Deliverable 4.1.

Maps for Salmonella prevalence geographical patterns in intensive livestock and slaughterhouses completed in high prevalence regions

JRP6 - NOVA - FBZ1 - 1st Call

Responsible Partner: UCM-VISAVET

GENERAL INFORMATION

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Maps for Salmonella prevalence geographical patterns in intensive livestock and slaughterhouses completed in high prevalence regions

Salmonella has been selected as example of FBD as it is one of the most common public health problems, causing significant human morbidity and even mortality and consequently high economic losses in both developing and developed countries. Foods of animal origin are still one of the major sources of infection for the general public, with eggs, broiler chickens and pigs being consistently identified among the top attributed food sources. Whereas control programmes for Salmonella in poultry have been applied in the whole UE with high success, only few European countries have implemented eradication or control programmes of Salmonella in swine, beef, or dairy production. Results from efforts made in Denmark, Sweden, Finland, Norway, Ireland, Germany, Great Britain and Holland, are somewhat inconsistent. So far, there are no national control programmes established in any Mediterranean country, where >40% of the pig farms were positive to Salmonella (EFSA baseline study, 2009). In consequence, further efforts to implement control programs for reduction of the prevalence of Salmonella infection in swine in the near future are envisioned. Prerequisites to the implementation of such an approach; scientific efforts directed to improve our preparedness and develop an effective risk-based surveillance system should be carried out.

The deliverable D.4.1. "Maps for Salmonella prevalence geographical patterns in intensive livestock and slaughterhouses completed in high prevalence regions", belongs to Task-4.1 whose general objective is to understand the spatio-temporal patterns of infection distribution in livestock and slaughterhouses and its association with human cases to optimize sampling strategies and the implementation of risk based surveillance strategies under two different conditions: low prevalence regions (Subtask 4.1.1) and high prevalence regions (Subtask 4.1.2).

The task 4.1 includes a total of four activities and four deliverables:

T-4.1. Identification of spatial relationships and patterns in Salmonella prevalence (M1-M24)		
TASK/SUBTASK	**ACTIVITIES**	**DELIVERABLES**
Sub-Task 4.1.1: Surveillance in high prevalence regions to detect introduction and changes in prevalence.	A. Intensive pig farm location, industry surveys (slaughterhouse and feed co-operatives) and human cases will be investigated in conjunction with routinely recorded surveillance information using spatial techniques (e.g. smoothing technique, cluster analyses) [M1-M12].	D-4.1. Maps for Salmonella prevalence geographical patterns in intensive livestock and slaughterhouses completed in high prevalence regions (**M12**)
	B. Geographical areas (broad spatial trend and local spatial correlation) and periods with higher probability of detection of infection will be identified by temporal and spatial autocorrelation analyses, which will allow reallocating efforts on sampling strategies. In addition, temporal trends on serotype distribution and antimicrobial resistance profiles in isolates from clinical human cases and those found in swine will be compared [M13-M24].	D-4.2. Identification of periods with higher probability of detection of infection identified in high prevalence regions and temporal evidences for an association with human cases (M24)

Sub-Task 4.1.2: Surveillance in low prevalence regions to reduce prevalence.	C. A detailed model of the spatio-temporal infection dynamics will be applied based on data-driven simulations incorporating the complete population demographic, the time-varying contact animal network and the local spread among proximal holdings (Bauer 2016, Widgren 2016a, Widgren 2016b). The model parameters will be calibrated against observed data from historical and ongoing monitoring [M1-M12].	D-4.3. Assessment of the spatio-temporal infection dynamics model in Salmonella in low prevalence regions (**M12**)
	D. Optimal surveillance strategies will be explored to detect introduction and an increasing prevalence [M13-M24].	D-4.4. Evaluation of optimal surveillance strategies (M24)

Specifically, the objective of the deliverable D.4.1 was to map the Salmonella prevalence geographical patterns in intensive livestock and slaughterhouses in high prevalence regions.

