



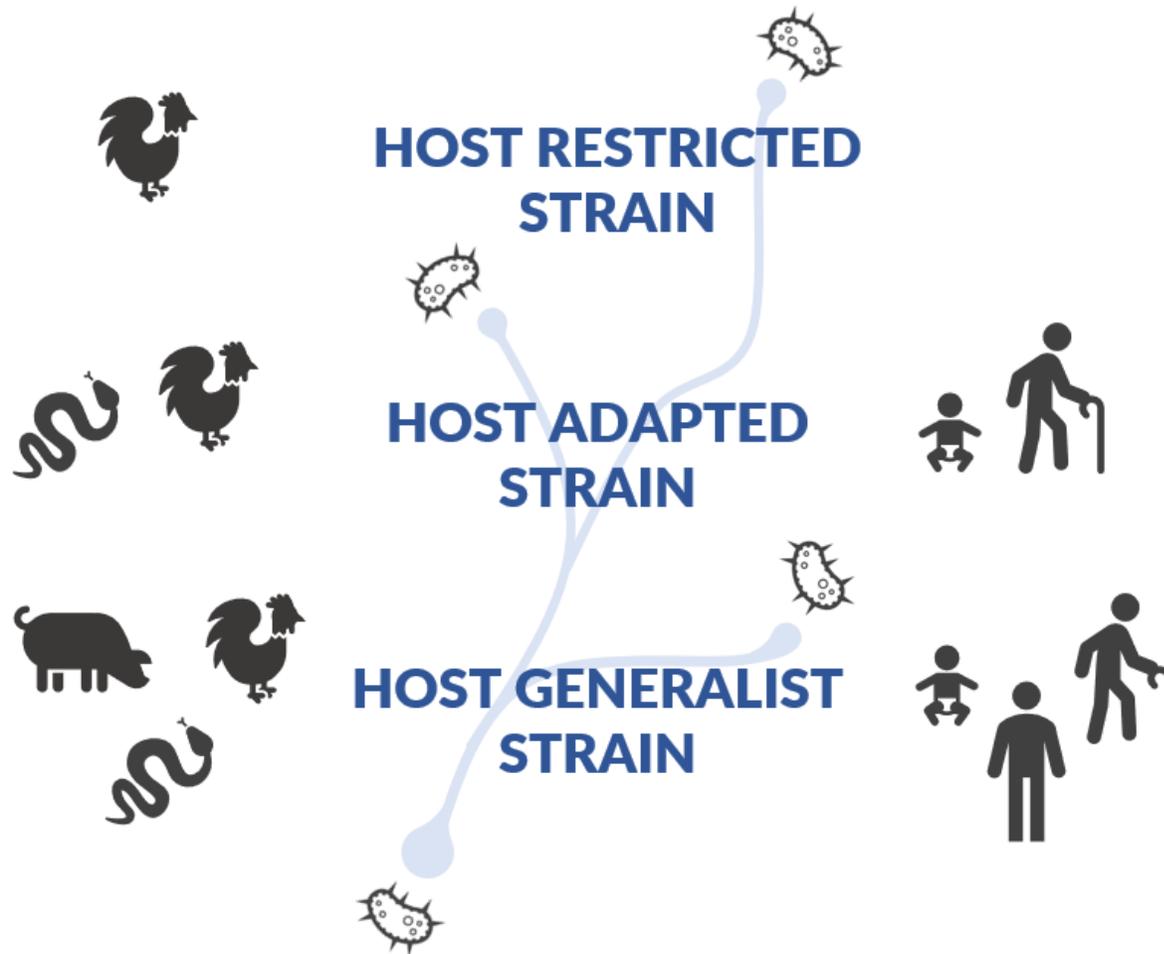
# Birds, cats, humans and host adaptation in *Salmonella* Typhimurium

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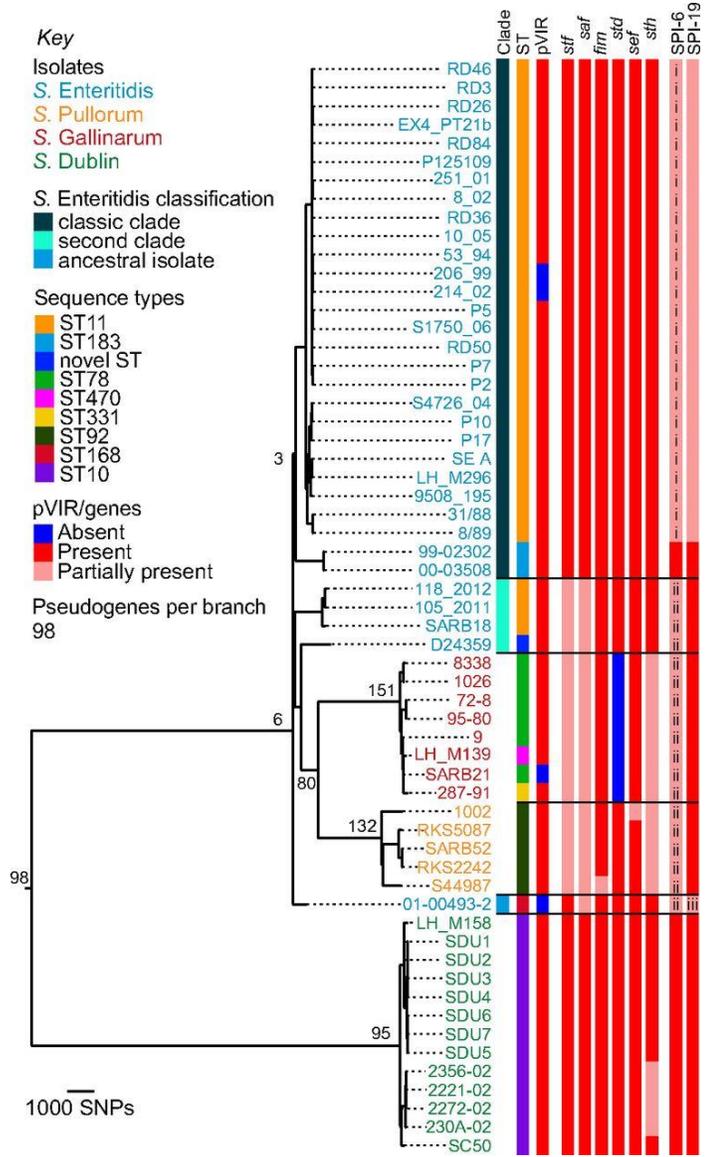
The Public Health Agency of Sweden

**SVA** NATIONAL  
VETERINARY  
INSTITUTE



## Evolution among *Salmonella*

- **Host adaptation**, environmental niche adaptation
- Acquisition of mobile genetic elements
- Loss of gene function
- Changes likelihood and severity of infection in a given host
- **Example: the Enteritidis lineage**



