Reoccurring, Emerging, and Persisting (REP) Strains: Opportunities for Illness Prevention

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U.S. Centers for Disease Control and Prevention

March 2024

Reoccurrence of Strains Is a Longstanding Concern

Epidemiol. Infect. (2008), **136**, 157–165. © 2007 Cambridge University Press
doi:10.1017/S0950268807008591X Printed in the United Kingdom

Recurrent multistate outbreak of *Salmonella* Newport associated with tomatoes from contaminated fields, 2005

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A Recurrent, Multistate Outbreak of *Salmonella* Serotype Agona Infections Associated with Dry, Unsweetened Cereal Consumption, United States, 2008†

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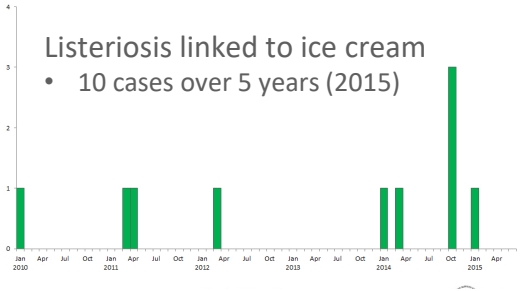
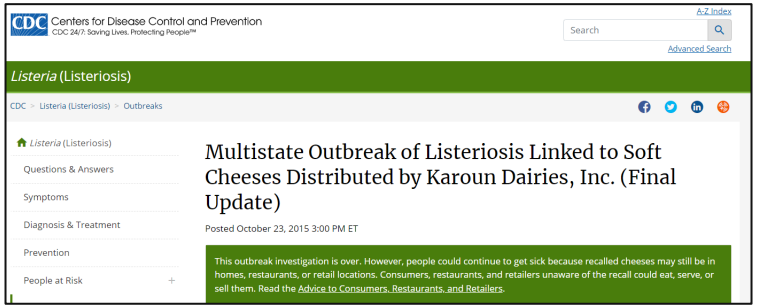
MS 12-209: Received 14 May 2012/Accepted 9 July 2012

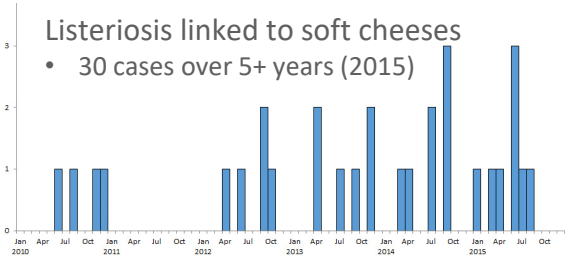
ABSTRACT

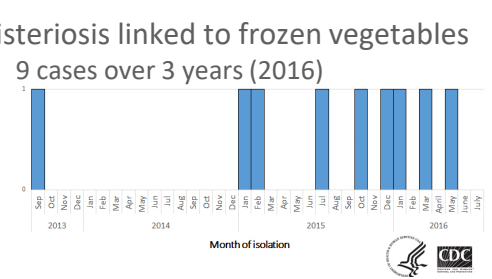
An outbreak of *Salmonella enterica* serotype Agona infections associated with nationwide distribution of cereal from Company X was identified in April 2008. This outbreak was detected using PulseNet, the national molecular subtyping network for foodborne disease surveillance, which coincided with Company X's voluntary recall of unsweetened puffed rice and wheat cereals after routine product sampling yielded *Salmonella* Agona. A case patient was defined as being infected with the outbreak strain of *Salmonella* Agona, with illness onset from 1 January through 1 July 2008. Case patients were interviewed using a standard questionnaire, and the proportion of ill persons who reported eating Company X puffed rice cereal was compared with

WGS Pilot for *Listeria* Began in Late 2013









Increasing Use of WGS for Salmonellosis and STEC Outbreaks

- Between 2014 and 2019, WGS performed on most isolates in multistate outbreaks

- Early uses of WGS information:
  - "Rule out" illnesses not likely part of an outbreak
  - "Rule in" illnesses with different PFGE patterns that were related
  - Increase confidence in connection between disparate isolates (by time, distance, or epidemiology)

Salmonella Newport Infections Linked to Ground Beef, 2016-2017

- 106 illnesses over a 10-month period linked to ground beef
- Outbreak strain found in 4 dairy cattle from a single state and ground beef collected from an ill person's home
- Traceback of ground beef led to numerous slaughter/processing facilities
- Root cause not identified

