of renal endothelial cells
      - haemolytic anaemia & thrombocytopenia
        - thrombocytopenic purpura (TTP)

Pathogenicity

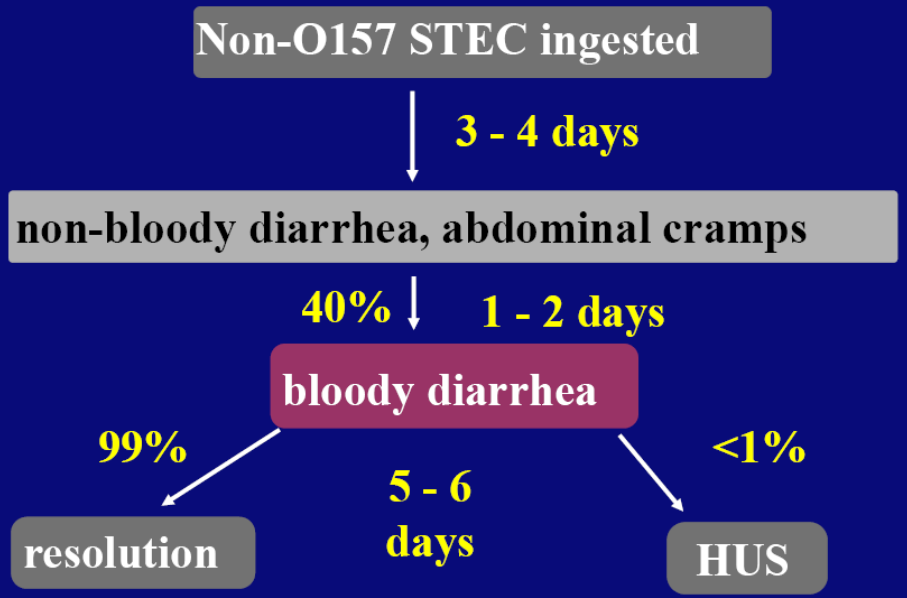
- E. coli can cause human disease when they possess *stx*1 or *stx*2.
- Individuals infected with strains producing *stx*2 more likely to develop severe disease than those infected with strains carrying Shiga toxin 1.
- Thought that E. coli must contain *stx*1 or *stx*2 and *eae* (intimin) and its substitutes to have the highest chance of causing disease in humans