**Enteritidis**  
Generalist, Human pathogen

**Gallinarum**  
Specialist, birds

**Pullorum**  
Specialist, birds

**Dublin**  
Specialist, cattle

## 2016 spring outbreak

- Spring cluster of cases of salmonellosis in Sweden, primarily children
- *S. enterica* subsp. *enterica* serovar Typhimurium, MLVA profiles 2-13-3-NA-212 (+ variants)
- Profile type historically associated with cats and passerine birds, especially in spring
- Phage type 40 or NST in older studies (phage typing no longer in routine use)
  
- Record year for findings of dead birds with salmonellosis
- Record year for salmonellosis in cats

Collaborative project to

- investigate outbreak with better typing techniques (NGS)
- revisit historical data

## ***Salmonella* Typhimurium in passerine birds**

- Vast majority of isolates have “bird type” MLVA profiles; 2-[10-15]-[3-4]-NA-212
- Strains lacking pSLT, little or no growth on Simmon’s citrate agar
- Certain species dominate among *Salmonella*-positive dead birds sent to SVA by the public



**Eurasian bullfinch**  
*Pyrrhula pyrrhula*  
Domherre



**Common redpoll**  
*Acanthis flammea*  
Gråsiska

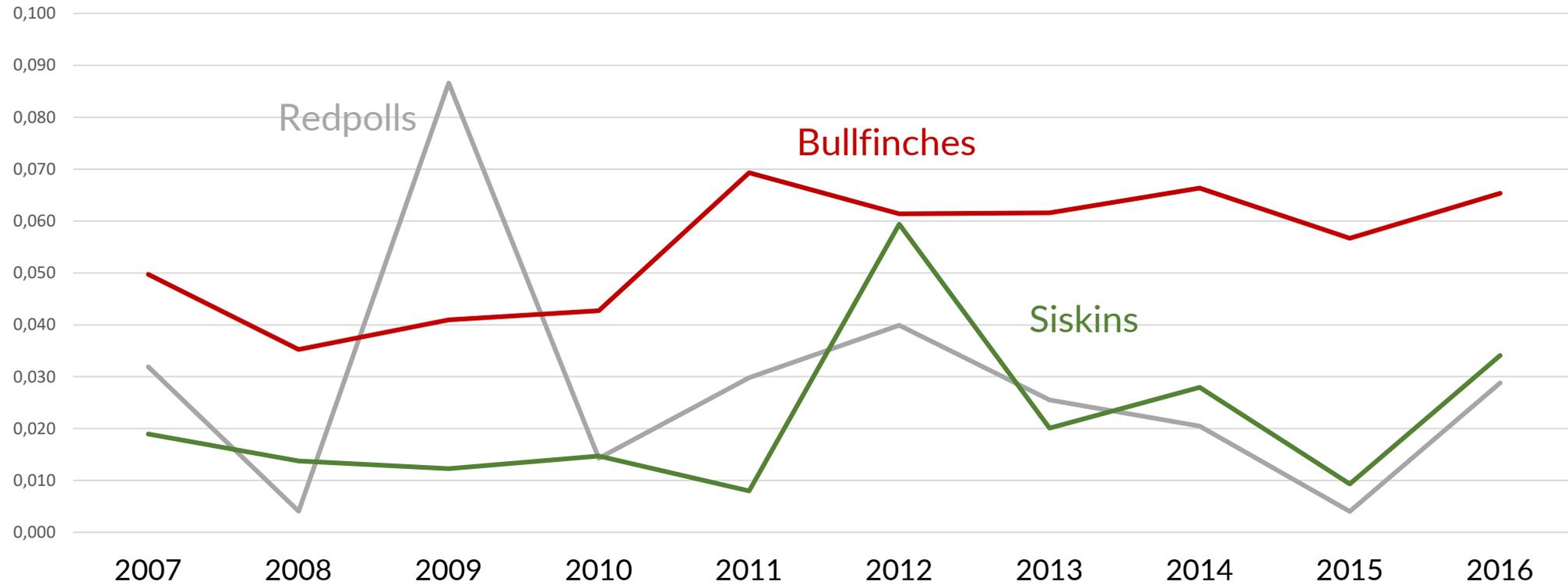


**Eurasian siskin**  
*Spinus spinus*  
Grönsiska

- Partially migratory: show up near habitations in weakened state due to food shortages
- Tendency to eat off the ground under birdfeeders : exposed to infection

# Normalized Swedish birdwatcher counts of passerines, 2007-2016

"Vinterfåglar in på knuten", last weekend of January every year – total included count of 865729 birds