Morbidity and Mortality Weekly Report

Protracted Outbreak of *Salmonella* Newport Infections Linked to Ground Beef: Possible Role of Dairy Cows — 21 States, 2016–2017

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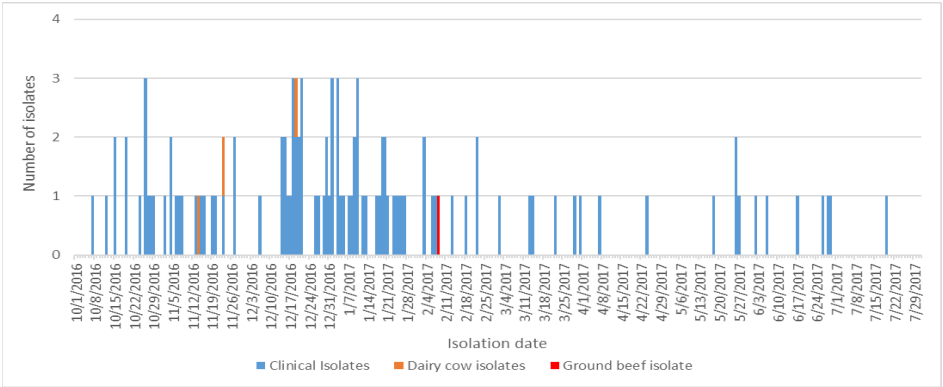
In January 2017, CDC identified a cluster of *Salmonella enterica* serotype Newport infections with isolates sharing an indistinguishable pulsed-field gel electrophoresis (PFGE) pattern, JJPX01.0010 (pattern 10), through PulseNet, the national molecular subtyping network for foodborne disease surveillance. This report summarizes the investigation by CDC, state and local health and agriculture departments, and the U.S. Department of Agriculture's Food Safety and Inspection Service (USDA-FSIS) and discusses the possible role of dairy cows as a reservoir for strains of *Salmonella* that persistently cause human illness. This investigation combined epidemiologic and whole genome sequencing (WGS) data to link the outbreak to contaminated ground beef; dairy cows were hypothesized to be the ultimate source of *Salmonella* contamination.

Specific ground beef information was available for 35 patients. Among these, 15 (43%) purchased ground beef as chubs (rolls) of varying sizes (range = 2–10 lbs), 18 purchased it on a tray wrapped in plastic, and two purchased preformed hamburger patties. Twenty-nine patients reported that they bought fresh ground beef, four bought frozen ground beef, and four did not recall whether it was fresh or frozen when purchased. When asked about ground beef preparation, 12 (36%) of 33 patients reported that they definitely or possibly undercooked it.