Sequence of events in *E. coli* O157:H7 infection

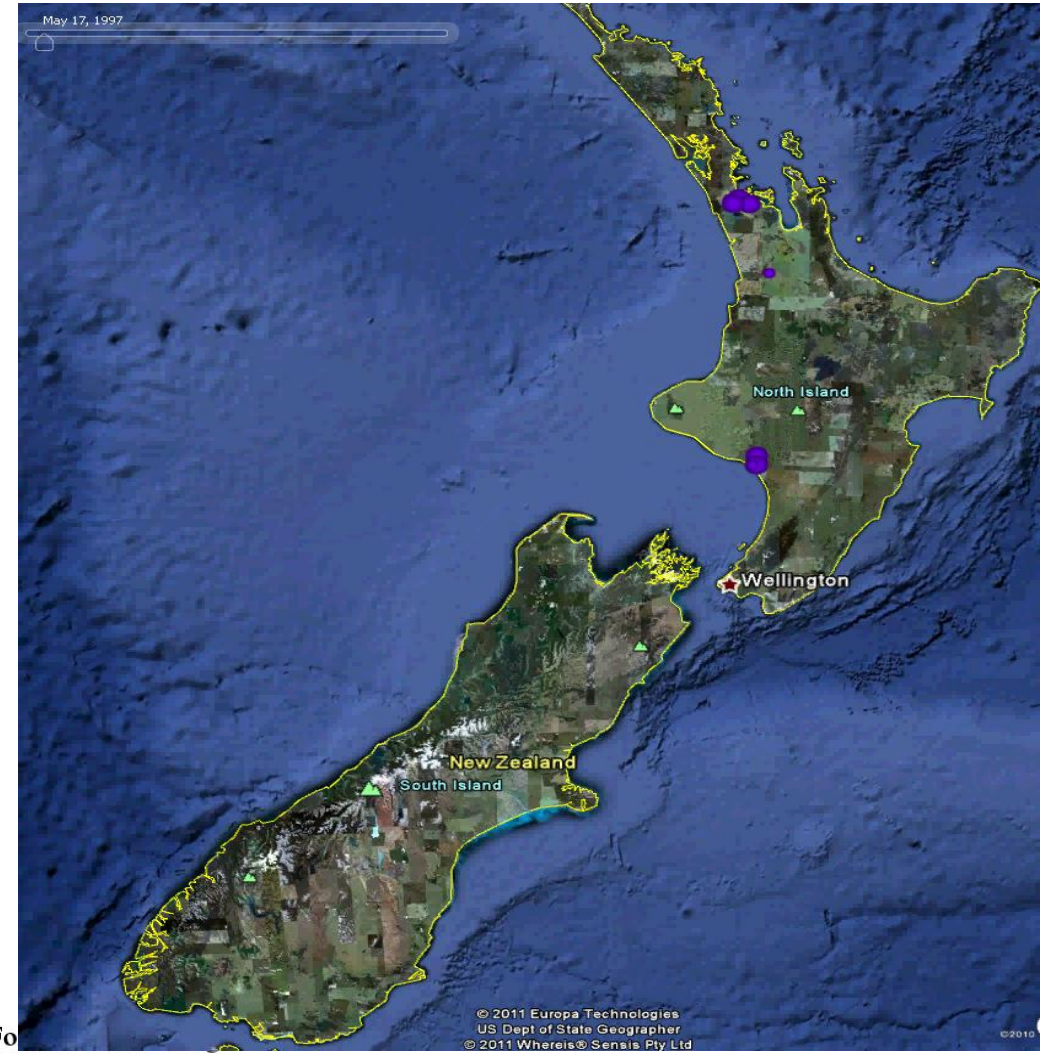


Mead. Lancet 1998

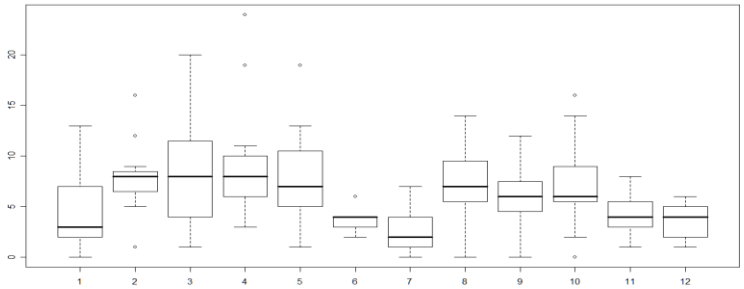
Sequence of events in Non-O157 infection