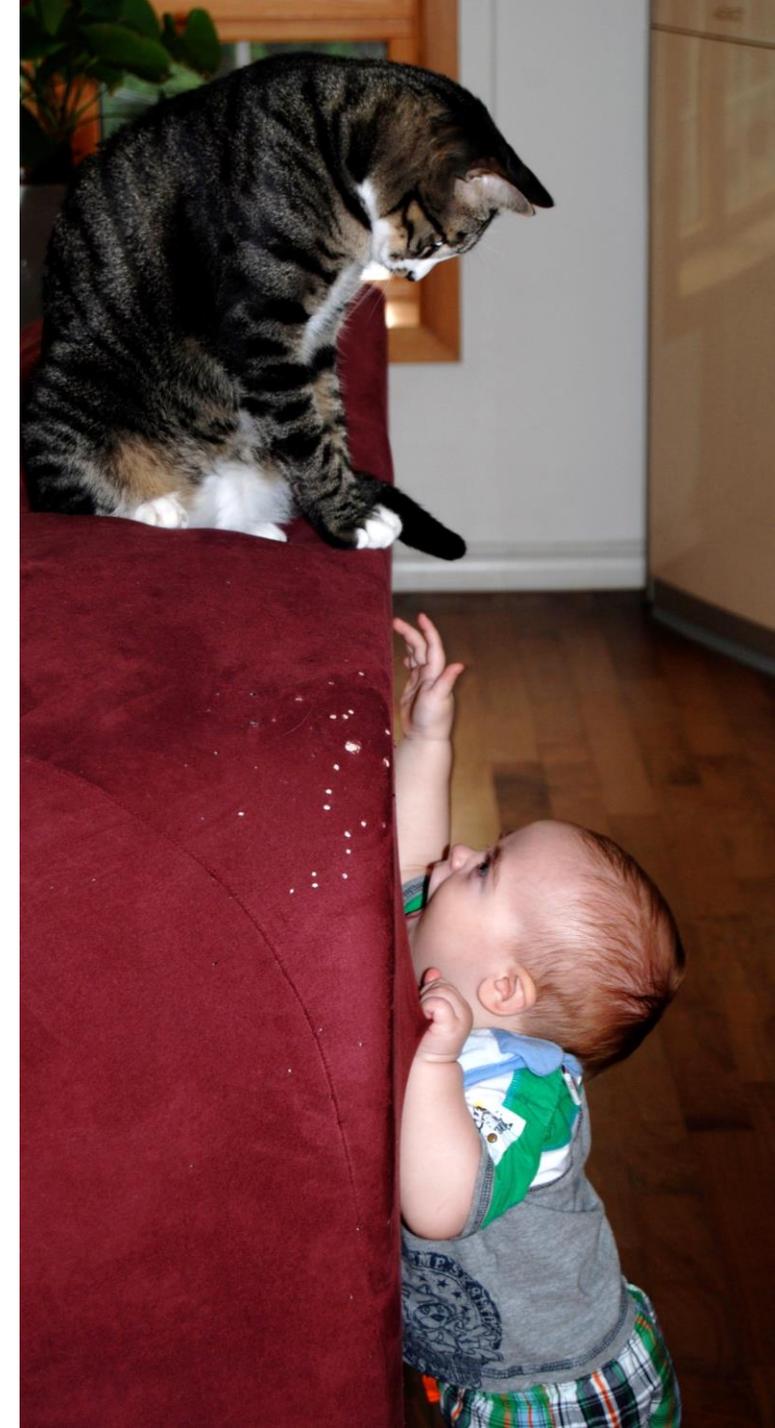
## ***Salmonella* Typhimurium in cats**

- Presumed infection sources include predation on infected birds and rodents, feed
- Anorexia, fever, vomiting, diarrhoea
- Non-specific signs of illness more common than gastroenteritis
  
- Vast majority of isolates (99%) have “bird type” MLVA profiles
- Predation on sick or dying birds -> high infectious dose?



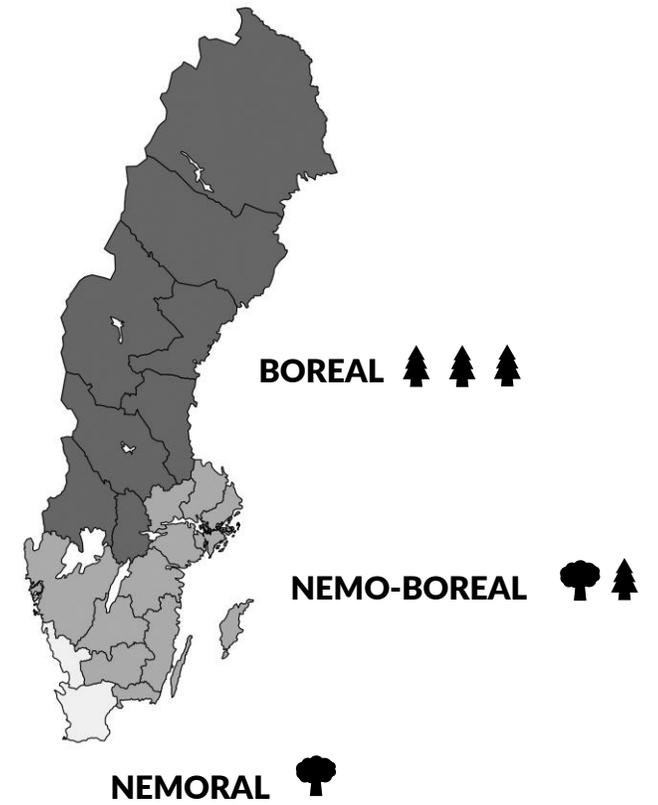
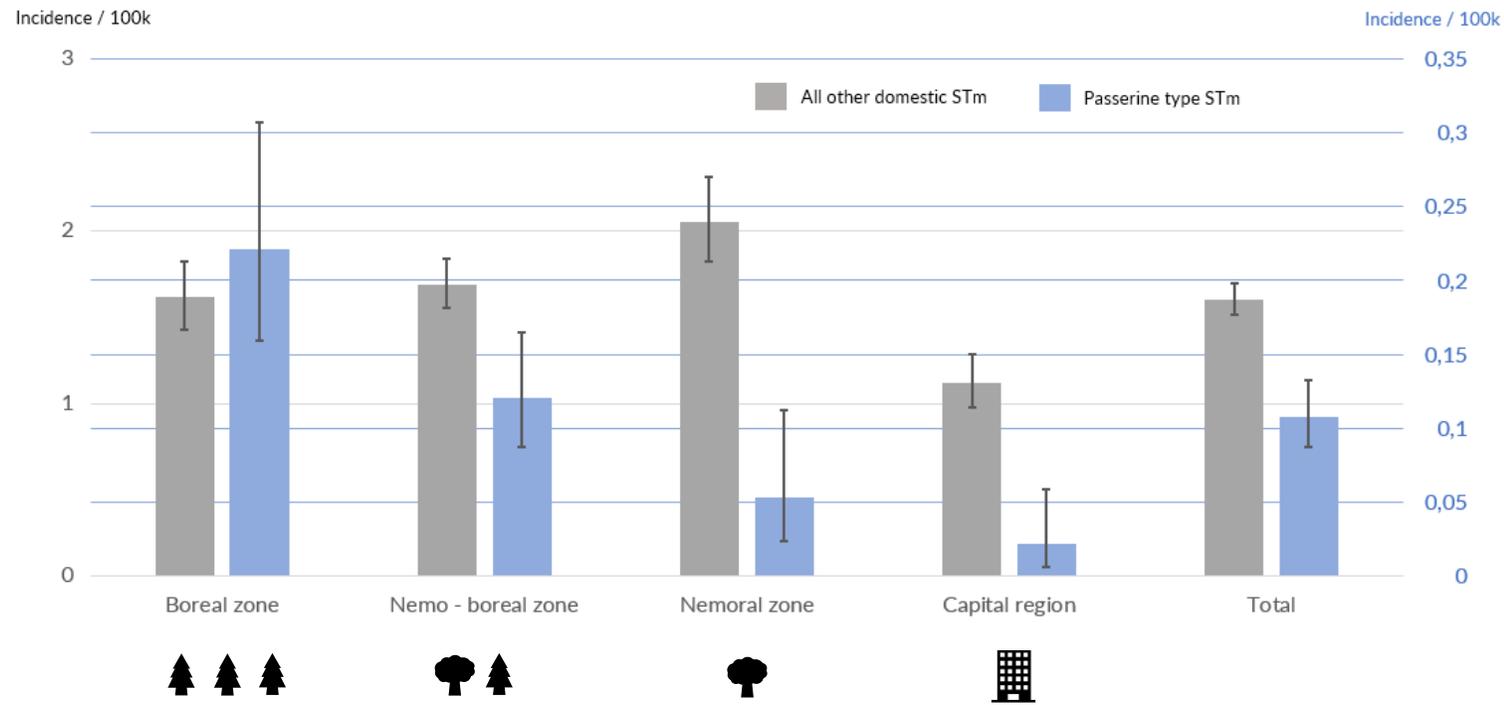
## "Bird type" *Salmonella* Typhimurium in humans

- Domestic cases, MLVA cluster definition 2-[11-15]-[3-4]-NA-212 based on profile variation in birds and cats
- 86 matching cases 2009-2016, high year-to-year variability
- Minor contribution to total number of salmonellosis cases



