Deliverable JIP1-2.9 Revised OH Knowledge Base - Integration, including lessons learned from the OH pilots

Workpackage 2-Integration

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ONE HEALTH SURVEILLANCE INITIATIVES IN EUROPE

Knowledge base of integrated, cross-sector surveillance initiatives in different member states of the EU

One Health is defined as cross-sector collaboration to design and implement programmes, policies, legislation and research to achieve better public and animal health outcomes. This is particularly relevant in the control of zoonoses and combatting antibiotic resistance (WHO 2019; OIE 2019). One Health traditionally includes public health, animal health and the environment. However, ORION and other projects defines that collecting and interpreting data from all three sectors is not a requirement to characterize a system as One Health, as long as systematic and organized collaborations between any of the sectors can increase efficiency, cost-effectiveness and cost-benefits of currently running systems (Bordier et al., 2018, OHEJP glossary).

In surveillance of foodborne pathogens and antimicrobial resistance (AMR), cross-sector collaboration according to the One Health principle is likely to have a positive effect on the sensitivity, timeliness and on the efficiency of control. Traditionally, the EU Member States (MS) carried out surveillance in individual sectors according to target populations with well-defined areas of responsibilities, communication channels and risk management roles. However, the advantages of using One Health (OH) principles is becoming more apparent. MS are beginning to define, structure and implement cross-sector collaboration more strategically, especially in the areas of foodborne zoonoses and antimicrobial resistance surveillance. It is rare to see full cross-sectorial surveillance systems, but smaller or more confined One Health surveillance initiatives (OHSI) exist in MS today. An initiative can be defined as a subsystem or component conceived to induce change in the larger system that it is a part of (Ruegg et al, 2018).

Often OHSI arise as a response to a specific need in the individual MS and continue to develop in that context for a specific purpose. The description of OHSI are seldom published and often only apparent to actual stakeholders, actors and users within the MS. Some initiatives are supported by legislation, some arise due to resource-saving activities and others are just a formalised of groups of people, who need to talk regularly to understand the OH perspective of their surveillance outputs.

Integration of surveillance can occur in many ways and at different stages of the surveillance pathway (Figure 1) (Filter et al, 2021). Usually, an OHSI will address only a few steps in the surveillance pathway and apply to just one or two components of the full surveillance systems.

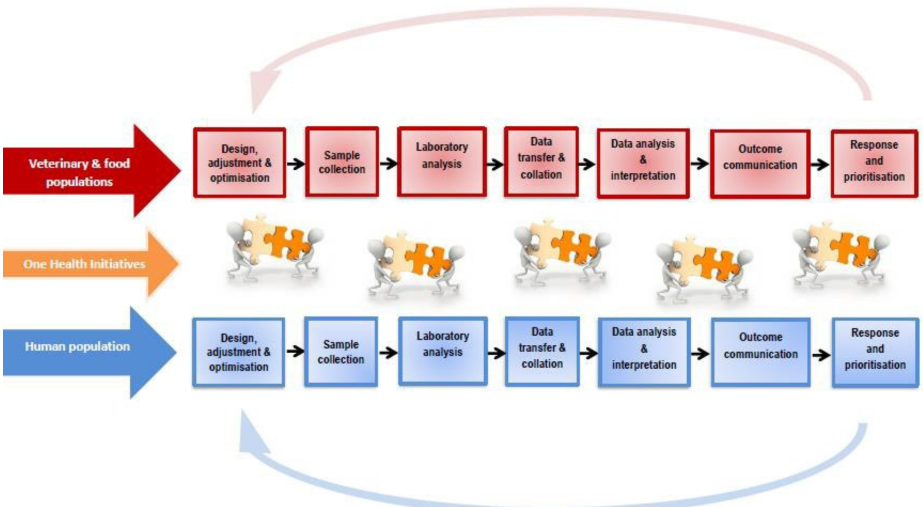

Figure 1. *Schematic illustration of potential One Health Surveillance Initiatives between sectorial surveillance pathways for a surveillance component.*

An OHSI can connect one or more steps in the otherwise sector-specific pathways. It could be a cross-sector sample collection-approach, a multi-sector expert group, multi-sector outbreak detection team or an institute dealing with emerging hazards in multiple populations. Some OHSI may be so comprehensive and established that they can become surveillance components in their own right. Smaller initiatives are more common and can be fluent and intangible, interconnecting or overarching several steps in the pathway.

One Health is today an established approach that is encouraged by most supra-national organisations e.g. the UN through their: Taking a multi-sectoral, one health approach: a tripartite guide to addressing zoonotic diseases in countries. However, at a national level changing into a One Health approach can be difficult, especially where surveillance programmes are long-running, well-established entities under separate ministries, with sector-specific agencies including their own scientific experts, which is often the case in European countries.

One thing that is nearly always required to induce change, innovation or new methods is proof-of-principle or proof-of-concept (Keen, 1981). This is normally the initial evidence that the new approach is feasible, effective and provides value above existing approaches (Rabinowitz, 2013). Without proof-of-principle inertia prevails, because it does not require additional resources or innovative thinking (Keen 1981). At the Stone Mountain meeting representatives from the U.S. Centers for Disease Control and Prevention (CDC), OIE, FAO, WHO, EU and Princeton University were assembled and subsequently published the report "One Health": A Policy Perspective – Taking Stock and Shaping an Implementation Roadmap" in May, 2010 (Rabinowitz, 2013). They described a need for proof-of- concept for two main postulates about One Health:

1) It is feasible to integrate human, animal, and environmental health efforts to predict and control certain diseases at the human–animal–ecosystem interface.
2) Integrated approaches that consider human, animal, and environmental health components can improve prediction and control of certain diseases.

The WP2 integration work package was also examining these issues and aimed to inspire others by collating and developing proof-of-concept that support following statements:

1) One Health Surveillance initiatives already exist and are implemented in EU countries
2) Integration at different levels the surveillance pathway, data analyses & interpretation and outcome communication a) are feasible, and b) can improve our understanding and control of these diseases
3) Development and implementation of One Health Surveillance Initiatives are complicated and collaboration is the foundation for a successful OHSI.

1. Existing and implemented One Health Initiatives in Surveillance

A survey was initially conducted to identify exiting and implemented OHSIs in the EU and beyond. ORIONs focus is the EU, but exciting initiatives are appearing around the world. Whereas the EU normally work to implement OHS within existing systems and organisations, some LMIC are developing OH surveillance systems from the beginning – often driven by AMR surveillance. This 'blank sheet' situation allows countries to establish the OH focus top-down from policy to governance to agencies, in contrast to the EU situation, where OH implementation requires changes to established institutions and traditions. Thus, the example of the ARMCO from Singapore was included in the survey to represent the top-down approach (Ellis-Iversen et al, 2019).

The OHSI were identified using a two-step approach with a screening questionnaire and then approaching a subset of responders for semi-structured interviews (for detailed description of methods see Deliverable-JIP1-D2.3 Report on requirement analysis for an "OH Knowledge Base – Integration" (ORION) | Zenodo.

The initial screening questionnaire identified 78 OHSI in 20 EU countries, of which 38 OHSIs matched the project definition of an OHSI i.e. concern foodborne pathogens, defined as surveillance activity and include active collaboration from at least two sectors. A total of 15 OHSIs were included in the final report: Inspiration and ideas: One Health Integration in Surveillance (Ellis-Iversen, 2019). In the report, each OHSI was described as a one-pager explaining the main objectives, the work carried out, actors, future developments and challenges. It also provided a contact for further information.

The 15 examples provide proof-of-principle that OHSI are possible for almost every step in the surveillance pathway except for 'sample collection', which no OHSI addressed (Figure 2). Surveillance samples are collected from individuals in different populations and it may not be an effective implement cross-sectorial work at this surveillance pathway step. In the EU, it may cause legal or organisational problems, if subjects had to submit samples to professionals from another sector e.g. human patients to veterinary surgeons.

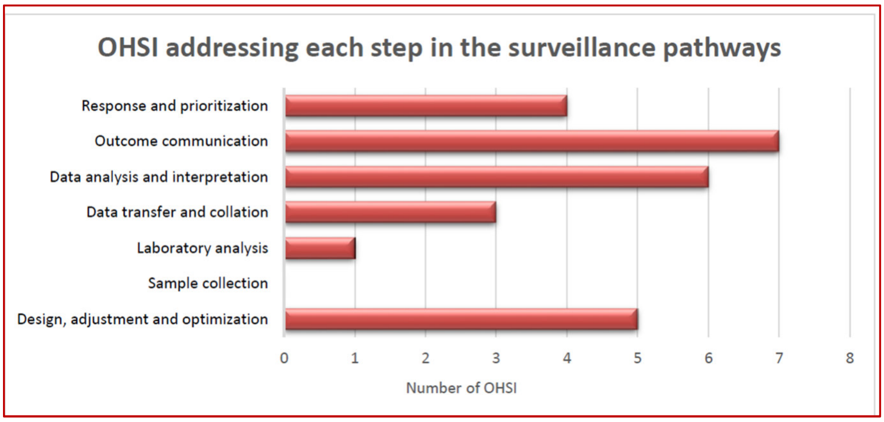

Figure 2. Number of One Health Surveillance Initiatives (OHSI) addressing each of the steps in the surveillance pathway

The cross-sector laboratory initiatives were implemented either for rare diseases or when applying a novel/advanced analysis, so all strains of one species may be sent for typing or sequencing in one sectoral laboratory specialized in the methodologies. Apart from saving resources, this may also lead to faster outbreak identification with subsequent response, and more collaboration between sectors.