CDC



VTEC: the movie

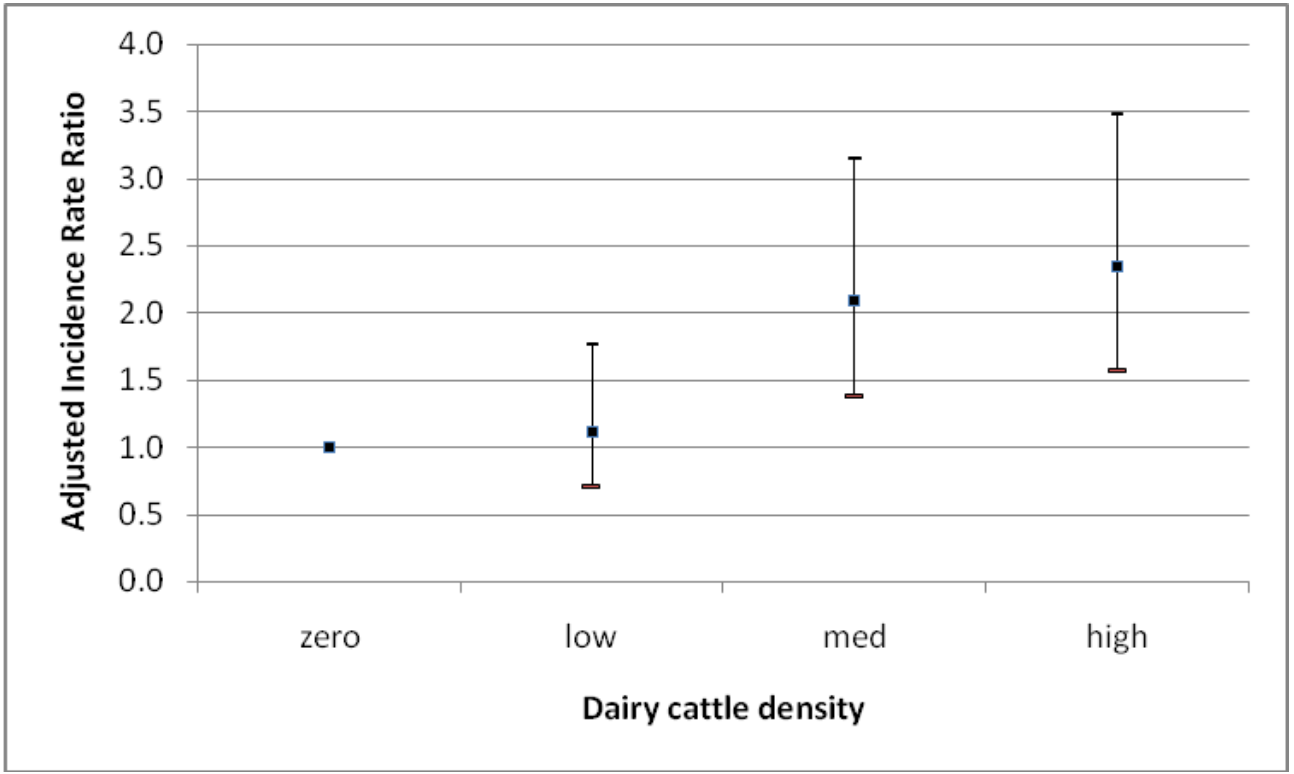


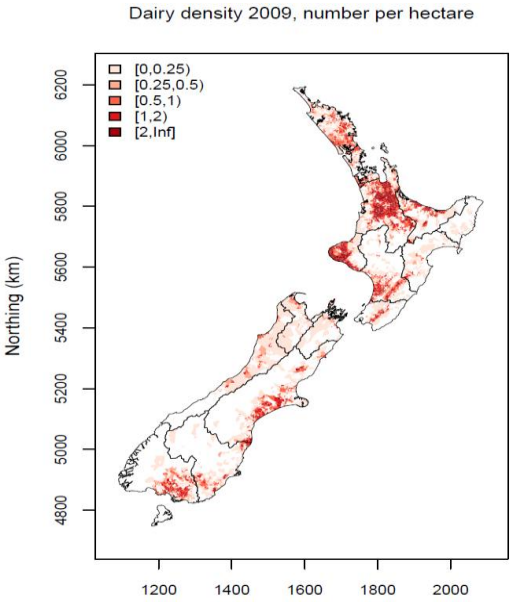
Cases predominantly chi

Fo

Te Kunenga ki Pūrehuroa

MASSEY UNIVERSITY





Rate of STEC O157 in rural areas three times that of urban areas and disease strongly associated with the density of dairy cattle

Thorburn, D., 2010. Ruminant density, Verocytotoxigenic *Escherichia coli* and cryptosporidiosis in New Zealand: Descriptive and ecological analyses. University of Otago, Dunedin.

F

Prevalence in cattle

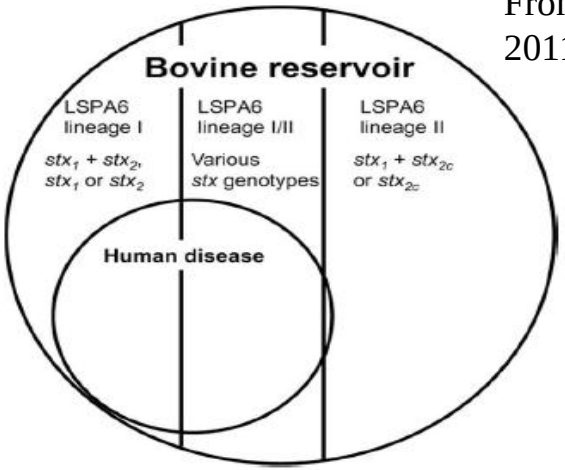
Animals sampled	O157-prevalence (range among plants)	O26-prevalence (range among plants)
Calves (*n* = 695)	**21.0%** (10.0% - 33.0%)	**29.1%** (19.0% - 40.0%)
Beef (*n* = 555)	**7.6%** (3.9% - 11.4%)	**6.7%** (4.8% - 9.4%)