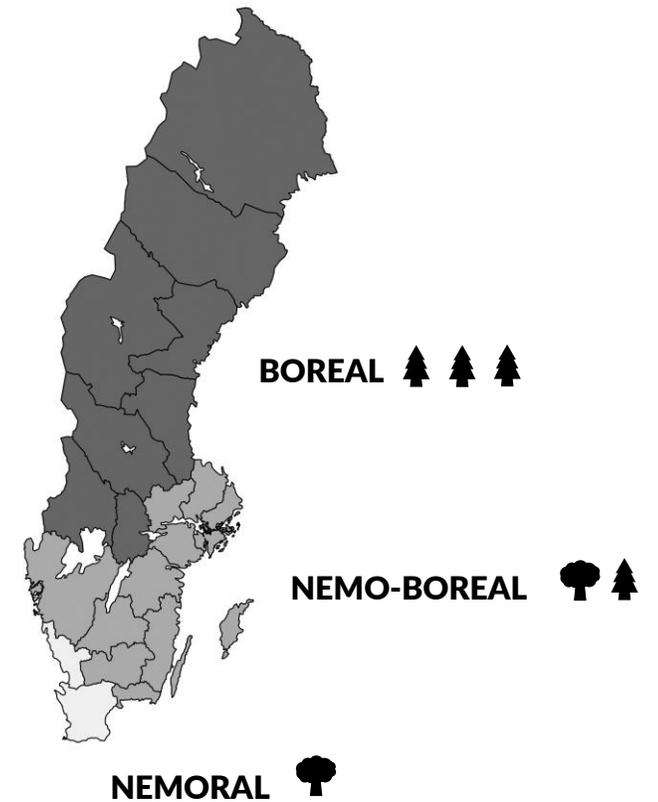
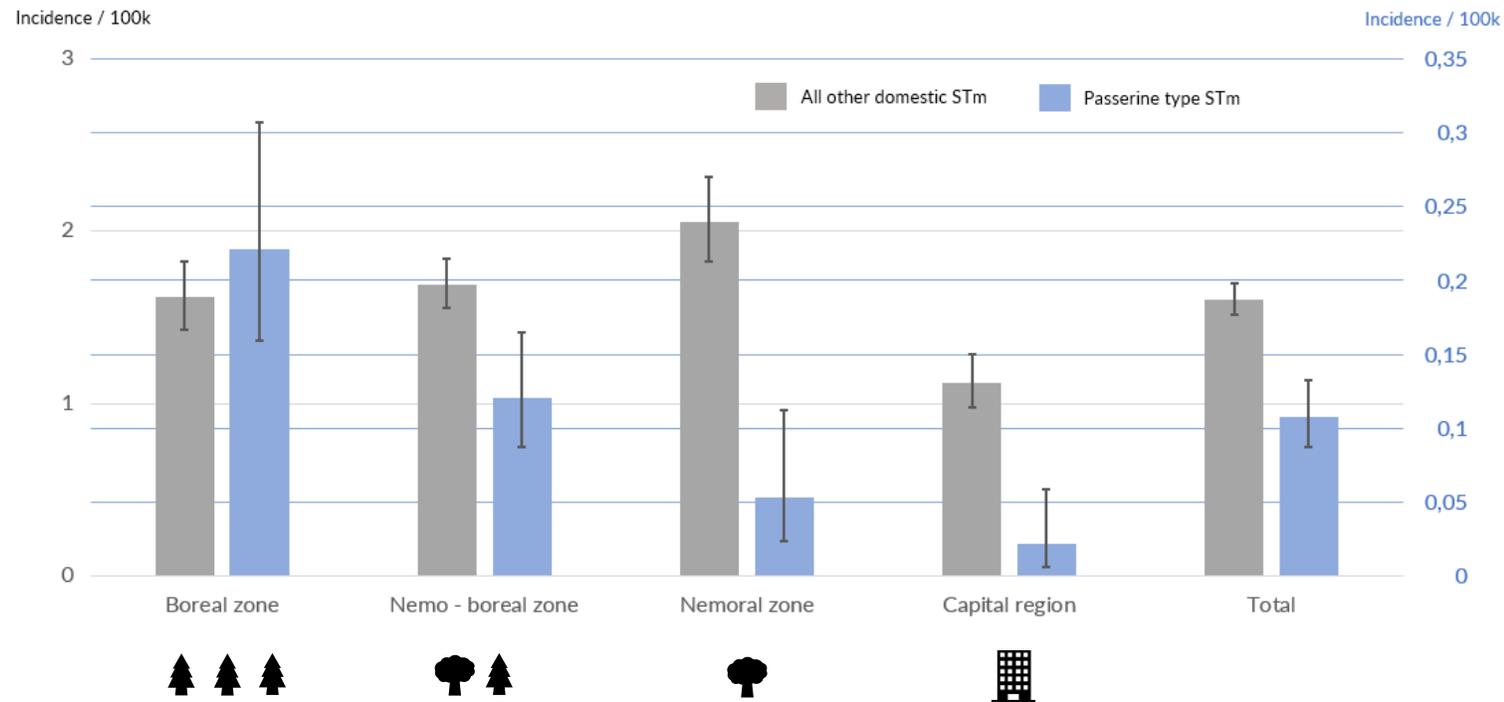
# "Bird type" *Salmonella* Typhimurium in humans