Multi-sectorial expert groups used to discuss and interpret surveillance result were also reported from several countries. In two countries, these were established groups to deal with new, emerging or changing pathogens and to generate prioritized advice on response and control; these groups included risk-managers and decision-makers as well as scientific experts. Other countries reported cross-sector groups that meet regularly and discuss the current situation, outbreaks and interpret or explain changes together.

Publishing a joint report on zoonoses from multiple sectors was common in the screening questionnaires, probably because it is a logic next step after the joint reporting by ECDC and EFSA. Some variation was reported between countries on how much the sectors shared data, collaborated on result interpretation and on the collation of the report.

A cross-sector governance structure for zoonotic or AMR surveillance was also reported from several countries. The governance structures were all at national level and were responsible for varying levels of strategy, optimization, communication and prioritization of response.

The survey was not comprehensive nor randomised to provide representativeness, but it showed clearly that OHS is feasible at almost every step of the surveillance pathway. It provides ideas and inspiration to other countries and specific examples could be used a proof-of-principle, when advocating for a new OHS in a country. The catalogue of OHSI can be found here: Report on OH Surveillance Initiatives.

2. Integration of data and OH-focussed dissemination is possible and provide added value – developing proof-of-concept – extending the knowledge base

Two pilot projects were conducted directly in this work package: One to increase the One Health interpretation of AMR and AMU surveillance in Denmark, and one to generate a proof-of-principle for how integrated OH data analysis can improve surveillance and disease control.

2.1. Pilot 1: Increasing the One Health interpretation of AMR and AMU surveillance

This pilot study aimed to explore how the zoonoses chapter of the DANMAP report could identify One Health objectives, and whether further integrated analyses and interpretations would enhance the One Health conclusions for decision-makers and other users of the report (Details can be found in the pilot project report "Increasing the One Health interpretation of AMR and AMU surveillance" (Annex 1).

The One Health surveillance objective of for the DANMAP chapter on AMR in Salmonella and Campylobacter was defined as: *monitoring trends of AMR in the food chain to individual drugs that may result in treatment failure in humans*. This was different than the previous objectives, where all results and data were represented side-by-side from each sector with a cross-sector discussion. Using the overarching OH objective provided a One Health focus and facilitated further data stream integration in the chapter of "Resistance in zoonotic bacteria and animal pathogens" in the national report of DANMAP (DANMAP 2018, DANMAP 2019). The OH integration consisted several steps 1) Identify the antimicrobial drug classes relevant for treating human patients with acute gastroenteritis; 2) present the resistance levels to each relevant drug for all populations in one figure; and 3) discuss the use the relevant antimicrobial drugs classes in animals and their OH implications (Figure 3).

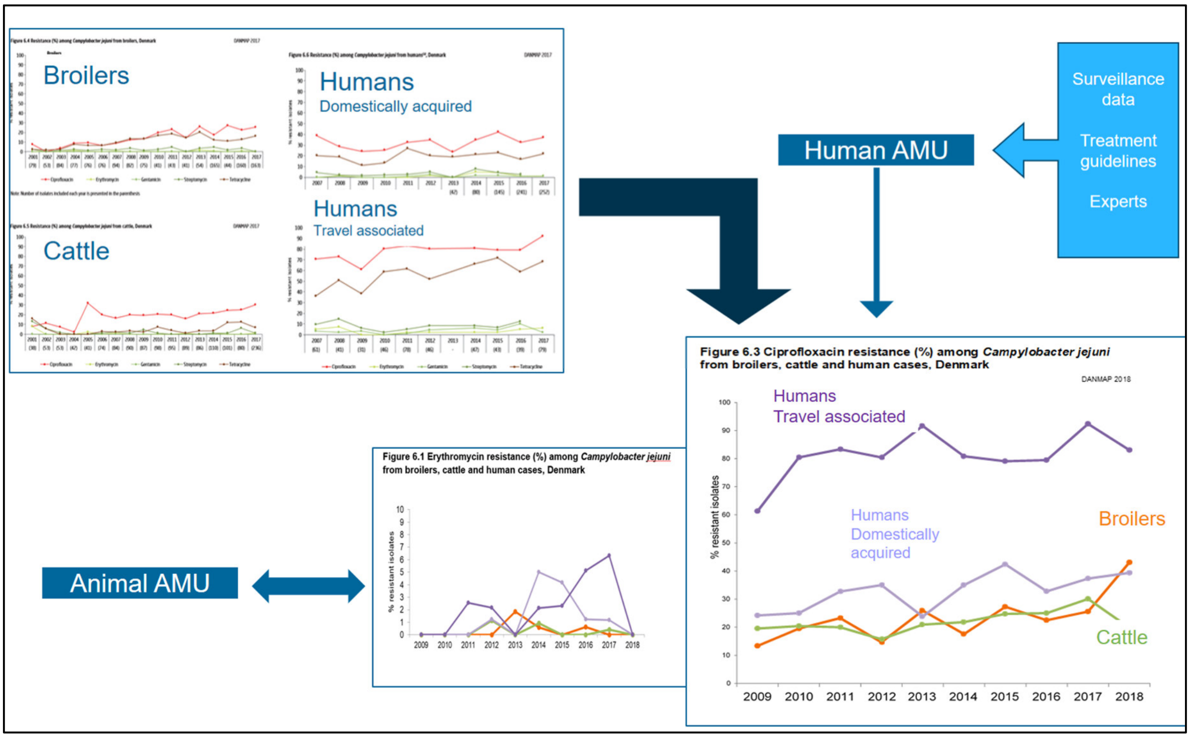

Figure 3: The process of moving from integrated to One Health interpretation of AMR in Campylobacter in Denmark.

The enhanced One Health focus improved the value for the users by clearly focussing on the One Health risk that AMU and AMR poses. The Danish Veterinary and Food Administration expressed: *"The overall target of our efforts on AMU and AMR in the food production is to support human health and ensure that it is and will be possible to treat human illnesses with antimicrobials. To achieve this target we aim to reduce or maintain a very low level of AMR throughout the food production, focusing on the critically* *important antimicrobials. When reporting the status of AMU and AMR surveillance it is important, that the impact and trends concerning the risk posed to human health, by foodborne AMR is addressed and if possible assessed. The enhanced One Health focus in the zoonoses chapter of DANMAP 2019 supports this agenda."* (Quote Gudrun Sandøe, Danish Veterinary and Food Administration).

International users also seek DANMAP as an example of integrated surveillance, and the OH approach has been presented to policy and scientists in Middle- and South America through PAHO-WHO workshops, Nigeria via the Fleming Fund and Asia as part of consultancy on integrated surveillance and AMR surveillance systems. When surveillance outputs are disseminated from a One Health perspective, it indirectly influences OH integration among the users, too.

The increased level of integration demanded additional resources from the authors, because the close collaboration and co-authoring required consensus on everything. This also meant that delays or changed priorities in one sector had knock-on effects on the other sector. The clearly defined output and using previously established collaborations facilitated the work and ensured results and implementation. The new approach was published in the DANMAP 2018 & DANMAP 2019 and has proved that OH interpretation and reporting of surveillance outputs beyond side-by-side is possible.

2.2. Pilot 2. Does One Health integration of surveillance data improve surveillance and disease control? - Integrating national Campylobacter surveillance data to establish proof-of-principle

This study was developed to investigate the usefulness of integrating data across sectors and to explore whether we could establish a proof-of-principle that could be used by others. At the same time, we wanted to support the Danish National Campylobacter Action plan with any potentially useful outputs.

Campylobacter surveillance is carried out at several steps of the food chain, and the Danish National Campylobacter action plan routinely uses all the individual outputs independently to assess compliance with its targets (Figure 4). The surveillance data from each data stream is also used by each actor for own relevant purposes, but no data integration or interpretation between data streams is used.

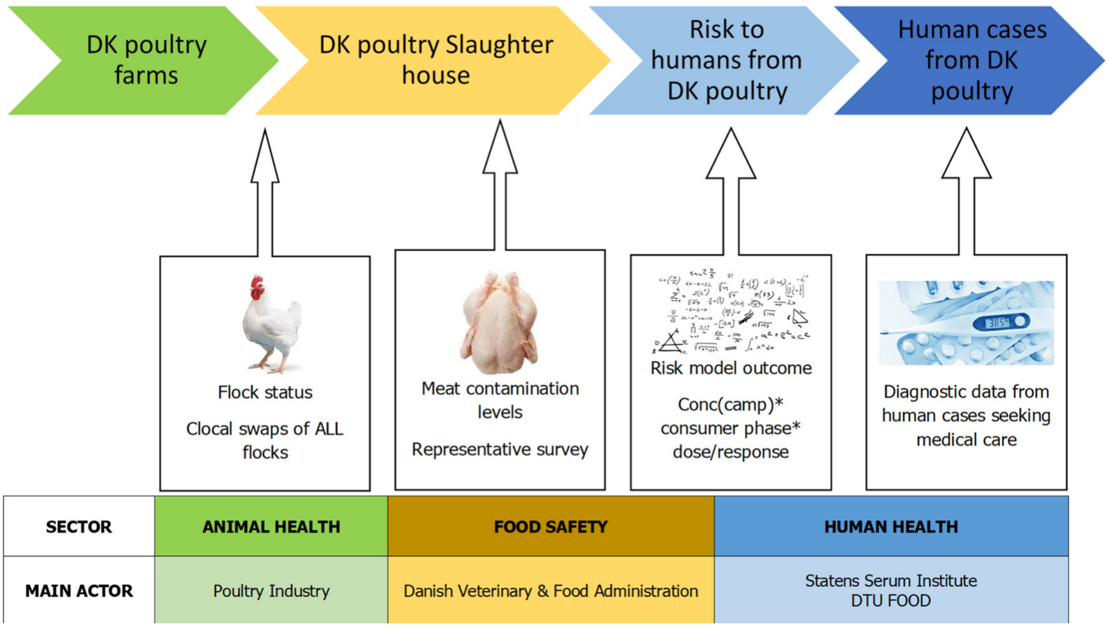

Figure 4. *The main surveillance components of the Danish surveillance system for Campylobacter in poultry*

Three studies were developed to look at different steps of data integration and explore questions relevant to Campylobacter control (Annex 2).