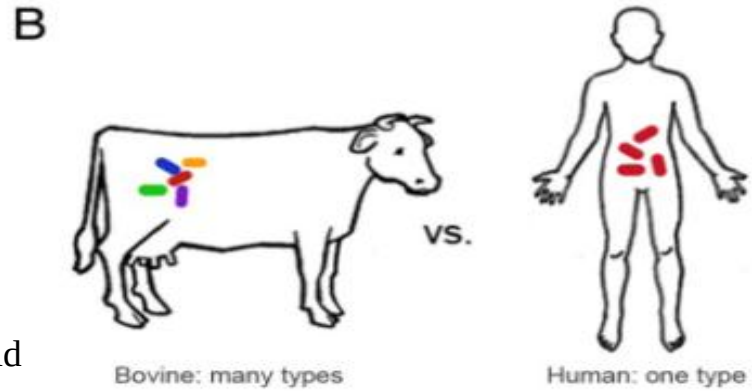
O157 and O26 are common – particularly in bobby calves

Typing of STEC O157

- Only subset of all types that cause human disease.
- Different strains, different virulence

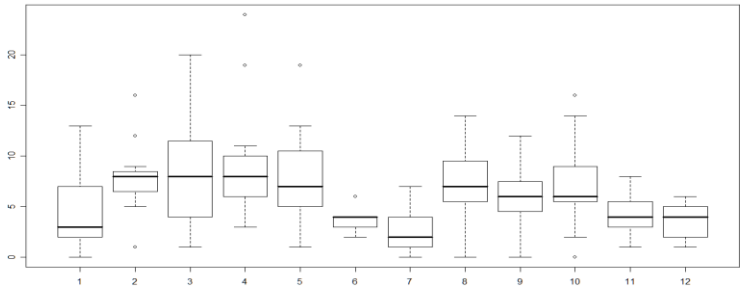
From Lee et al 2011





From Leopold PNAS 2009

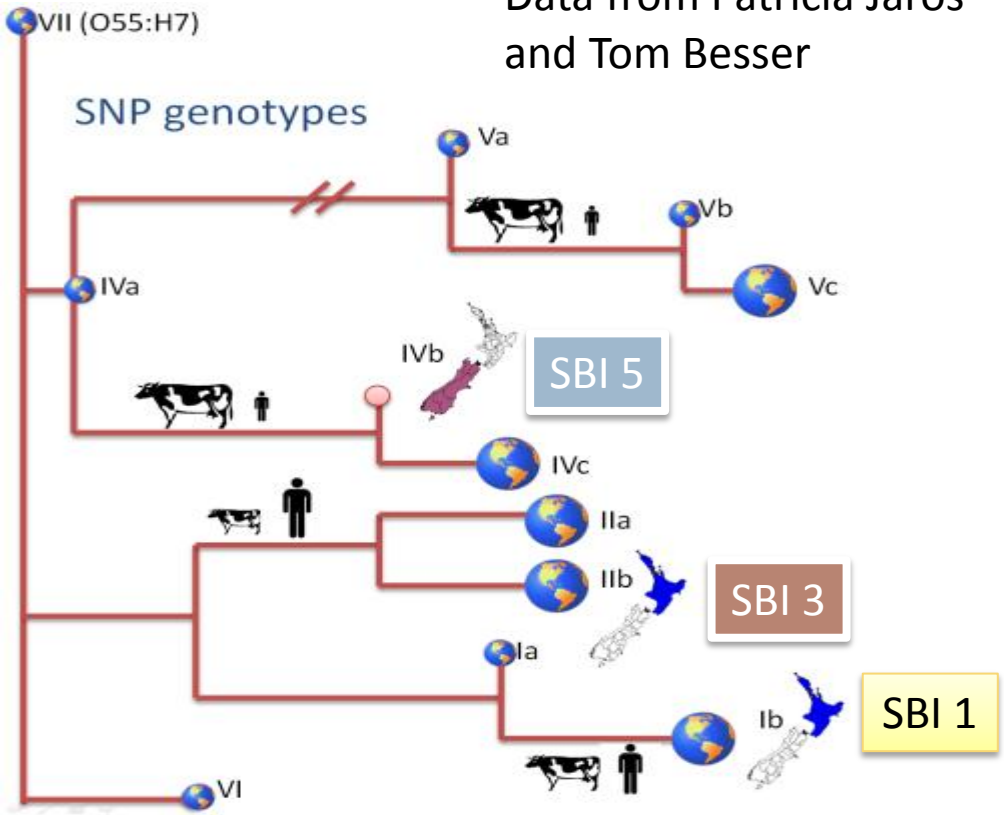
STEC cases 2000-9:

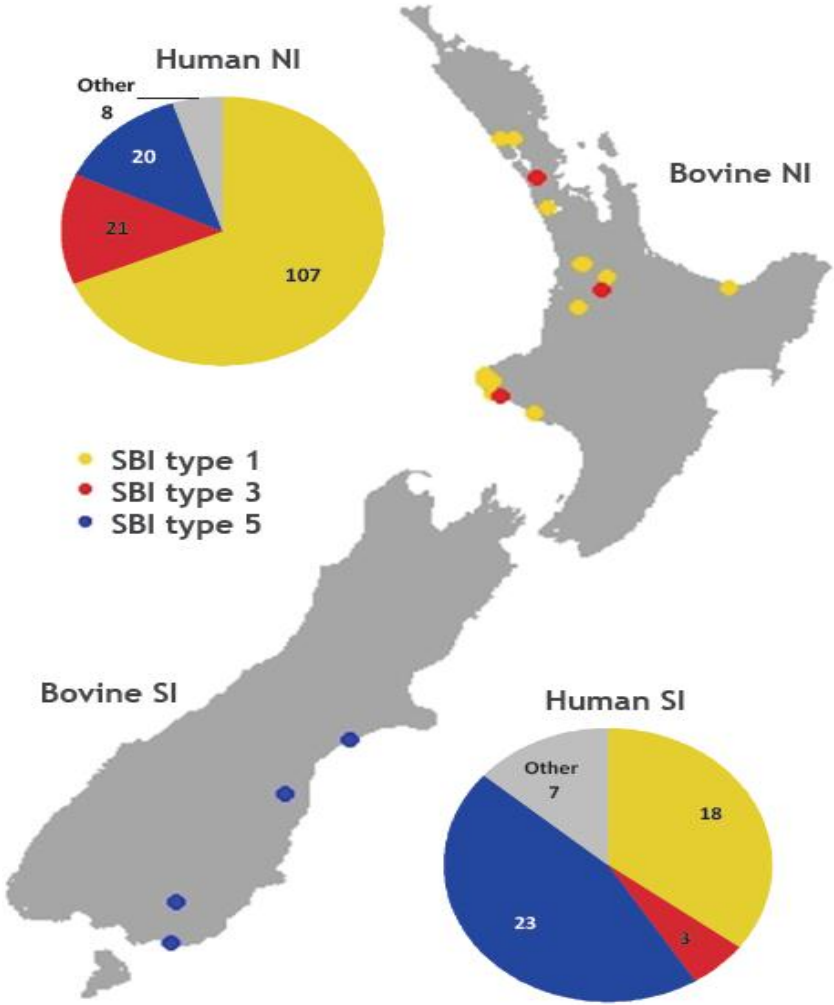


Cases predominantly children <5y.o.

STEC O157 in New Zealand

Data from Patricia Jaros and Tom Besser





IDReC Infectious Disease Research Centre

mEpiLab

mEpiLab.massey.ac.nz

STEC O157 infection pathways?

- O157 (and O26) common in cattle in NZ
- Human infection associated with children in rural areas with high dairy cattle densities.
- Compared to overseas NZ has higher proportion of human cases of ‘stress-sensitive’ O157 type 5.
- Both above indicate non-food pathways predominate.
  - Water, direct contact

Acknowledgements

- Staff – lecturers, RAs
  - Dr Jackie Benschop
  - A/Prof Cord Heuer
  - Dr Julie Collins-Emerson, Dr Anne Midwinter,,
  - Dr Simon Spencer, Dr Jonathan Marshall, Dr Patrick Biggs
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  - Rukhshana Akhter, Errol Kwan, Lynn Rogers, Sarah Moore, Angie Reynolds
- PhD students: Petra Mullner, Vathsala Mohan
- Masters students
  - Particularly Tui Shadbolt, Ann Sears
- MidCentral Public Health
  - Dr Jill McKenzie
- MedLab Central
- ESR - Dr Phil Carter
- AgResearch – Grant Hotter, Adrian Cookson
- Dr Michael Baker
- Dr Chris Jewel (Warwick)
- Dr Barbara Holland, Dr Geoff Jones, Dr Alasdair Noble,
- Prof Martin Hazelton
  - Allan Wilson Centre
- Dr Danny Wilson, Prof Paul Fearnhead

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