- Higher risk in boreal zone, lower in nemoral zone and capital region



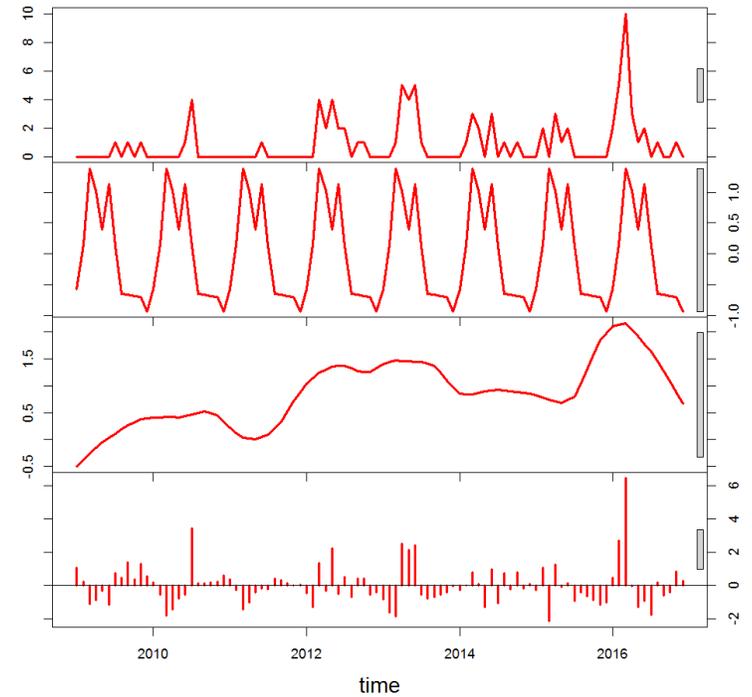
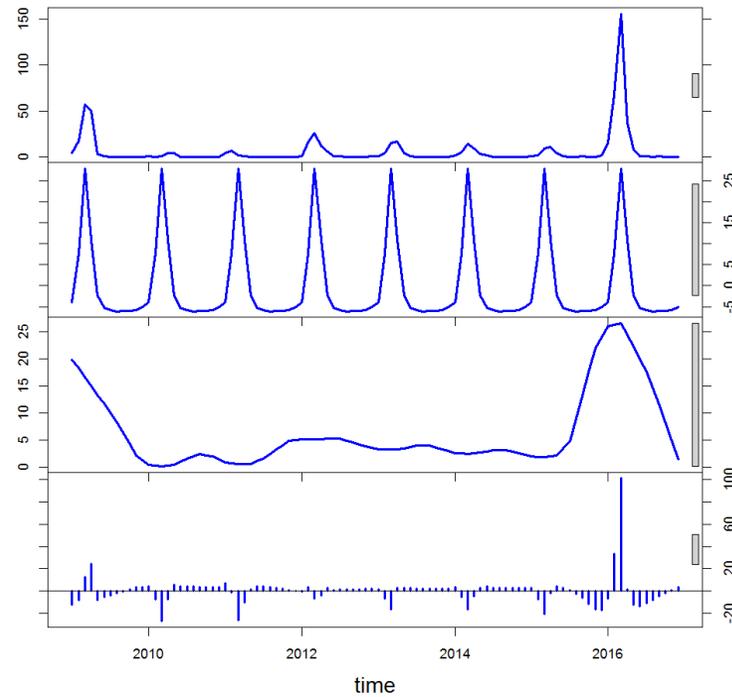
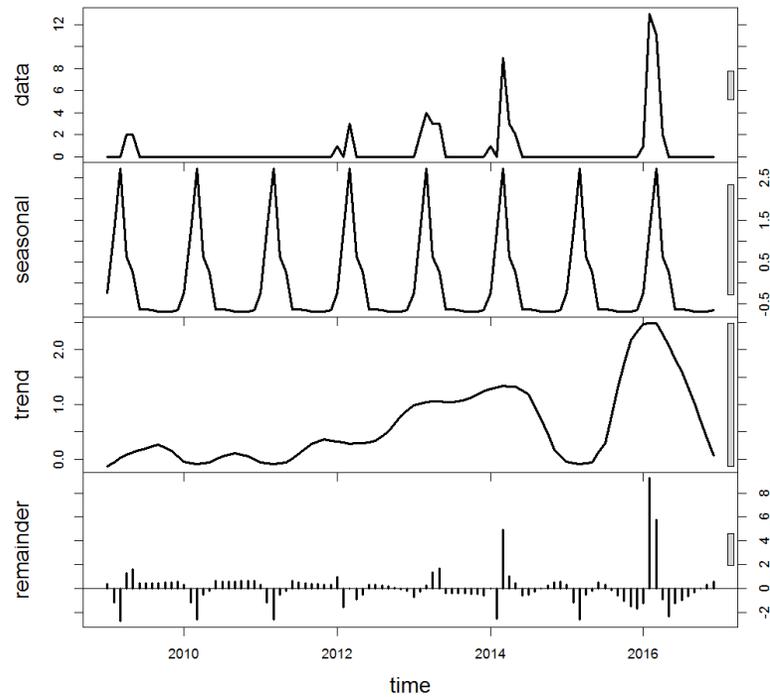
# "Bird type" *Salmonella* Typhimurium in humans

- Higher risk in boreal zone, lower in nemoral zone and capital region
- Bird populations (north vs. south)
- Probability of having a cat and/or a garden to feed birds in (capital vs. rest of country)

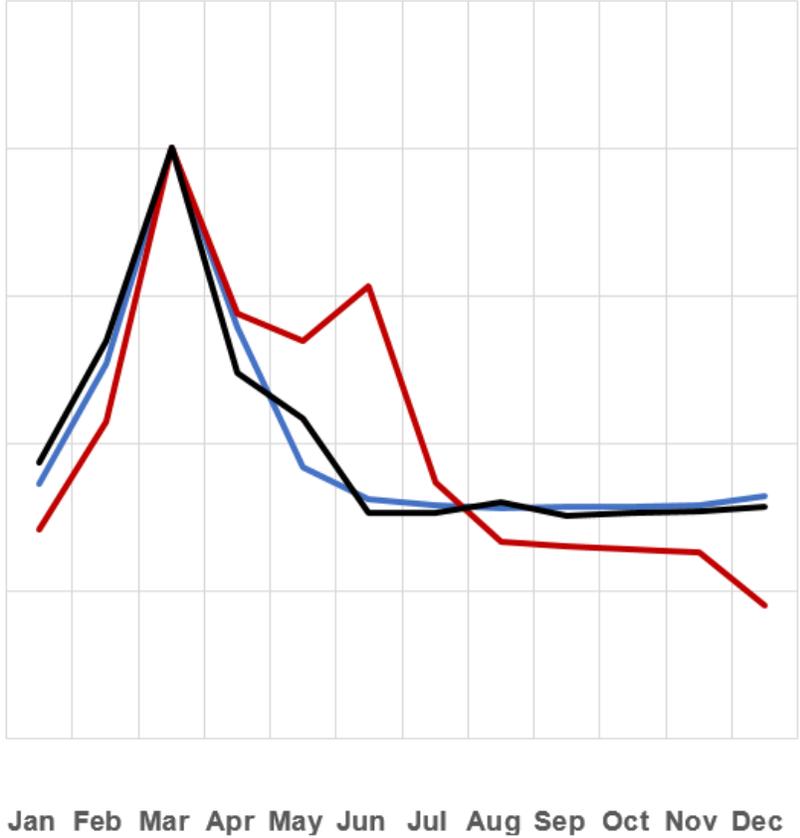
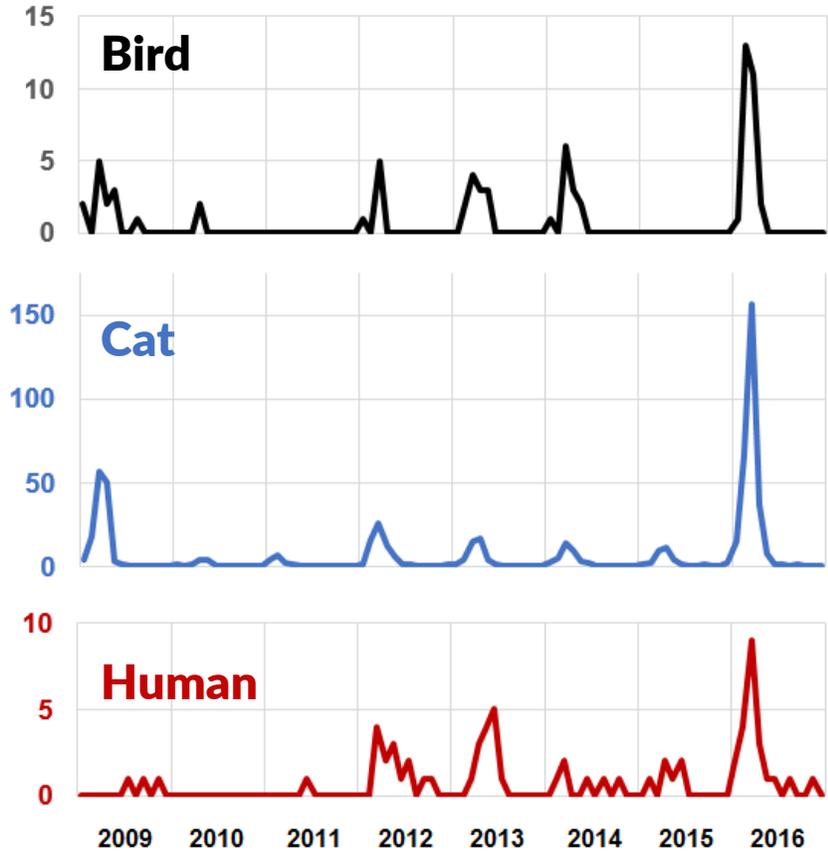