***Study 1** explored surveillance outcomes across data streams by comparison of Campylobacter prevalence at flock and carcass levels and assess whether adjustments are needed.*

The prevalence was compared across the animal health and food safety data streams, since in principle the same surveillance units were monitored and some agreement or similarity was expected. The seasonal patterns were similar in the two datasets, but the flock prevalence on carcasses at the end of the slaughter line was consistently higher than the flock prevalence in birds at the start of the slaughter line. When adjustments were made for the precision of the laboratory method and sample sizes the prevalence estimates were more similar, but this did not explain all the differences.

This small comparative study illustrates the value of adjusting surveillance outputs for the uncertainties generated by the designs of the individual surveillance components, such as laboratory test choice and sample sizes, when integrating data from different data streams and comparing outcomes over time. Thus, comparing true/adjusted prevalence rather than apparent/measured prevalence enhances the precision, comparability and interpretability of surveillance information collected in different sectors. If the data formatting, integration and adjustments were implemented routinely, surveillance outputs could be compared precisely between surveillance periods, components and countries.

***Study 2** investigated whether any new information on public health risk arises from data stream integration by testing the agreement of surveillance outcomes for individual flocks and carcasses, and how this information could feed into the National Campylobacter Action Plan.*

The agreement between status of individual flocks at the two measuring points, birds and carcasses, was explored. The result showed that about one third of the positive carcasses originated from *Campylobacter* negative flocks.. The mean and median contamination levels of the positive carcasses from negative flocks were significantly lower than the levels of Campylobacter on carcasses from positive flocks.

It is possible that some of the disagreement between the outcomes for each flock in the two data streams are due to uncertainties in data collection and data quality that occur when using data for a different purpose than originally intended. However, the difference in contamination levels suggested that the cause of contamination in the two groups was different, and cross-contamination at the slaughterhouse was much more common than previously anticipated. This was a new finding resulting from the process of data integration. This generated information will be relevant for the National Action Plan, as it highlights a need for addressing cross-contamination risk at slaughterhouses to reduce the risk to humans.

***Study 3** designed a risk-based control programme by using information from the data streams and assessed the value of risk-based control by combining it with a public health risk model to measure the effect on public health.*

All farms in the animal health data stream were classified in three groups according to the Campylobacter status of the flocks they delivered in 2018: Always negative, low risk and high-risk (HighR-CHR) farms. Two classification strategies were applied, one based on the annual number of positive flocks and one based on annual percentage of positive flocks, both with cut-offs at the 3^{rd} quartile.

Secondly, three scenarios were defined describing how effectively the HighR-CHRs were able to control Campylobacter in their flocks the year following the classification year. For each scenario in each strategy the exposure model calculated relative risks, which were compared to the actual relative risk for 2019 (RR=0.94) in the current National Action Plan i.e. without risk-based control[1]. The status of the other two groups of farms were assumed to be unchanged.

The risk-based control approach could have reduced the annual flock prevalence significantly, if the HighR-CHR only delivered negative flocks. If the HighR-CHR were classified in 2018 and managed to keep campylobacter out of all their flocks in 2019, the risk to public health could have been reduced to about half. Other, and maybe more realistic scenarios, provided smaller reductions, but still reduced the risk to public health significantly compared to the current risk without risk-based control (Figure 3).

The pilot study proved that integrating surveillance data from different sectors and from different points in the food chain was possible, albeit required cumbersome data cleaning and formatting. Furthermore, adjusting some of the outcome estimates according to surveillance design improved the precision of the estimates and the ability to compare and work across data streams.

The pilot also demonstrated that when data streams from different populations are integrated, it provides additional information and may generate new knowledge. Our study showed that cross contamination in slaughterhouses occur much more frequent than anticipated and poses a risk to public health. If integration of the surveillance data streams is implemented routinely, this could be a potential new surveillance point and a potential new control target for the action plan.

The integration of the surveillance data streams supported the One Health objective by contributing to reduced risk to public health. When combined with other methodologies e.g. risk-based approaches, it can provide new perspectives and new options for control. In this case, we found a more cost-effective method, where targeting control to 25% of farms may possibly reduce the risk to public health significantly more than targetting all farms with less effort.

The pilot study provided proof-of-principle that by integrating data from different sectors, we can add value to current systems and to the data collected. It also highlighted the importance of looking along the whole food chain and across the sectors of animal health, food safety and public health to reduce the risk of human campylobacteriosis.

Surveillance data is never perfect, and has best-fit for the purpose it is collected for. Once we use this data for other purposes and integrate it with other data streams, the weaknesses and uncertainties still exist, they will affect the final estimates and answers. It is important to highlight this, and ensure transparency around assumptions and weaknesses, when models and integrated data analysis are used for decision-making.

2.3. Pilot 3. Descriptive surveillance framework farm-to-patient

The aim of this study was to develop at template for describing national OH surveillance systems. The project was abandoned due to COVID-19 and staff changes.

3. Other ORION pilot projects- extending the knowledge base

Orion is a large, integrated project and includes partners from seven EU MS and 13 institutes. Each country carried out at least one pilot study to enhance of facilitate OH integration of surveillance across sectors. The pilot studies had different aims, targeted different organisms and included different sectors, but all attempted to make an improvement towards One Health surveillance in their country. Twelve pilot projects were completed during the time of ORION, and the details of each can be found in the ORION KNOWLEDGE HUB.

[1] The National Action Plan monitor the annual risk to public health risk of human campylobacteriosis associated to broiler meat produced in Denmark relative to same risk in 2013.

To ensure coherence between the pilots, use integration opportunities, avoid overlaps and share ideas between the studies, three workshops on the pilot projects were organised and chaired by WP2 Integration. A workshop in June 2019 co-hosted with WP1 focussed on finding commonalities and potentials for collaboration between pilot projects. The need for a generic way to document the planned pilot and expected outcomes were also discussed, and a template for pilot project description was developed and agreed. Furthermore, the Codex was introduced, and it was discussed, how the outcomes of the different pilot projects would fit into the Codex and thus, become anchored within the ORION project. The next pilot project workshop was co-organised with WP3 in January 2020, and updates, evaluation of lessons learned and reporting templates were discussed. The pilots were now progressing and the project leads presented progress and preliminary outcomes, and we initiated the discussion on lesson learned. WP3 and WP2-integration developed frameworks for OH progress evaluation for each pilot to apply. The last workshop in March 2021 focussed on the lessons learned from each workshop, and how these could be incorporated into the Codex. The ORION leads of each pillar in the Codex collated the relevant lessons and chaired the discussion on lessons within their pillar. Each pilot project will deliver a report in the template generated by the coordination team and WP2 integration. The pilot report template contained an overview of objectives and outcomes of the pilot, and included the OH progress evaluation frameworks and lessons learned from the pilot project. The pilot report will be available online and can be referenced by other project reports (ORION KNOWLEDGE HUB)

Among the pilot projects, three explored further integration of NGS data between sectors and into their current surveillance systems in Norway, UK and Denmark. Denmark generated a new fully implemented and functional surveillance component and thus, a new OHSI, to identify human outbreaks of Campylobacter and their potential links to poultry meat in real-time. The other two were able to explore and solve different levels of legal and technical issues in setting up a similar system for salmonella (UK) and Listeria (NO), and thus, progressed nicely towards new OH surveillance components in these countries. Two pilot projects worked on mapping the OH surveillance landscape, data streams and actors in their country, one for AMR (BE) and one for Hepatitis E (NL) with the aim to further integrate surveillance and data in the future. Two other pilot projects improved their OH dissemination by further integrating reporting across sectors: Sweden in their Annual Zoonoses Report and Denmark in their DANMAP report. Both initiatives are now fully integrated in the countries. The German pilot projects focused on testing OHS-support tools, which were generated in ORION on existing surveillance programmes. Visit ORION KNOWLEDGE HUB for further details on the individual pilot projects.

4. Lessons learned

The main advantage of conducting pilot studies within the ORION project, in addition to gathering information from literature or interviews, was the opportunity of learning through the process, and learning lessons about the applicability of the OH approach in practice. This acquired knowledge may guide others in developing OHSIs in the future.

By the time of the 2nd workshop, many pilots experienced that lack of tools, methodology or technical solutions were often not what hindered or complicated integration across sectors. It was often 'individuals', 'the human factor' or 'sensitivities' that slowed things down or hindered implementation of novel solutions. The OHEJP CODEX also considers collaboration the foundation all OH integration (Filter et al, 2021) and where many focus on technical solutions for OH, less is known about the values and attributes that are needed for effective OHS (Larkan, 2016; Stephen 2016).

Many lessons on collaboration were learned throughout the project. Positive lessons and tools that facilitated collaboration and characterised positive outcomes were: frequent meetings/workshop between partners, mutual and clear definitions and goals from the beginning of the project agreed between all partners, templates/check lists/schematic drawings, data-sharing agreements in place and that the project addressed a mutual need/interest. Other things that motivated good collaborations were piggy-backing on existing partnerships and previously established trust, when political interest or pressure existed, and if equal priority/interest/buy-in/enthusiasm from the participating organisations was present. Clear areas of responsibilities and a continuous focus on the outcomes and goals rather than on detailed process and resources, were also experienced as positive in building collaborations.