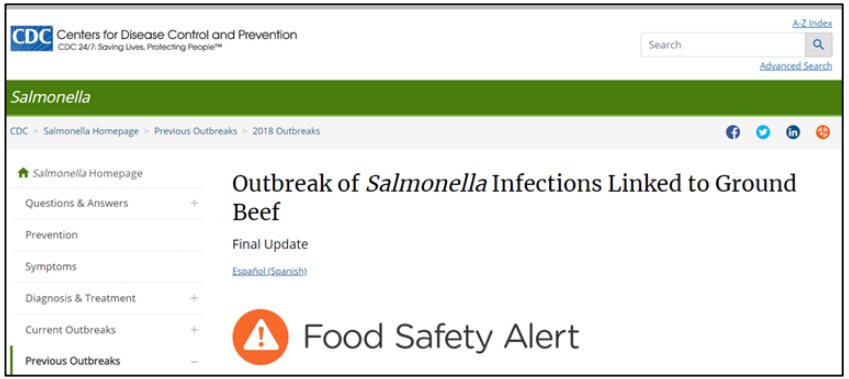
Traceback Investigation

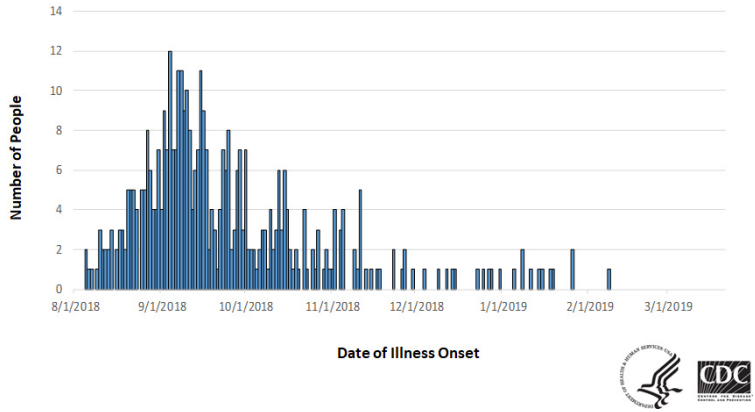
USDA-FSIS conducted traceback on ground beef purchased within 3 months of illness onset for 11 patients who provided shopper card records or receipts. Approximately 20 ground



Return of 2016-2017 *Salmonella* Newport Strain in 2018

- Acute outbreak of 403 illnesses linked to ground beef
- Outbreak strain found in ground beef from ill people's homes and unopened packages of ground beef from retail locations
- Traceback pointed to one slaughter/processing establishment, recall of ~12 million pounds of ground beef

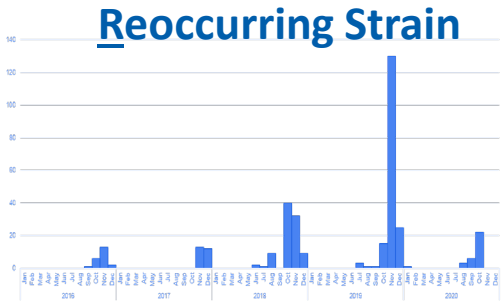


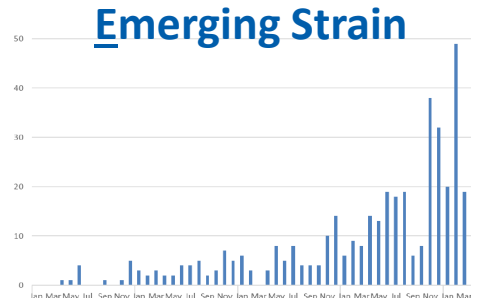


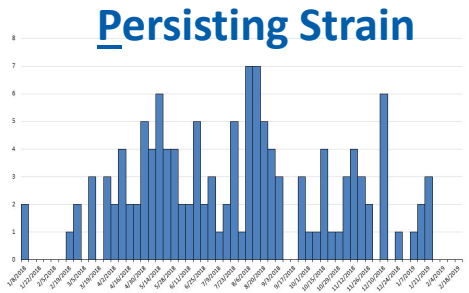
Defining REP Strains

- A group of bacteria, closely related by whole genome sequencing, that continues to cause illness over time
  - Genetic diversity often larger than acute outbreaks

- What escalates a strain to being monitored as a REP strain?
  - Repeated outbreaks
  - Concerning resistance patterns
  - High illness severity
  - Presence of non-clinical isolates