# Seasonal decomposition

- Data from 2009-2016 used to identify seasonality, corrected for long-term trends



# Seasonality overlay



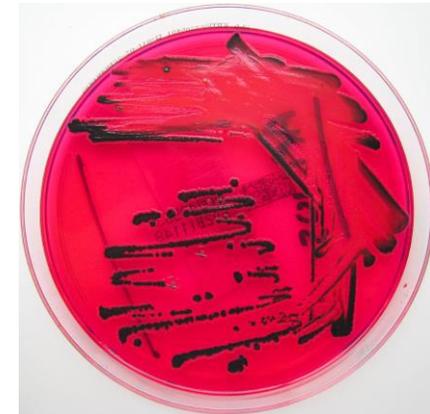
# Associations between year-to-year observational and microbiological data

Spearman's rank correlation

	STm birds	STm cats	STm humans
Passerine count	(Pos)	Pos*	(Pos)
STm birds		Pos**	(Pos)
STm cats			(Pos)

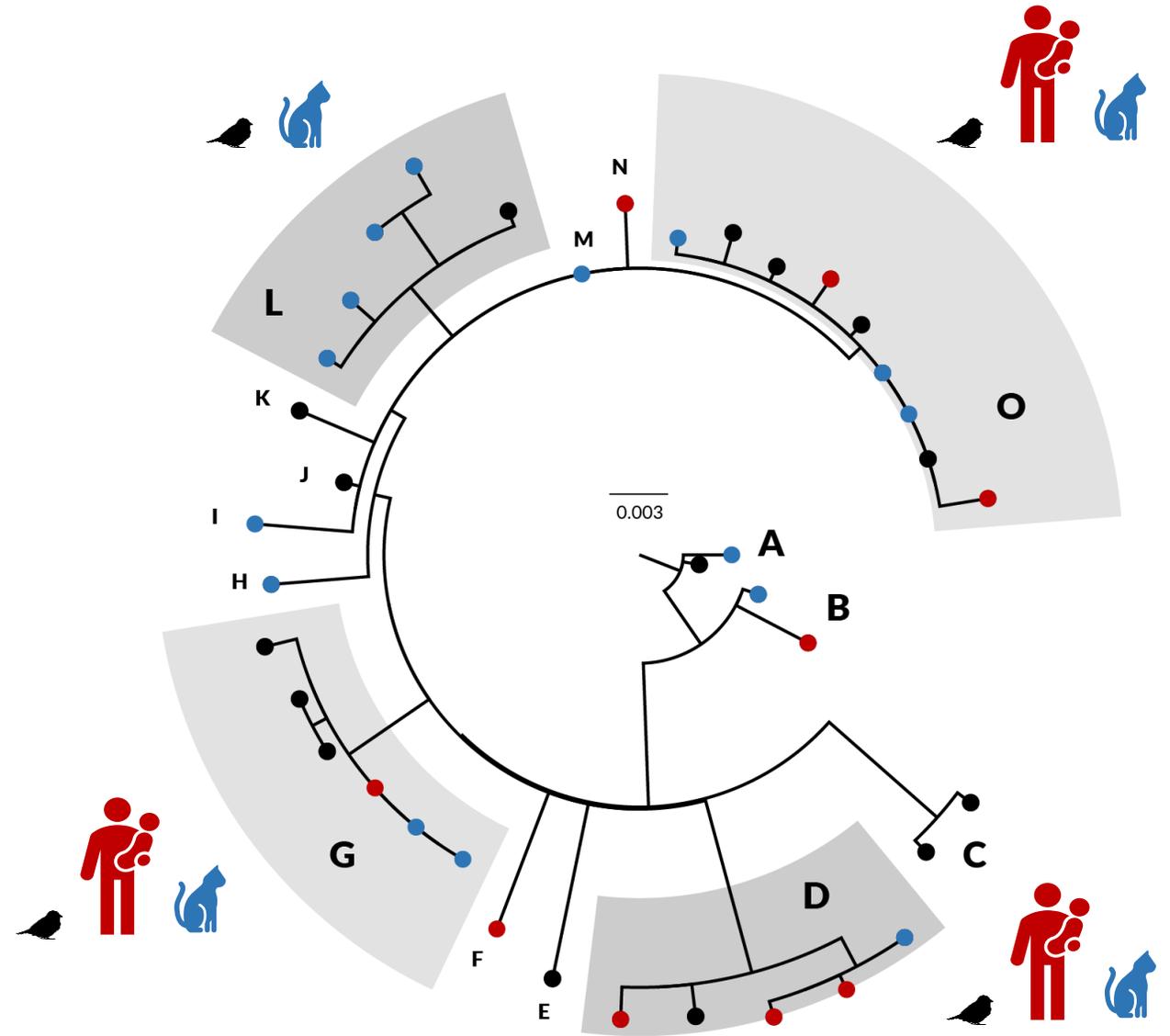


\*  $p < 0.05$ , \*\*  $p < 0.01$



## Whole genome sequencing of outbreak isolates

- Not a clonal outbreak
- No clustering by host



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MLVA variation of limited use for differentiation among isolates