Some pilot projects saw collaboration grow after having 'planted the seed' a while ago. However, this approach is not well-suited for a project with a specific end time. In general, it was recognised that OHSI take time to develop and establish, which does not always fit well with academic project funding streams and deadlines. Some pilot projects experienced that success in starting up an OHSI could be very person-dependent and convincing individuals to integrate their expert topics with others could be a barrier.

All the collaboration barriers experienced in the pilots in ORION appear to be common challenges and have previously been collated and reported in a systematic review (Ribeiro et al, 2019). They are to be expected when starting up new partnerships, and it is not always possible to transfer others experiences on to a new situations.

Inability to enlist leadership support both internally in the organisations and externally was highlighted as problem. This is also a known barrier for additional OH integration between policy areas and portfolios (Ribeiro et al 2019). For some of the OHSI-developing pilot projects, it could be difficult to get buy-in from or within organisations without proof-of-principle. Interestingly, in contrast our tool-developing pilot projects found that, despite offering and demonstrating an actual tool, it was difficult to obtain adoption in existing OHSI.

The lack of concept-of-principle to facilitate advocacy for agreement within and between agencies and up the management ladder is the problem addressed by this work package. We have gathered a catalogue of pre-existing initiatives to inspire and provide proof-of-principle. We have further nurtured collaboration, knowledge-sharing and between the ORION pilot projects and anchored them within the project, whilst ensuring some level of standardisation allowing lessons to be shared in an effective way. We have further conducted two pilot studies improving the OHS in Denmark, whilst providing proof-of-principle of added value of data integration and OH-focussed dissemination.

5. Impacts and dissemination

The OH reporting approach is implemented in the annual DANMAP reporting. With the reports strong international profile, the OH reporting concept is disseminated far and has potential to enhance the understanding of the complex OH risk of AMR. The national authorities have commended the work for highlighting the OH risk. Both impacts are described as part of the pilot project above.

The Campylobacter data integration outcomes are currently under discussion for implementation with the authorities Danish Veterinary and Food Administration, the Danish poultry industry and the Danish National Campylobacter Action Plan.

5.1. *Publications*

- Ellis-Iversen, Petersen & Helwigh 2019. Inspiration and ideas: One Health Integration in Surveillance. Technical University of Denmark. ISBN (Electronic)978-87-93565-41-8. Report on OH Surveillance Initiatives Accessed 18/03/21. ISBN: 978-87-93565-41-8

- DANMAP 2018, chapter 6. Resistance in zoonotic bacteria and animal pathogens. www.DANMAP.org

- DANMAP 2019, chapter 6. Resistance in zoonotic bacteria and animal pathogens. www.DANMAP.org

- Alessandro Foddai, Nao Takeuchi-Storm, Johanne Ellis-Iverse. Integrating Danish Campylobacter surveillance data streams to investigate broiler flock prevalence and potential cross-contaminations at slaughterhouse. In the pipeline for submission to peer reviewed journal

- Alessandro Foddai, Maarten Nauta, and Johanne Ellis-Iversen. Risk-based control of Campylobacter spp broiler farms and slaughtered flocks to mitigate risk of human campylobacteriosis - A One Health approach. In the pipeline for submission to peer reviewed journal

- Filter, Buschhardt, Dórea, Lopez de Abechuco, Günther, Sundermann, Gethmann, Dups-Bergmann, Lagesen, Ellis-Iversen, One Health Surveillance Codex: promoting the adoption of One Health solutions within and across European countries, One Health, 2021, https://doi.org/10.1016/j.onehlt.2021.100233

- Delivery reports D2.3 and D2.6 and Annual progress reports for ORION, Weblink: ORION - One Health EJP

5.2. ***Presentations***

- PAHO-WHO Workshop Resistencia a los antimicrobianos, detección y vigilancia en las Américas at Simposio RELAVRA Congreso ALAPAC 2021. *Best Practices in integrated surveillance*, March 2021 by Johanne Ellis-iversen

- COHESIVE extended workshop on: Informal discussion and signal exchange of zoonotic trends across Europe, *DANMAP integrated AMR and AMU surveillance – The benefits of OH collaborations in understanding risks and signal sharing*. February 2021 by Johanne Ellis-iversen

- National DANMAP seminar on antibiotika-forbrug og –resistens, *Highlights fra DANMAP 2019*, Nov 2020 by Birgitte Borck Høg

- PAHO-WHO: Role of Molecular Biology in Integrated AMR surveillance within the framework of One Health: *Best Practices in integrated surveillance*, August 2020 by Johanne Ellis-iversen

- National Institute of Health, Republic of Korea: Multi-sectorial One Health AMR Initiative for AMR control, *Data integration for One Health Surveillance*, Nov 2019 by Johanne Ellis-iversen
- Delegation visits Hong Kong with representatives from Centre of Health protection, Department of Food and Environmental Hygiene and Department of Agriculture, Fisheries and Conservation, *Integrated Surveillance* Nov 2019 by Johanne Ellis-iversen

- Fleming Fund Fellows from Nigeria, November 2019 *Integrated surveillance* by Johanne Ellis-Iversen

- Meeting with representatives of the poultry industry and of the Danish Veterinary Administration (2020). Integrating surveillance data streams and simulation modelling to inform risk-based control of Campylobacter spp. from "farm to patient" by Alessandro Foddai

- National seminar in Denmark on Campylobacter research organized by SSI for industry, academia and policymaker 2021 by Alessandro Foddai

- Epi-risk team meeting, DTU-Food, 2020. Discussion on CHR risk-based Campylobacter spp. control in Danish conventional poultry farms by Alessandro Foddai

- Epi-group meeting, Dept. of Global Health Surveillance, DTU-Food (2021). Integrating surveillance data streams and simulation modelling to inform risk-based control of Campylobacter spp. from "farm to patient" by Alessandro Foddai

- SCAR Animal Health and Welfare Collaborative WG of ERANET, representatives of EU governments, *DANMAP - One Health Surveillance in action*, 2019 by Johanne Ellis-Iversen

- Nordic Zoonoses Meeting, Uppsala, *DANMAP in a One Health perspective*, Sept. 2019 by Channie Kahl Petersen

- WP2 integration and its pilot's projects also presented updates at every consortium meeting and workshop.

6. Acknowledgements

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Written by WP2-integration Lead: Johanne Ellis-Iversen 19/03/21

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ANNEX 1:

WP2-INTEGRATION DTU/SSI PILOT PROJECT 1:
INCREASING THE ONE HEALTH INTERPRETATION OF AMR AND AMU SURVEILLANCE

Background

Integrated and OH AMR surveillance systems are developing all over the world, but only few examples of One Health reporting exists. Many AMR surveillance systems are working on combined reporting of data from several sectors, but the outcomes are rarely integrated before analysis and are seldom interpreting data directly to a One Health objective. Data analysed and reported from a OH perspective, facilitates One Health risk management.

DANMAP is the Danish surveillance system for antimicrobial consumption and resistance in humans, food and animals, and has existed since the mid-1990s. The annual DANMAP reports gives a detailed and comprehensive picture of five data streams: AMR in people, food and animal and AMU in people and animals, enabling stakeholders to understand the complexity of the system that drives AMR. However, very little actual integrated cross-sector data analysis were included in the report and the One Health objectives and interpretations of the results were vague and poorly defined.

The DANMAP report is a "show case" worldwide and has inspired EU reports, as well as many new surveillance systems around the world. Danish experts and stakeholders are frequently requested for talks at international conferences, and Denmark often hosts representatives from other countries, who come to learn about integrated surveillance and DANMAP. In 2016, the report was downloaded 9000 times to computers all over the world. Thus, any improvements made to the DANMAP report has the potential to impact AMR surveillance on a global scale.

Objectives & expected outcomes

This pilot study aimed to explore, whether the zoonoses chapter on AMR in Salmonella and Campylobacter of DANMAP could report to One Health objectives, and whether further integrated analyses and interpretations could enhance and clarify the One Health conclusions for decision-makers and other users of the report.

Process

The working group consisted of the authors of the DANMAP zoonoses chapter from DTU FOOD and SSI. The working group started out by identifying the One Health objective for AMR in Campylobacter and Salmonella. Then two planning meetings were held to decide how to identify and address the OH objective, what data was available, what analyses were needed and which knowledge gaps could be identified.

Other objectives beyond the OH were also agreed for each section. For AMR surveillance in Campylobacter, only an OH objective existed, as zoonotic important Campylobacter do not cause disease in animals. AMR in Salmonella has several objectives: the OH objective and animal health objectives. Resistance to critically important antimicrobials, despite not being used for treatment of human salmonellosis, and resistance in different Salmonella serovars were also of interest to users of the report.

An outline of each section was developed including headings and sub-headings. This constituted the working group's key agreement document that steered data needs, analyses and interpretations throughout the process.

To address the knowledge gap of robust information on antimicrobial agent-of-choice for treatment

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of acute gastro-enteritis in the primary sector, a study was initiated. Additional data analyses were requested from the DANMAP experts on human antimicrobial use, on what antimicrobials were prescribed by general practitioners for indications similar to acute gastroenteritis, with the hope to identify which antimicrobials were used and how many were treated for acute gastroenteritis annually. Experts working on treatment guidelines were also consulted, and all available national and regional treatment guidelines were reviewed (unpublished study).

The practicalities around data sharing and data collation were also addressed, and it was decided that data exchange at aggregated level were sufficient to achieve the OH objectives and thus, no special data sharing agreements beyond the usual ones were needed.