1. Background

Spain is one of the main swine producing countries, currently ranking first in number of swine in the EU (with 28.3 million animals in 2015). The production of pork in 2015 reached 3.8 million tonnes, with more than 45 million animals being slaughtered. Worldwide, Spain is the fourth largest pork producer after China, United States and Germany. Mainly an exporting country, Spain has also become the EU's third largest exporter of swine after Germany and Denmark. The swine industry accounts for 14% of the final agricultural production in Spain, and it is the most important livestock species in economic terms, representing 37% of the final livestock production.

Pork is the main source of human salmonellosis after poultry in the EU, given that it is the third most frequently contaminated meat, after fresh chicken and turkey, and it is widely consumed. Because of this, monitoring and surveillance activities have been implemented along the food chain in order to assess the risk posed by pork and pork products as a source of *Salmonella* for the general public and to prevent outbreaks. Under this context, we review and describe the Salmonella surveillance systems in Spain "from farm to fork", that is, from its animal source (of swine origin) up to the identification of Salmonella of animal origin in human outbreaks. Our aim is to identify potential gaps and assess the feasibility of a more integrated approach in a One Health framework aplying spatio-temporal analysis.

2. Objectives

The objective of the deliverable D.4.1 was to map the Salmonella prevalence geographical patterns in intensive livestock and slaughterhouses in high prevalence regions. It integrates three activities:

A) Identify available data on intensive pig farm and slaughterhouse location and characteristics.
B) Identify available surveillance data on intensive pig farm location, industry surveys (slaughterhouse and feed co-operatives).
C) Investigate recorded surveillance information in intensive livestock and slaughterhouses using spatial techniques.

3. Progress of the activities: main results.

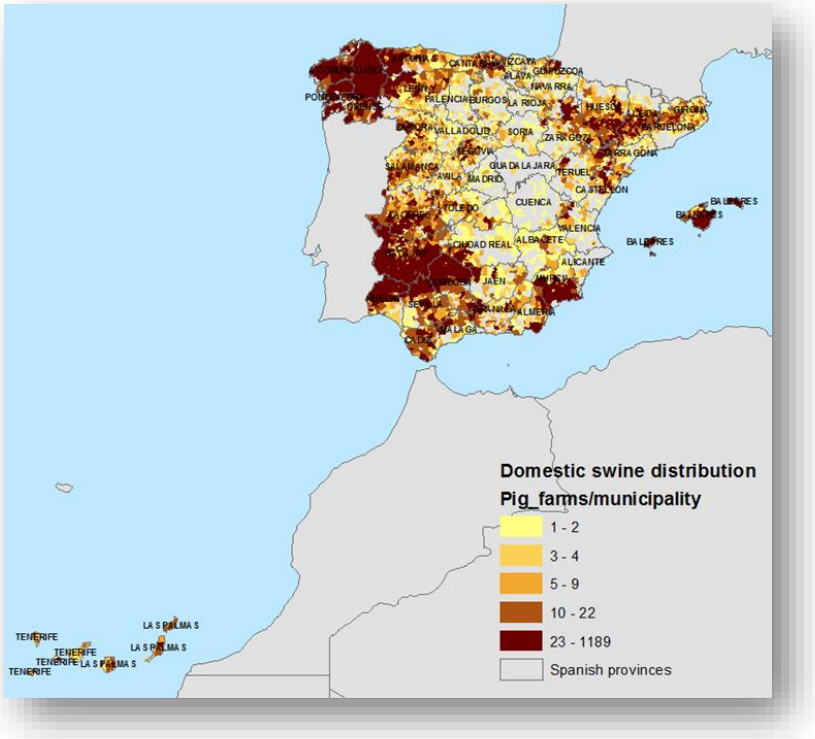
A) Identify available data on intensive pig farm location and slaughterhouse location and characteristics.