Why? Probably reversible SLVs

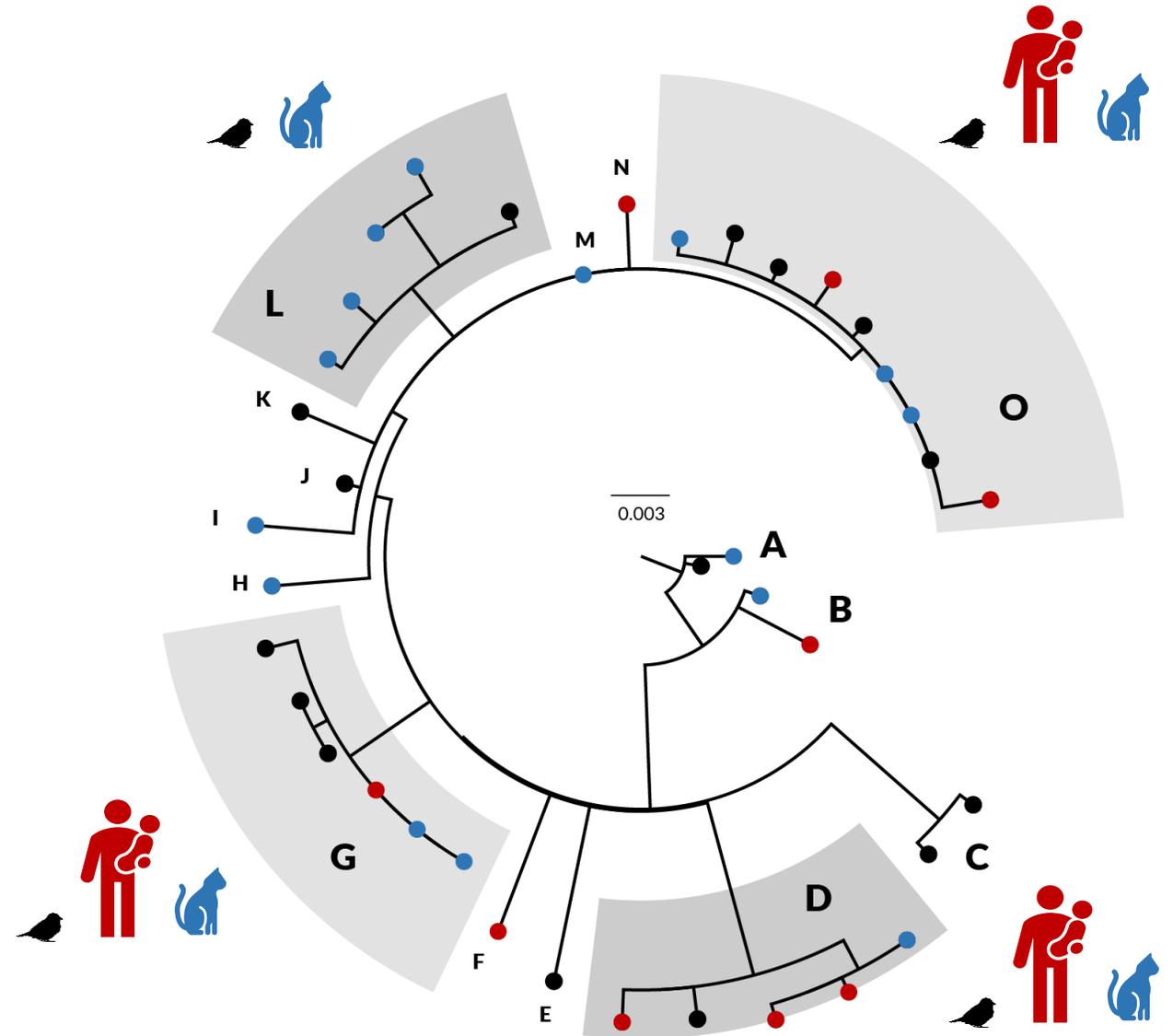
2-**14**-3-NA-212



2-**13**-3-NA-212

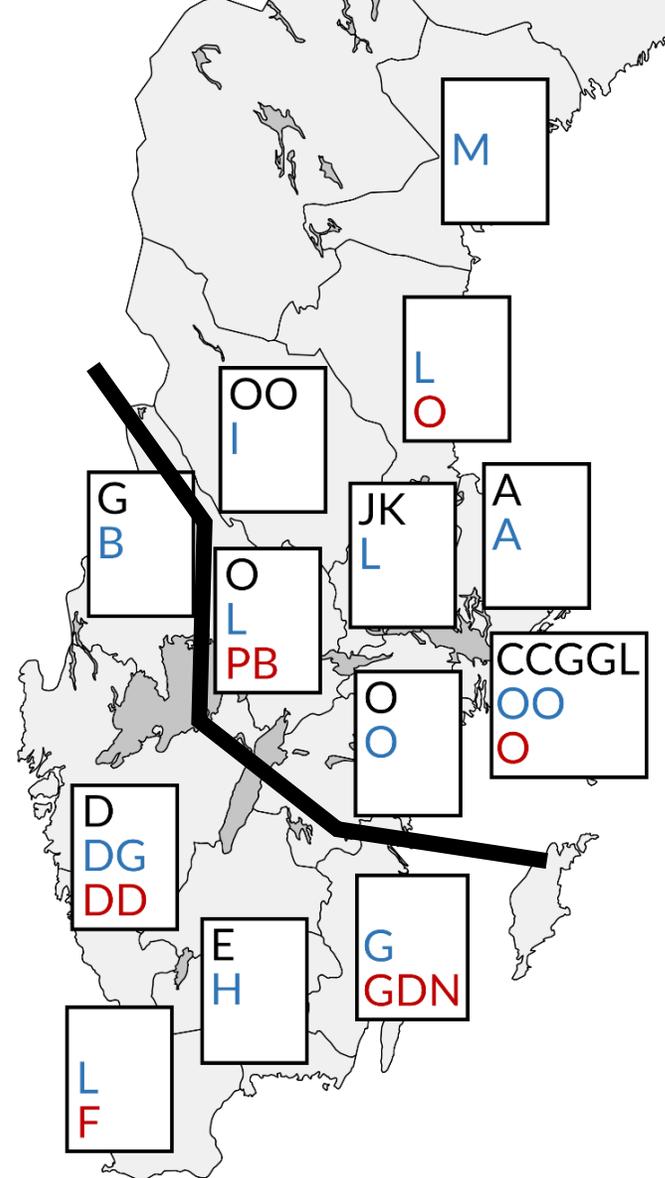
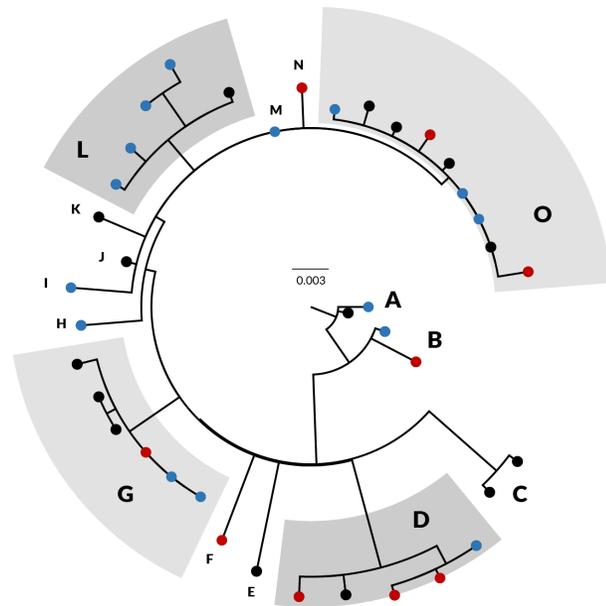