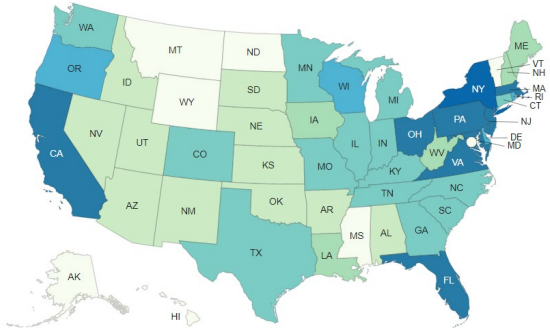


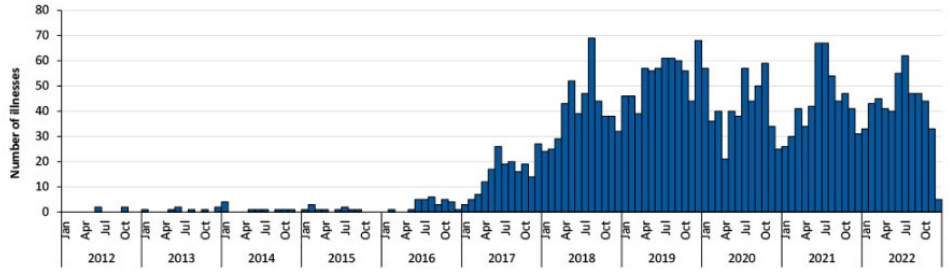
Why We Investigate REP Strains

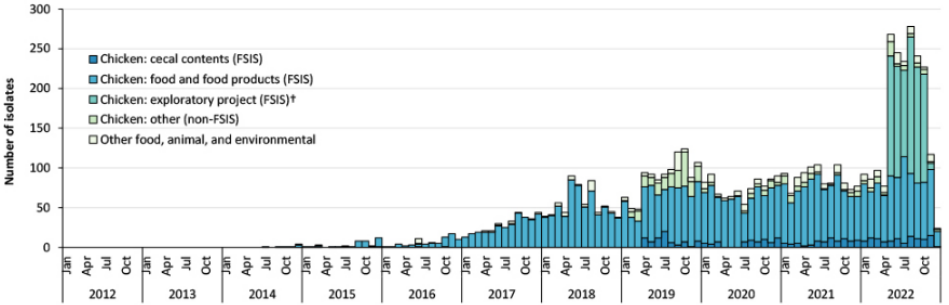
The presence of a strain that causes illnesses over a long period suggests the existence of animal and/or environmental reservoirs for the strain.

Salmonella Infantis Infections Linked to Chicken

- Classified as a REP strain in June 2021
- 2,900 illnesses since 2012
- Strain associated with two outbreaks linked to chicken products
- Commonly isolated from chicken
- Typically contains the pESI plasmid that carries resistance genes
- Most clinical isolates resistant to first-line antibiotics used to treat severe salmonellosis



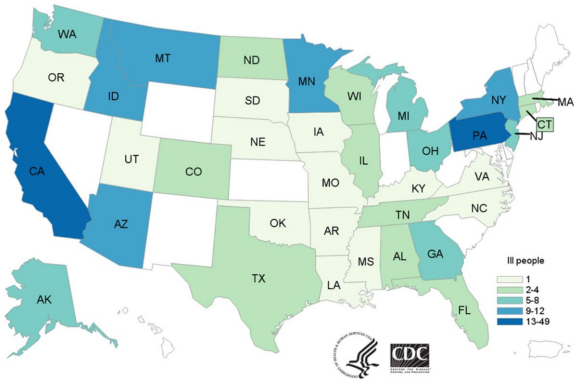




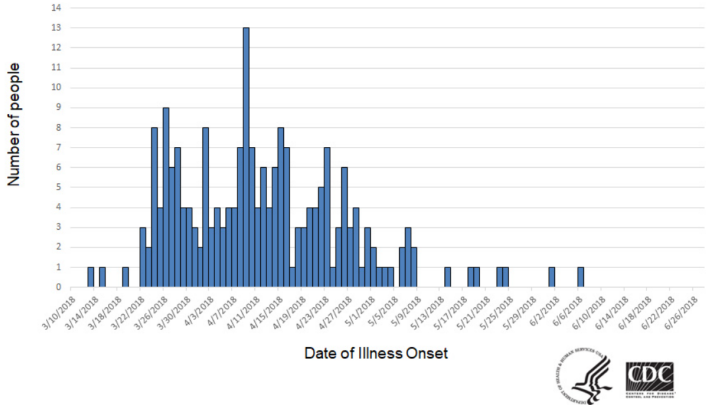
E. coli O157 Infections Linked to Romaine Lettuce, 2018

- **210 ill people from 36 states**
  - 96 hospitalized, including 27 people who developed hemolytic uremic syndrome (HUS) and 5 deaths
  - Illnesses onset dates: March 13, 2018 to June 6, 2018
  - Largest multistate outbreak of Shiga toxin-producing *E. coli* (STEC) infections since 2006 outbreak linked to spinach

People infected with the outbreak strain of *E. coli* O157:H7, by state of residence, as of June 27, 2018 (n=210)



People infected with the outbreak strain of *E. coli* O157:H7, by date of illness onset*