Results

The overarching One Health objective of AMR surveillance in Campylobacter and Salmonella was defined as: *Monitoring trends of AMR to antimicrobials drugs that may result in treatment failure in humans.* It was recognized that additional objectives existed, especially for some of the Salmonella serotypes, which were associated with high morbidity and or mortality or targeted by national control programmes in animals. Results for these would still be included, as the report has other users than risk managers working in One Health.

Once the antimicrobials used for treatment of acute gastroenteritis were identified, the integrated analyses focused on resistance to these and other critically important ones. The data was integrated and analysed in the same figures, illustrating the AMR trends in humans, food and animals to each relevant drug. The text then further reflected on how/whether that antimicrobial class was used in animals.

The figures in the DAMMAP report evolved from previously presenting AMR to all antimicrobials for individual populations to focusing on the antimicrobials of relevance for One Health and comparing AMR trends between populations (fig. 1). DANMAP 2018 interpreted AMR in Campylobacter in a One Health perspective and DANMAP 2019 contained both One Health sections and was published in October 2020 (danmap.org) .

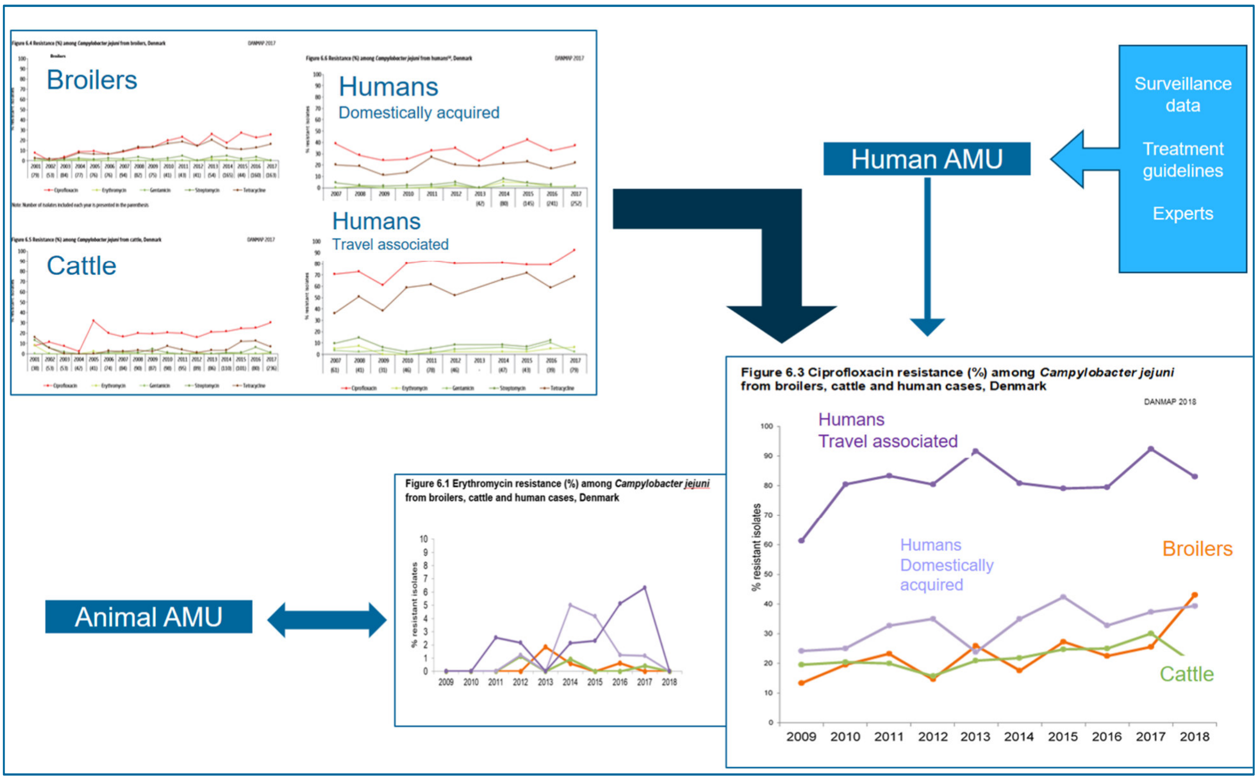

Figure 1: The process of moving from integrated reporting to One Health interpretation of AMR in Campylobacter in Denmark.

Implementation and impacts

The new focus of the DANMAP chapter of AMR in in Campylobacter and Salmonella provided a coherent and relevant One Health perspective of AMR, drawing in and combining all five data streams in the surveillance programme in to one interpretation.

The new outline of the chapter was published in DANMAP 2019, and for the users of the surveillance reports, the increased OH focus, supported their policy and risk management and facilitated the One Health perspective. The change was particularly well received by the Danish Veterinary and Food Administration, who found it useful and expressed:

"The overall target of our efforts on AMU and AMR in the food production is to support human health and ensure that it is and will be possible to treat human illnesses with antimicrobials. To achieve this target we aim to reduce or maintain a very low level of AMR throughout the food production, focusing on the critically important antimicrobials. When reporting the status of AMU and AMR surveillance it is important, that the impact and trends concerning the risk posed to human health, by foodborne AMR is addressed and if possible assessed. The enhanced One Health focus in the zoonoses chapter of DANMAP 2019 supports this agenda." (Gudrun Sandøe, Danish Veterinary and Food Administration, Personal communication).

The One Health approach has also been presented and discussed internationally. European agencies and institutes have been introduced to the concept through ORION and COHESIVE meetings and workshops. It was also included in a presentation to The European funding body members of ERANET and in one for the annual Nordic Zoonosis meeting, where public health, animal Health and Food Safety institutes from all the Nordic countries assemble. Further afield, the OH interpretation approach has been presented and discussed in Middle and South America through workshops organized by PAHO-WHO; in Asia through meetings with government- and agency-representatives; and in Nigeria via Fleming Fund Fellows (see list of presentations at the end of document).

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Reflections on the OH perspectives and Lessons Learned

The OH evaluation matrix

The expected One Health outcomes were to enhance collaboration and to improve data interpretation including many data streams and carry out multi-sector data-interpretations. DANMAP already reported in a very integrated way with regular author meetings and figures and text for each population side by side (table 1. Yellow squares). However, the expected outcome of this was to analyse data together and develop one text addressing all populations for One Health relevant antimicrobials (Table 1. Orange squares). These goals were achieved.

- *Table 2. Routine practices before pilot (yellow), pilot expectations (orange), and achieved expectations (green circles) out of steps towards OH surveillance*

Steps in the surveillance pathway	**Levels of integration**			
Data analysis/interpretation COLLABORATION	Undertaken separately in each sector	Undertaken separately and collated by a single sector	Undertaken separately and then combined by a cross-sectoral working group	Jointly undertaken by multi-sectoral working groups
Data analysis/interpretation DATA STREAMS	Interpretation of each data stream individually in each individual sector to sector specific objectives	Interpretation of multiple, sector specific data streams in each sector to sector specific objectives	Interpretation of multiple data streams from multiple sectors to sector specific objectives with cross-sector consultation	Interpretation to joint cross-sector objectives of multiple data streams from multiple sectors in cross-sector collaboration

Lessons learned listed by each relevant principle in the OHS Codex

Collaboration

The collaborations and work flows benefitted from piggy-backing on already existing structures and people, who had a long tradition for collaboration.

The need for the change to OH reporting was equally recognised by all collaborators. This generated an mutual enthusiasm that benefitted the work.

Knowledge

The pilot project generated new knowledge on national and regional treatment guidelines and highlighted the disagreement between them. This was a surprise even to experts in the field.

Data sharing

Normally, all raw data collected at DTU and due to newly introduced GDPR laws, this was no longer possible. However, we discovered that aggregated data was sufficient and less resource demanding.

Fit-for-purpose data sharing is resource saving

Dissemination

Improving an established communication with known stakeholders and users, facilitated the dissemination.

Agreeing all text in detail was more resource demanding than previous reporting type.

The One Health perspective was highly commended by policy and other users, because it directly encourages OH working in risk management, too.

SWOT-like considerations

Process	
Things that worked very well during the study	We all agreed the final outcome and objectives from the beginning and kept this in focus. Equal enthusiasm and shared vision from both institutes Very effective meetings to develop outline and assign tasks
Things that were difficult or didn't work well during the pilot study	Because the work was much more integrated, not meeting deadlines was frustration for others It was very time-demanding to agree the final text, now that everyone was responsible for everything
Outcome/product	
Prospects for implementation of the pilot study outcome and further development opportunities	The work is already implemented and part of routine practice
Expectations that were not fulfilled and/or barriers for uptake	We expected GDPR and data sharing to be a challenge. However, we found out that sharing raw data was not necessary and by each entering aggregated data into shared spreadsheets, we cut down the workload significantly

Written by Johanne Ellis-Iversen 23/03/21

List of publications & presentations from pilot project

Publications

DANMAP 2018, chapter 6. Resistance in zoonotic bacteria and animal pathogens. www.DANMAP.org

DANMAP 2019, chapter 6. Resistance in zoonotic bacteria and animal pathogens. www.DANMAP.org

Presentations

PAHO-WHO Workshop Resistencia a los antimicrobianos, detección y vigilancia en las Américas at Simposio RELAVRA Congreso ALAPAC 2021. *Best Practices in integrated surveillance*, March 2021 by Johanne Ellis-iversen

COHESIVE extended workshop on: Informal discussion and signal exchange of zoonotic trends across Europe, *DANMAP integrated AMR and AMU surveillance – The benefits of OH collaborations in understanding risks and signal sharing*. February 2021 by Johanne Ellis-iversen

National DANMAP seminar on antibiotika-forbrug og –resistens, *Highlights fra DANMAP 2019*, Nov 2020 by Birgitte Borck Høg

PAHO-WHO: Role of Molecular Biology in Integrated AMR surveillance within the framework of One Health: *Best Practices in integrated surveillance*, August 2020 by Johanne Ellis-iversen

National Institute of Health, Republic of Korea: Multi-sectorial One Health AMR Initiative for AMR control, *Data integration for One Health Surveillance*, Nov 2019 by Johanne Ellis-iversen

Delegation visits Hong Kong with representatives from Centre of Health protection, Department of Food and Environmental Hygiene and Department of Agriculture, Fisheries and Conservation, *Integrated Surveillance* Nov 2019 by Johanne Ellis-iversen

Fleming Fund Fellows from Nigeria, November 2019 *Integrated surveillance* by Johanne Ellis-Iversen

SCAR Animal Health and Welfare Collaborative WG of ERANET, representatives of EU governments, *DANMAP - One Health Surveillance in action*, 2019 by Johanne Ellis-Iversen

Nordic Zoonoses Meeting, Uppsala, *DANMAP in a One Health perspective*, Sept. 2019 by Channie Kahl Petersen

WP2 integration and its pilots projects also presented updates on at every consortium meeting and workshop.