2-**12**-3-NA-212



## Regionality of genotypes

- Co-occurrence of genotypes between hosts within regions
- Moderate regional bias of genotype distribution
- Contrast with Swedish *Salmonella* Dublin; host-adapted to cattle, genotype regionality persists over decades



Northeast:  
H-O clade 17/28  
61%

Southwest:  
H-O clade  
1/15  
7%

# Public awareness

## Media attention 2016

### Publication of advice to reduce cases

- Keeping clean under bird feeders
- Keeping cats away from bird feeders
- Hygiene when cleaning bird feeders & litterbox
- Kitchen hygiene, handwashing
- Avoiding contact between ill cats and children

The screenshot shows the website of the Swedish Public Health Agency (Folkhälsomyndigheten). The top navigation bar includes links for 'Tillsyn', 'Publicerat material', 'Om Folkhälsomyndigheten', 'Pressrum', 'Kontakt', 'Innehåll A-O', and 'In English'. A search bar is located on the right. Below the navigation bar, there are four main menu items: 'Folkhälsorapportering & statistik', 'Livsvillkor & levnadsvanor', 'Mikrobiologi & laboratorieanalyser', and 'Smittskydd & beredskap'. The main content area features a breadcrumb trail: 'Nyheter och press' > 'Nyhetsarkiv' > '2016' > 'April' > 'Personer smittade med salmonella från fågel eller katt'. The headline reads 'Personer smittade med salmonella från fågel eller katt'. Below the headline, there is a date 'PUBLICERAT 07 APRIL 2016' and a short summary: 'Under 2016 har hittills fler personer än väntat insjuknat av en salmonellatyp som är vanlig hos småfåglar och katter. Flera av de som insjuknat är små barn.' There is a blue 'ÖP' logo and a navigation bar with 'Start', 'Nyheter', 'Sport', 'Familj', 'Opinion', 'Nöje & Kultur', 'Bostadspuls', and 'Mer'. The main article is dated 'JÄMTLAND 8 mars 2016' and has the headline 'Salmonella drabbar katter i länet - och du kan smittas också'. Below the headline, there are social media sharing options for 'delningar', 'Dela på facebook', and 'Dela på twitter'. The article features a photo of a bird at a feeder. Below the photo, there is a caption: 'Smittan drabbar ofta finkfåglar som domherre. Foto: COLOURBOX'. The article title is 'Salmonella låg bakom dödsfall vid fågelbord'. Below the title, there is a date 'Publicerad 27 feb 2016 kl 16:38' and social media sharing options for 'Rekommendera', 'Tweeta', 'Dela', and 'Meja'. The article text starts with 'Småfåglar riskerar att drabbas av salmonella vid fågelborden. Utbrotten, ...'. To the right, there is a screenshot of the 'AFTONBLADET' website. The headline is 'Stor ökning av salmonella hos katter'. Below the headline, there is a date 'INRIKES tis 09 feb 2016' and a short summary: 'HÄLSA. Salmonella hos katter ökar dramatiskt. Hittills i år har nästan lika många fall som under hela förra året upptäckts, enligt Statens veterinärmedicinska anstalt (SVA). Fram till den första veckan i februari har 72 positiva prover från katt analyserats vid SVA. Under hela 2015 var motsvarande siffra 83.' Below the summary, there is a quote: 'Elina Lahti, veterinär vid SVA, säger att mörkertalet förmodligen är stort.'

## Conclusions

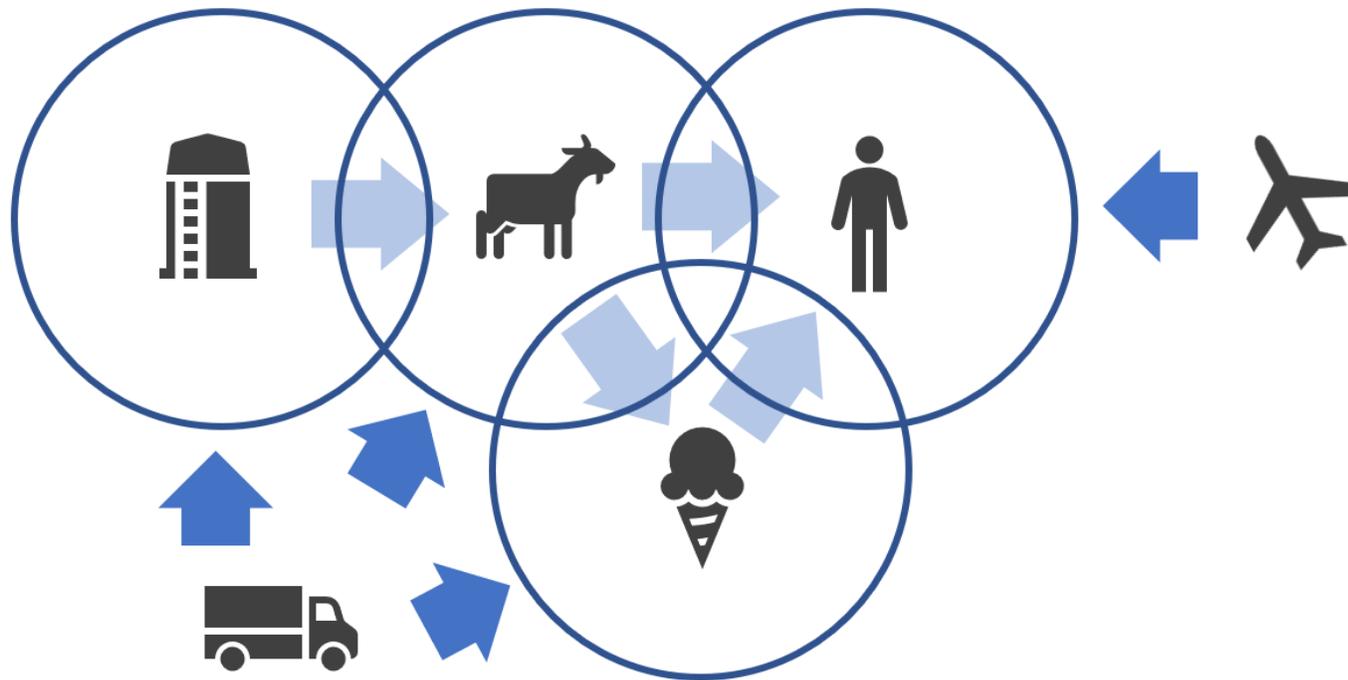
- Historical and outbreak data strongly support hypothesis of STm transmission to humans and cats from birds
- Correlated seasonality, year-to-year variation and phylogeography
- Matching subtypes
- Likely driver of phenomenon is food shortages and population fluctuations in passerine populations
- Human cases continue into summer; unknown sources or cats and birds that are infected without showing signs of disease?
- Not a major source of human salmonellosis, but basic precautions can reduce the risk for the public while also protecting from other zoonotic infections



# Looking forward

Molecular source attribution- given a genome sequence, what is your best guess for a source?

Genomic signatures of host adaptation; Enteritidis/Typhimurium in hedgehogs, Fulica in porpoises...



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