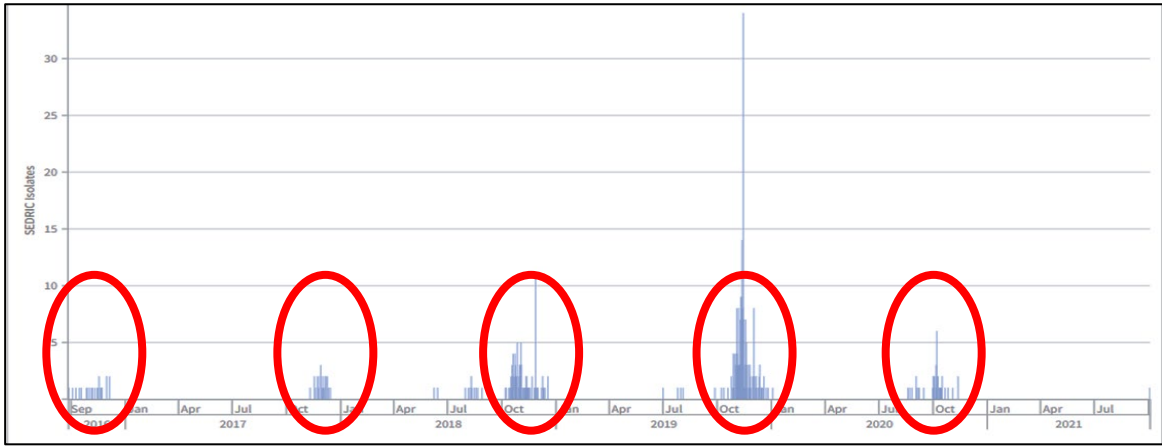
*n=210 for whom information was reported as of June 27, 2018. Some illness onset dates have been estimated from other reported information.

REPEXH01: Geographic Origins of Outbreak Vehicles

- 2017 Lake Wildwood recreational water outbreak
- 2018 outbreak linked to romaine from the Yuma growing region
- A 2019 beef isolate from CA also identified during an unsolved cluster investigation, but the source of the cattle was unknown
- Strain exhibits genetic diversity of up to about 25 allele differences

E. Coli O157 REPEXH02 Strain

- Reoccurring strain that caused repeated outbreaks each year from 2016-2020
- REP strain is genetically less diverse (0-8 allele differences), but isolates fall into 2 subgroups
- Consistent linkage to leafy greens grown in California when a source is identified



2016 outbreak
- 20 U.S. cases
- Vehicle: unknown

2017 outbreak
- 25 U.S. cases
- 42 Canada cases
- Vehicle: leafy greens (suspected)

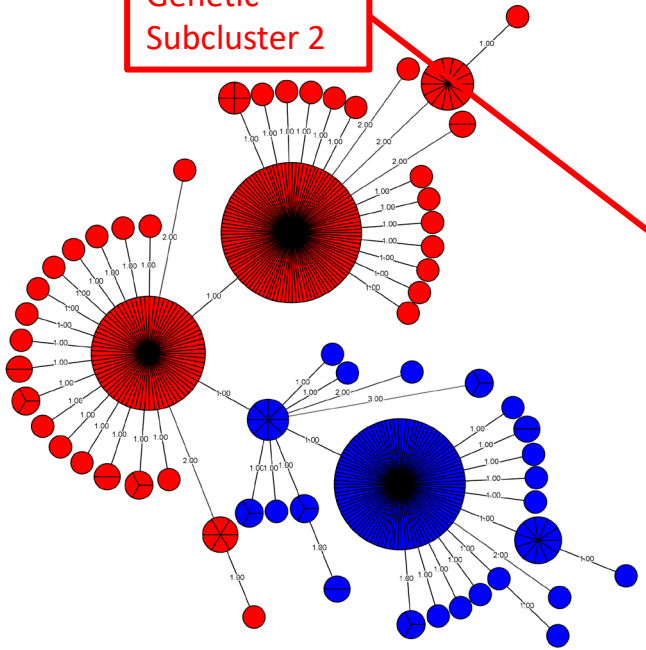
2018 outbreak
- 62 U.S. cases
- 29 Canada cases
- Vehicle: romaine lettuce (Central Coast, CA)
- Outbreak strain found in ag water reservoir

2019 outbreak
- 167 U.S. cases
- 4 Canada cases
- Vehicle: romaine lettuce (Salinas, CA)
- Outbreak strain found in unopened romaine bags

2020 outbreak
- 40 U.S. cases
- Vehicle: leafy greens
- Outbreak strain found in cattle feces