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ANNEX 2: WP2 INTEGRATION PILOT PROJECT 2

DOES ONE HEALTH INTEGRATION OF SURVEILLANCE DATA IMPROVE SURVEILLANCE AND DISEASE CONTROL?

- INTEGRATING NATIONAL CAMPYLOBACTER SURVEILLANCE DATA TO ESTABLISH PROOF-OF-PRINCIPLE

Background

The concept of One Health (OH) describes collaborative efforts between at least two sectors aimed at improving human, animal and/or environmental health (Bordier et al., 2018). Often the primary mutual OH objective is to protect human health, involving actors in other sectors to implement mitigating actions e.g. along the food chain. Actors often collect their own data and use it for surveillance of their won sector and often data is collected at several points along the food chain. If this surveillance data from different points in the food chain were combined and analysed across sectors, we may enhance our understanding of the risk and from this, improve surveillance and reduce public health risk, without increasing the need for additional data. This could provide added value for risk mitigation and improve cost-effectiveness of the surveillance system.

The principle of risk-based surveillance was developed in the animal health sector to identify and prioritize for surveillance of the pathogen of interest, the strata of the population that are at higher risk of: being exposed, infected, affected, detected, transmit infection or cause other consequences, and thus, to optimize cost-effectiveness of surveillance activities (Stärk et al., 2006; Alban, 2020). The same principle can be applied for control of food borne pathogens, by identifying the food product that poses a high risk to public health, and targeting control efforts at that production. This will result in a lower cost-benefit ratio than targeting producers that pose low risk to public health with mitigating actions.

The Danish National Campylobacter Action Plan (2018-2021) aims to maintain low flock prevalence, to reduce the risk to public health relative to 2013 (due to fresh poultry meat) by 50% (Anonymous, 2019) and to reduce human campylobacteriosis incidence by 5%. Poultry meat is the most important source of campylobacteriosis in Denmark and the main poultry companies are represented in the action plan alongside government, advisors and public health. Surveillance of Campylobacter in Denmark occurs at several points along the poultry meat chain (figure 1).

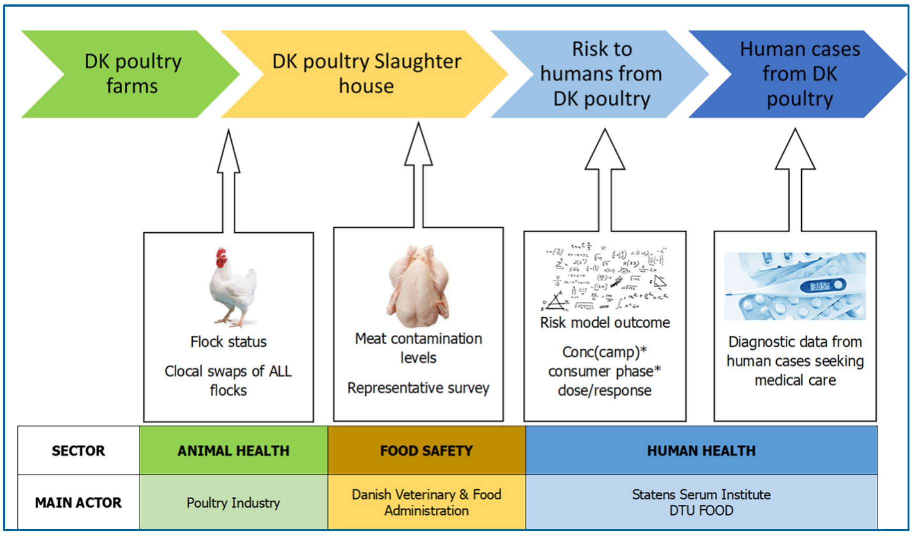

Figure 1. Part of the Danish surveillance system for Campylobacter in poultry

The Campylobacter status of all broiler flocks is monitored by pcr testing of cloacal swabs of every flock slaughtered in Denmark, at the entry to the slaughterhouse, and the data is administered and used predominantly by the industry. The level of contamination on chilled carcasses ready for retail is monitored by quantitative testing of randomly selected leg skins from approximately one third of all slaughtered flocks, and the data is owned and administered by the Danish Food and Veterinary Administration. Surveillance data on incidence of campylobacteriosis in humans is diagnostic data from practitioners, hospitals and clinical microbiological laboratories, analysed by Statens Serum Institute. Due to the small proportion of human cases seeking medical care and large uncertainty around source attributions, the public health diagnostic surveillance data is precise enough for measuring risk posed by chicken meat. Instead, the action plan uses an exposure model to estimate the risk posed to the consumer from Danish chicken meat. The model combines a consumer phase model describing the presence, transfer and survival of Campylobacter during food preparation with a dose response model (Teunis and Havelaar, 2000; Nauta et al., 2008; Nauta, et al. 2012; EFSA, 2011; EFSA, 2020). The main target of the National Action Plan 2018-2021 is to maintain low flock prevalence and reduce public health incidence by 5%. Nevertheless, the flock prevalence increased from 16.6% in 2017 to 24.6% in 2018, while the number of human confirmed cases increased from 4,257 to 4,546 (Anonymous, 2019); and are expected to increase in the future (Kuhn et al., 2020). New methods and perspectives on Campylobacter risk and control are needed in the future action plan to reach the targets and reduce risk to public health. It is possible that data integration across sectors may provide some new insights and solutions.

Objectives & expected outcomes

The objective of the pilot study was to investigate, whether OH integration of surveillance data from different sectors: 1) was possible and 2) could improve surveillance and campylobacter control in the food chain to reduce risk to public health.

Surveillance data from the Danish National Campylobacter Action plan was used to explore these objectives.

Study 1 – Explore surveillance outcomes across data streams by comparison of Campylobacter prevalence at flock and carcass levels and assess whether adjustments are needed.

Study 2 - Investigate whether any new information about the public health risk arises from the data stream integration by testing the agreement of surveillance outcomes for individual flocks and carcasses, and how this information could feed into the National Campylobacter Action Plan.

Study 3 – Design a risk-based control programme by using information from the integrated data streams and assess the value of risk-based control by using the integrated surveillance data and the public health risk model to measure the effect on public health.

Performed activities

Data cleaning and collation

Flock and carcass data (2013-2019) were extracted by the Danish Veterinary and Food Administration (DVFA) in pdf and excel-formats and sent to DTU-FOOD, where the datasets were handled and harmonized using the R-programme. Files, outliers and missing values were identified, and discussed with data providers. The data and metadata were described, and the analyst acquired an in-depth understanding of the surveillance components. Towards the end of 2019, the surveillance data was partly collated with the national Central Husbandry Register (CHR register) to allow for geo-referencing and identification of production type of the broiler farms at the time of sampling. Each farm was identified by its CHR number.

The two main national data streams used in this pilot consisted of: Flock status tested by cloacal swabs 2018-2019 and carcass status by testing of leg skin samples from 2019. For both datasets, a flock was identified by the combination of: CHR of origin, poultry-house on farm and the date of sampling at the slaughterhouse. In the flock surveillance component, all slaughtered flocks were tested with a polymerase chain reaction (PCR) and results were recorded as "positive" or "negative". In the carcass component a survey of randomly selected flocks (about 1/3) were tested by culture, yielding meat contamination results in colonies forming units per gram (cfu/g). Flocks with < 10 cfu/g were classified as negative and otherwise considered as positive.

Results

Study 1. To explore surveillance outcomes across data streams by comparison of Campylobacter prevalence at flock and carcass levels and assess whether adjustments are needed.

The monthly prevalence of infected flocks was compared to the prevalence of flocks positive in the carcasses. The apparent prevalence (AP) (also called measured prevalence) and the true prevalence (TP) (also called adjusted prevalence) were both estimated for each component. The TP estimate was adjusted for laboratory methods and sample sizes used in the two data streams.

In study 1, both the monthly AP and true prevalence TP were higher in the carcasses than in the flocks, especially during summer (June-August), suggesting differences in uncertainties of the two data streams, but also potential cross-contamination at slaughterhouses. When the apparent prevalence estimates were adjusted for laboratory test method and sample size, the true prevalence were estimated were more similar than the AP estimates (figure 2.).

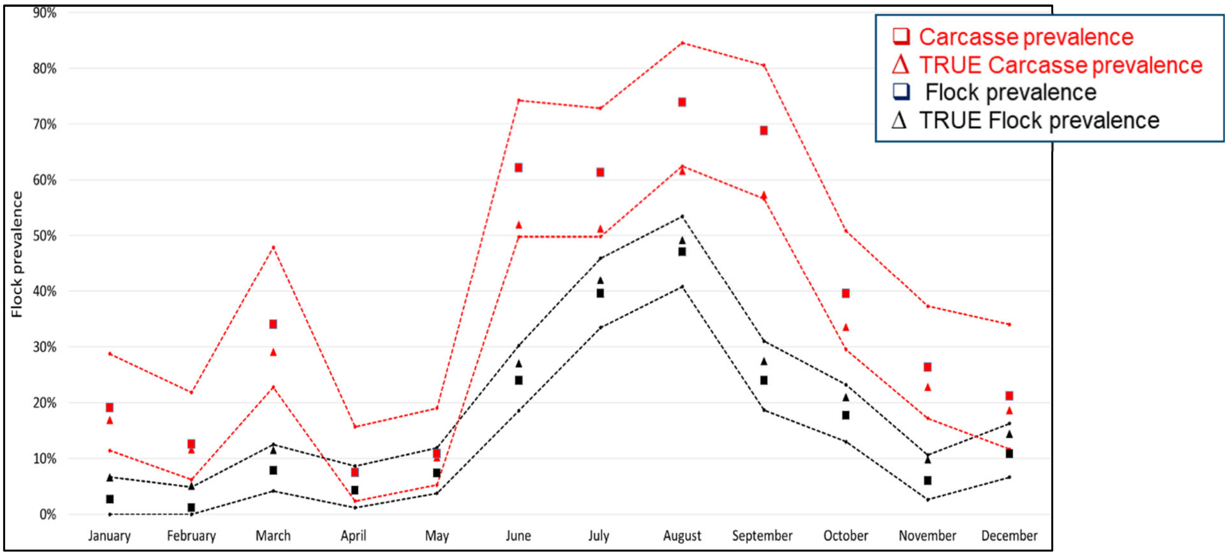

Figure 2. Comparison of prevalence estimates and their adjustments from two data streams in the Danish Surveillance system for Campylobacter

This illustrates the value of adjusting surveillance outputs for the uncertainties generated by the designs of the individual surveillance components, such as laboratory test choice and sample sizes, when integrating data from different data streams and comparing outcomes over time. Thus, comparing true prevalence rather than apparent prevalence enhances the precision, comparability and interpretability of surveillance information collected in different sectors. If the data formatting, integration and adjustments were implemented routinely, surveillance outputs could be compared precisely between surveillance periods, components and countries. This could improve comparisons of surveillance outputs across countries using different sample sizes and tests, and would overcome the need of sharing official sensitive (raw) data in international forums.

More scientific details can be found in:

Alessandro Foddai, Nao Takeuchi-Storm, Jette Sejer Kjeldgaard, Johanne Ellis-Iversen. Integrating Danish Campylobacter surveillance data streams to investigate broiler flock prevalence and potential cross-contaminations at slaughterhouse. In preparation for peer reviewed journal

Study 2 to investigate whether any new information about the public health risk arises from the data stream integration by testing the agreement of surveillance outcomes for individual flocks and carcasses, and how this information could feed into the National Campylobacter Action Plan.

The agreement between the birds' and carcasses testing within the same flock was assessed using the binary status classification i.e. positive and negative and levels of concurrence in simple percentages and weighted K-values.

The result showed that about one third of the positive carcasses originated from Campylobacter negative flocks (table 1). The mean and median contamination levels of the positive carcasses from negative flocks were significantly lower than the levels of Campylobacter on carcasses of positive flocks (Mean: 410 cfu/g vs. 1342 cfu/g; Median: 30 vs 615). More detailed outputs and calculations can be found in: Alessandro Foddai, Nao Takeuchi-Storm, Jette Sejer Kjeldgaard, Johanne Ellis-Iversen. Integrating Danish Campylobacter surveillance data streams to investigate broiler flock prevalence and potential cross-contaminations at slaughterhouse. In the pipeline for submission to peer reviewed journal.

Table 1. Percentage of Campylobacter positive carcasses and flocks in slaughterhouses and the agreement between them.

	Positive Flock	Negative Flock	Total samples
Positive Carcasses	16%	9%	234
Negative carcasses	1%	74%	715
Total samples	166	783	949

It is possible that some of the disagreement between outcomes for each flock in the two data streams is due to uncertainties in data collection and data quality that occurs, when using data for a different purpose than the original one. However, the difference in contamination levels suggests that the cause of contamination in the two groups is different, and cross-contamination at the slaughterhouse is a likely cause for contamination of carcasses from negative flocks. This was a new finding and new knowledge for National action Plan derived by data stream integration and highlights a need for addressing this risk at slaughterhouses to reduce the risk to humans.

If integration of the two data streams was done routinely, it would provide a new surveillance point to monitor the levels of cross contamination potentially for each slaughterhouse, with the aim to reduce problem.

Further details of study 1 and study 2 can be found in:

> Foddai, Takeuchi-Storm, Kjeldgaard, Ellis-Iversen.Integrating Danish Campylobacter surveillance data streams to investigate broiler flock prevalence and potential cross-contaminations at slaughterhouse. In preparation

Study 3. – Design a risk-based control programme by using information from the integrated data streams and assess the value of risk-based control by using the integrated surveillance data and the public health risk model to measure the effect on public health.

All farms were classified in three groups according to the Campylobacter status of the flocks, they delivered in 2018: Always negative (Neg-CHRs), low risk (LowR-CHRs) and high-risk (HighR-CHRs) farms. Two classification strategies were applied, one based on the annual number of positive flocks (I) and one based on annual percentage of positive flocks (II) per positive farm, both with cut-offs at the 3rd quartile (5 positive flocks and 27.8% positive flocks, respectively).

Secondly, three contamination levels A, B and C were defined, describing how effectively the HighR-CHRs were able to control Campylobacter in their flocks the year after classification (2019). The three contamination levels were pairwise combined with the two risk based classification strategies (I-II), yielding six simulation scenarios (A-I and A-II; B-I and B-II, C-I and C-II). Scenarios A assumed full control and that the HighR-CHRs only delivered negative flocks to the slaughterhouse i.e. zero cfu/g on carcasses from these farms, while in Scenarios B and C assumed 50% control (cfu/g divided by 2) and 33% control (cfu/g divided by 3), respectively. For each scenario in each strategy, the exposure model calculated the risks of human campylobacteriosis at national level relative to 2013. The RRs estimated for each scenario were compared to the relative risk for 2019 (RR=0.94) based on original cfu/g in the current National Action Plan i.e. without risk-based control . The status of the other two groups of farms were assumed unchanged.

The risk-based control approach could have reduced the annual flock prevalence significantly, if the HighR-CHR only delivered negative flocks. If the HighR-CHR were classified in 2018 (by strategy I) and managed to keep campylobacter out of all their flocks in 2019 (scenario A), the risk to public health could have been reduced to about half of what it was without risk-based control. Other, and maybe more realistic scenarios, provided smaller reductions, but still reduced the risk to public health remarkably compared to the current status (figure 3).

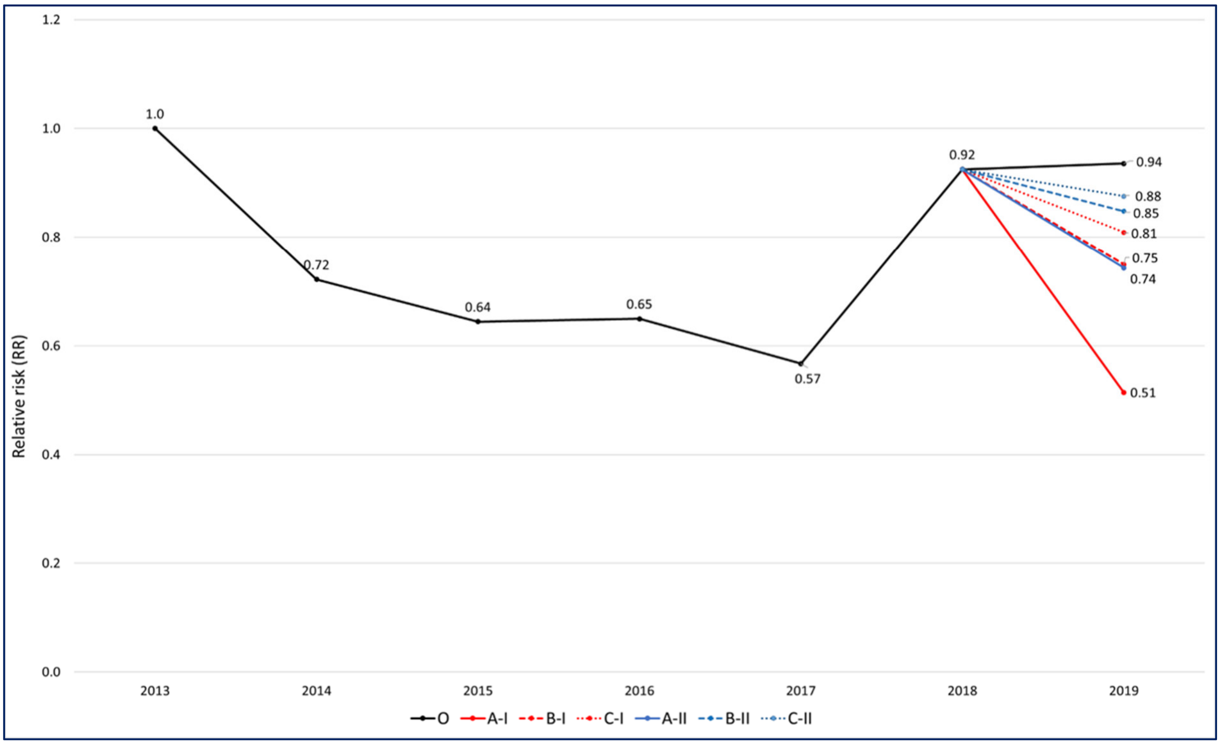

Figure 3. The relative risk to public health from poultry slaughtered in Denmark and the estimated change from six alternative risk-based control scenarios.