Food and Environmental Samples Yielding the REPEXH02 Strain

Genetic Subcluster 2



Genetic Subcluster 1

Salinas / Genetic Sub-Cluster 2

- 2019: outbreak isolates and unopened pre-packaged salads containing romaine from Salinas
- 2020: outbreak isolates and cattle feces

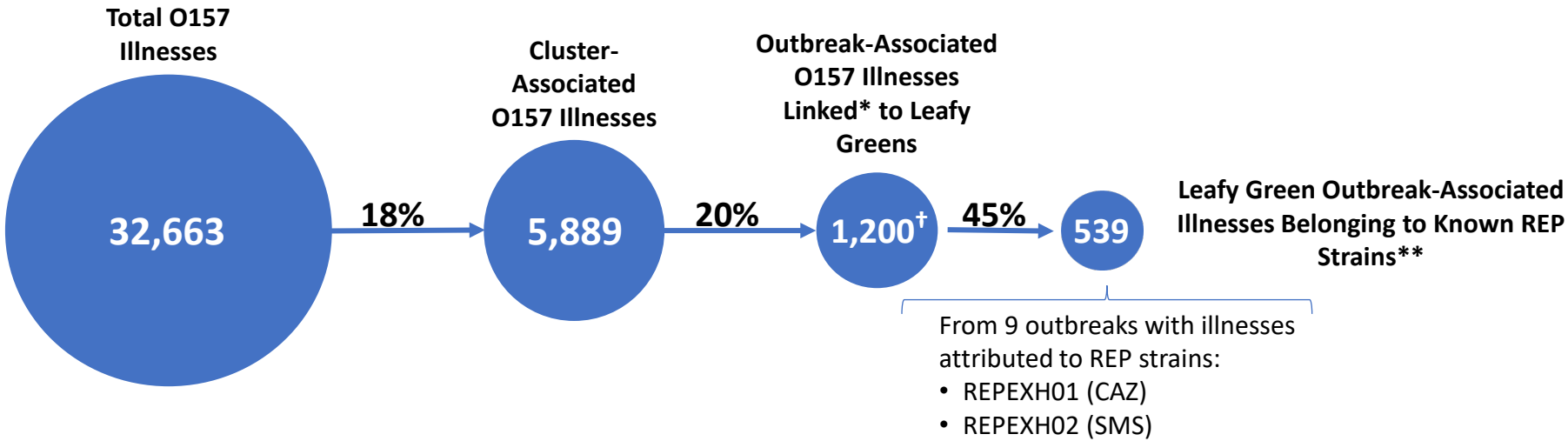
Santa Maria / Genetic Sub-Cluster 1

- 2018: outbreak isolates and irrigation reservoir sediment
- 2019: cattle trough sediment/water and cattle feces

California Growing Regions

Note: MST (0-8 alleles) created by EDLB PulseNet - Data are preliminary and subject to change

STEC O157 Clinical Isolates Uploaded to PulseNet, 2009-2022



*Illnesses from 40 outbreaks with a confirmed or suspected link to leafy greens

† 840/1200 isolates have been sequenced

**REP strains are defined using sequence data; PulseNet fully transitioned to using WGS in July 2019, therefore the number of isolates belonging to REP strains from 2009-2019 may be under-represented.

Common REP Strain “Phenotypes”

- Consistent / increasing illnesses, many non-human isolates from primarily the same food (often meat/poultry)
  - REPJPX01 strain associated with chicken an exhibiting multidrug resistance
- Genetically narrow, repeated vehicles, reoccurring, strong regional and seasonal pattern
  - REPEXH02 strain associated with repeated Fall outbreaks linked to leafy greens from the California Central Coast
- Genetically diverse, multiple vehicles, persisting
  - REPEXH01 strain that includes the 2018 Yuma romaine outbreak

Where We Want to Go with REP Strains

- Develop specific strategies for each strain: goals, key partners, etc.
- More data sharing and collaboration, both across federal agencies and with academia and industry
- Move from a monitoring to prevention mindset
  - How do we interrupt the paths from reservoirs to food vehicles to prevent illnesses from these strains
  - How can understanding these pathways improve food safety broadly?
- Inherently One Health endeavors, requiring multidisciplinary evaluation of the interplay between humans, animals, and the environment

Thank you!

For more information, contact CDC
1-800-CDC-INFO (232-4636)
TTY: 1-888-232-6348 www.cdc.gov