Further details on the technical methods, analysis and all output can be found in:

Foddai, Nauta & Ellis-Iversen. Risk-based control of Campylobacter spp. broiler farms and slaughtered flocks to mitigate risk of human campylobacteriosis - A One Health approach, Submitted for peer-review

Conclusion

The pilot study proved that integrating surveillance data from different sectors and different points in the food chain was possible, albeit required cumbersome data cleaning and formatting. Furthermore, adjusting some of the outcome estimates according to surveillance design, improved the precision of the estimates and the ability to compare and work across data streams.

The pilot demonstrated that when data from different populations is integrated, it provides additional information and may generate new knowledge. Our study showed that cross contamination in slaughterhouses occur much more frequent than anticipated and contribute about one third of all positive carcasses and thereby, poses a risk to public health. If the integration of the surveillance data is implemented routinely, this could be a potential new surveillance point and a potentially new control target for the action plan.

The integration of surveillance data streams supported the One Health objective of reducing risk to public health and when combined with other methodologies e.g. risk-based approaches, it can provide new perspectives and new options for control. In this case, we found a more cost-effective method, where targeting control to ≈20% of farms (HighR-CHR), it may be possible to reduce the risk to public health significantly.

The pilot study provided a proof-of-concept that by integrating data from different sectors, we can add value to current systems and to the data collected. It also highlighted the importance of looking along the whole food chain and the sectors of animal health, food safety and public health to reduce the risk of human campylobacteriosis.

Surveillance data is never perfect, and has best fit for the purpose it is collected for. Once we use this data for other purposes and integrate it with other data streams, the weaknesses and uncertainties still exist, they will affect the final estimates and answers. It is important to highlight this and ensure transparency around assumptions and weaknesses, when models and integrated data analysis are used for decision-making.

Implementation and impacts.

Implementation of the outcomes from this study are currently under discussion with the big poultry companies, the Danish Veterinary and Food Administration and the technical working group of the Danish National Campylobacter Action Plan. Especially, the more cost-effective risk-based control strategy is discussed, and the cross-contamination issue is considered of importance, too. The study has also raised the issues of what practical, effective solutions exist to produce Campylobacter-free flocks, and whether reduction of cross-contamination in the slaughterhouses is possible. The findings have potential to change the Campylobacter situation in Denmark.

Furthermore, the pilot study is proof-of-principle that integrating surveillance data along the One Health continuum, can generate new knowledge, improve surveillance and create more cost-effective solutions. We hope other agencies and institutes can use our experiences to encourage data owners to allow surveillance data integration to improve surveillance and zoonotic control.

The pilot study was presented to and discussed with:

- Representatives of the Danish poultry industry from the two major Danish companies that produce the majority of broilers in Denmark.
- The Danish Veterinary and Food Administration (FVST)
- Scientists and policy advisors from DTU-Food (Department of Global Health Surveillance).
- The ORION consortium and other OHEJP members and stakeholders
- A national seminar on Campylobacter research organized by SSI for industry, academia and policymakers
- Two peer-reviewed publications are in prepraration

Reflections on the OH perspectives and Lessons Learned

The OH evaluation matrix

The pilot project achieved most of its goals and improved OH working within the surveillance system (Table 2). However, the collaboration objective was not fulfilled during the time of ORION. Partly, because the COVID19 situation made it difficult to start up, build and establish new relations; and partly, because there was a need for proof-of-concept before other sectors understood the advantages and the impact it could have. It is likely that, if the data integration is implemented as part of the National Action Plan then all the other sectors will join in on the interpretation of the data in the future.

Table 2. Routine practices before pilot (yellow), pilot expectations (orange), and achieved expectations (green circles) out of steps towards OH surveillance

Steps in the surveillance pathway	Levels of integration			
Data interoperability	Unstructured data	Internal harmonisation (organization own coding practices)	Structural interoperability* across sectors	Semantic interoperability* across sectors
Data analysis/interpretation – COLLABORATION	Undertaken separately in each sector	Undertaken separately and collated by a single sector	Undertaken separately and then combined by a cross-sectoral working group	Jointly undertaken by multi-sectoral working groups
Data analysis/interpretation – DATA STREAMS	Interpretation of each data stream individually in each individual sector to sector specific objectives	Interpretation of multiple, sector specific data streams in each sector to sector specific objectives	Interpretation of multiple data streams from multiple sectors to sector specific objectives with cross-sector consultation	Interpretation to joint cross-sector objectives of multiple data streams from multiple sectors in cross-sector collaboration
Outcome communication	Undertaken separately in each sector	Joint dissemination in separate sectoral activities	Joint dissemination by a single sector	Joint cross-sectoral dissemination

Lessons learned listed by relevant principle in the OHS Codex

Collaborations

- Cross-sector collaboration with the private industry was not very relevant during the stages of the pilot project under ORION, because the data cleaning and analyses took longer than expected and the interpretation was of data outputs only. The decision-making and potential implementation, which commence after the end of the pilot will require increased collaborations, when translating the mathematical outputs into real-life practices
- Good collaborative and trust-reliant relationships are necessary to gain access to data owned by others.
- Good communication between data analyst and data owners/providers is necessary to understand the data and avoid mistakes in interpretations of outcomes.

Knowledge

- When surveillance data is integrated across sectors and analysed from a different perspective (e.g. OH), it is likely to generate new knowledge and new solutions. We hope this proof-of-principle can be used by others in the future to encourage and advocate data-integration

Data

- Surveillance data is never perfect, but when applying it to a different purpose than originally intended, the precision and completeness decreases further. This must be considered, when interpreting and communicating the outcomes.
- The data integration procedures required specialist skills in data handling, formatting and analysis. Furthermore, it also required an understanding for the surveillance design and data collection and a good relationship with data owners is paramount.
- If integrated interpretation is implemented routinely, set data extracts, programme files and agreed assumptions are needed. Some improvements at the data collection stage to facilitate integration could also be considered.

Dissemination

- Discussions of results were mainly virtual, due to COVID-19. This is not ideal, when collaborations are new.
- The technical side of the study is written up for scientific journals. Two articles are in the pipeline and are almost ready for submission to peer reviewed journals.
- However, different lines of communication is also needed. To influence industry or policy different type of communication is needed and each needs to focus on the recipient and their point of view to facilitate understanding among stakeholders.

SWOT-like considerations

Process	
Things that worked very well during the study	• Collaborations with data providers • Discussion of results with actors and stakeholders • Writing of papers to be submitted for publication in peer reviewed journals.
Things that were difficult or didn't work well during the pilot study	• Data management and cleaning took longer than expected • Data quality, especially in ID variables, was not as precise as hoped and caused some problems. • Integration between surveillance data and the national CHR register (for geo-referencing over time), was challenging due to data quality, and the attempt was abandoned. Instead the data was integrated at farm/premise/flock level.
Outcome/product	
Prospects for implementation of the pilot study outcome and further development opportunities	• Implementation and usefulness of the findings for the National Action Plan is currently discussed among industry and DVFA • Encouragement for better and more precise data entering in the surveillance programme was fed back to data providers. Better data quality will increase the sustainability of the data by expanding its uses. • Future implementations of the risk based stratification of farms and flocks, within the current action plan can improve efficacy of disease control along the food chain and could reduce risk of human campylobacteriosis remarkably.
Expectations that were not fulfilled and/or barriers for uptake	• We had hoped for earlier and more collaboration with industry, but this was hampered by COVID19 and lack of proof-of-concept • An initial objective of developing a general description framework for OH systems using the data from this study by DTU-Food and SSI was abandoned due to inequlity in efforts and staff changes. It is possible the COVID19 was the underlying reason for this.

Written by Johanne Ellis-Iversen & Alessandro Foddai 23/03/21

List of publications & presentations from pilot project

Alessandro Foddai, Nao Takeuchi-Storm, Jette Sejer Kjeldgaard, Johanne Ellis-Iversen. Integrating Danish Campylobacter surveillance data streams to investigate broiler flock prevalence and potential cross-contaminations at slaughterhouse. In preparation for peer reviewed journal

Alessandro Foddai, Maarten Nauta, and Johanne Ellis-Iversen. Risk-based control of Campylobacter spp broiler farms and slaughtered flocks to mitigate risk of human campylobacteriosis - A One Health approach. Submitted to peer reviewed journal

Presentation, to the Epi-risk team, DTU-Food (19/10/2020). Discussion on CHR risk-based Campylobacter spp. control in Danish conventional poultry farms

Presentation to representatives of the poultry industry and of the Danish Veterinary Administration (FVST, 07/12/2020). Integrating surveillance data streams and simulation modelling to inform risk-based control of Campylobacter spp. from "farm to patient".

Presentation to the epi-group, Dept. of Global Health Surveillance, DTU-Food (10/02/2021). Integrating surveillance data streams and simulation modelling to inform risk-based control of Campylobacter spp. from "farm to patient".

Presentation at ORION Full Consortium meeting – open day (09/03/2021) WP2 integration, Pilot 2- Integration of surveillance data streams

Presentation at ORION Full consortium meeting – Pilot Lessons learned Workshop (10/03/2021). ORION Lessons Learned, Pilot DTU: Data integration and risk based control (OH-style).

Presentation at a national seminar New activities for improved control of Campylobacter organized by SSI for industry, academia and policymakers. *Can we reduce public health risk, by controlling Campylobacter at a small number of farms?*

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