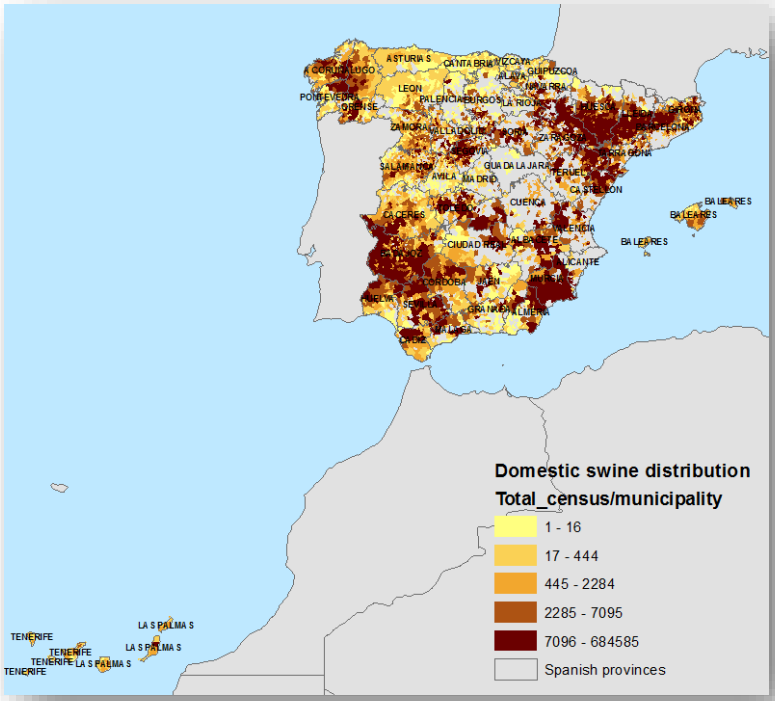
We have gather information about intensive pig production system in Spain from the Official Register of Livestock Farms (REGA) from the Agriculture Ministry (Law 8/2003 of April 24th). An Excel database has been created with the information retrieved. It included information on:

- Geographical coordinates
- Zootechnical classification
- Breeding type
- Census

The total number of swine holdings in 2016 in Spain is 86,353 of which 83,703 (97%) are breeding and production farms, representing 99.81% of the total swine census (28.7 million heads). Of the 83,703 pig producing farms in Spain, 46,218 (55.3%) are classified as commercial and 37,485 (44.7%) as own-consumption farms by the Ministry of Agriculture. 96% of the own-consumption farms are reared in an intensive system. However, commercial farms are reared both intensively (72% of farms) and extensively (28% of farms).

The distribution of pig farms and pig census by municipality is represented in these figures:





Most pig heads are concentrated in areas with medium to high density of farms (between 5-22 farms/municipality), but pig heads are also distributed among the areas with many pig farms, particularly in Murcia (southwest), where farm density reaches the maximum category (1189 farms/municipality). In contrast, north-eastern Spain shows a picture with many pig heads concentrated in a few pig farms.

Almost 80% of the total census is represented by fattening pigs, which concentrates in north-eastern Spain.

B) Identify available surveillance data on intensive pig farm and industry surveys (slaughterhouse and feed co-operatives)

The information about Salmonella surveillance in Spain has been reviewed in the legislation and in EFSA's annual summary reports (EU and for Spain). We have also searched for additional information on Salmonella surveillance by contacting personally or navigating through the website of the institutions mentioned in Spain's country reports.

The official Spanish databases and sources reviewed are:

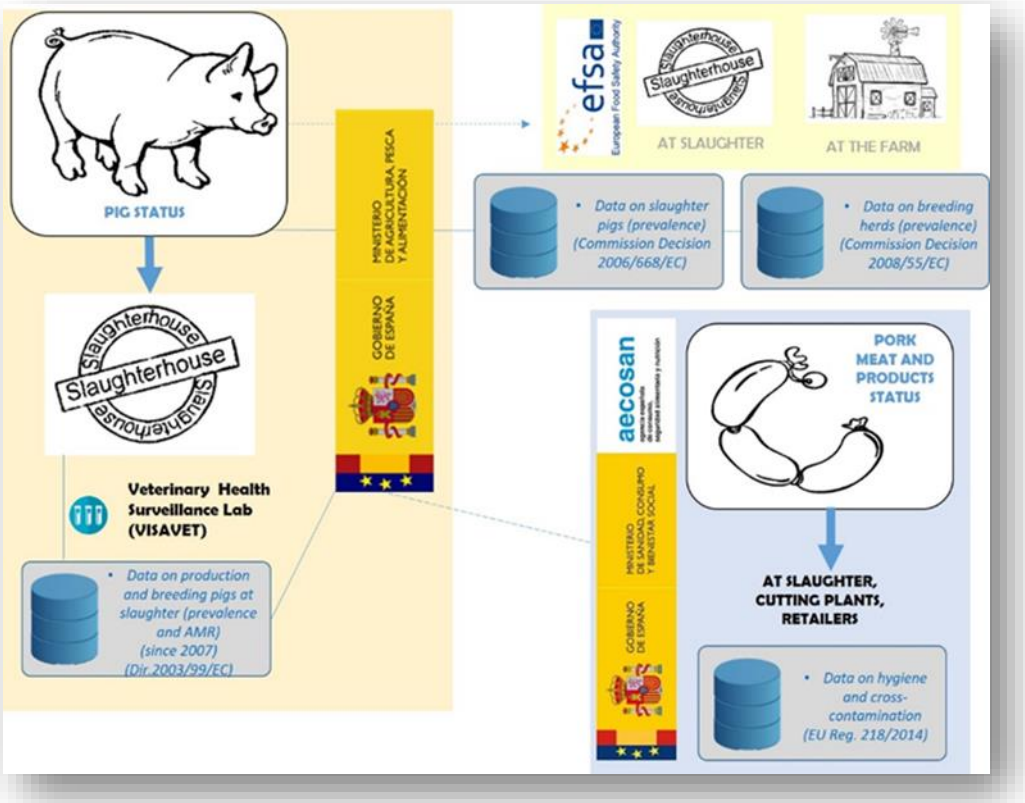
1. Monitoring program of Salmonella in SLAUGHTER PIGS according to the EU legislation (ranging between 160 and 400 farms sampled annually in 2002-2015). This programme involves the annual collection of a sufficient number of samples at the slaughterhouse following EFSA recommendations (EFSA 2012), so that ideally altogether the annually selected slaughterhouses process at least 50-60% of the pig population slaughtered every year, and slaughterhouses from at least 50% of regions in Spain are included (Figure). Sampling is then stratified by slaughterhouse based on its annual throughput, and one or more samples

(typically fecal samples) are collected from a variable number of farms (ranging between 160 and 400 farms sampled annually in 2002-2015) and processed individually or as pools.

2. Baseline survey of Salmonella in SLAUGHTERHOUSES as part of a European-wide effort to determine the prevalence of Salmonella infection in pigs at slaughter (2006-2007). For the survey on pigs at slaughter, 2,619 lymph node samples from pigs originating from different farms were collected in Spain from slaughterhouses accounting for > 80% of the of all slaughtered fattening pigs.
3. Baseline survey of Salmonella in BREEDING FARMS as part of a European-wide effort to determine the prevalence of Salmonella infection in sow farms (2008). Here, 3,660 fecal samples were collected from 366 farms (~10 samples/farm) from farms selected to include different sizes, management systems and regions in Spain.
4. Monitoring program of Salmonella on PORK MEAT AND MEAT PRODUCTS available at the annual country reports, provided to EFSA by the Regional Health Services. It includes the number of units tested and that resulted positive to Salmonella in fresh meat (at the processing plant, at retail and at the slaughterhouse), in meat products raw but intended to be eaten cooked (at the processing plant and at retail) and occasionally, in raw but ready to be eaten raw meat products.

According to this, Salmonella monitoring at the animal source comprises prevalence surveys in pigs and microbiological checks to check that meat hygiene standards are met.

Figure. Salmonella surveillance “from-farm-to-fork” (from pig source)



Data sources on annual monitoring programme and EFSA baseline survey revealed a prevalence of infection around 30% in slaughter pigs, though a wider range is observed when looking at the results from the annual programme (generated through a smaller sample size). Prevalence at the farm level in breeding herds was higher according to the EFSA baseline survey (~57%)

C) Investigate recorded surveillance information in intensive livestock and slaughterhouses using spatial techniques

Between 2002 and 2015 a total of 3,697 samples from pigs originating from 2,986 farms were sampled at 36 abattoirs located in 11 out of the 17 Autonomous Communities in Spain (Figure).

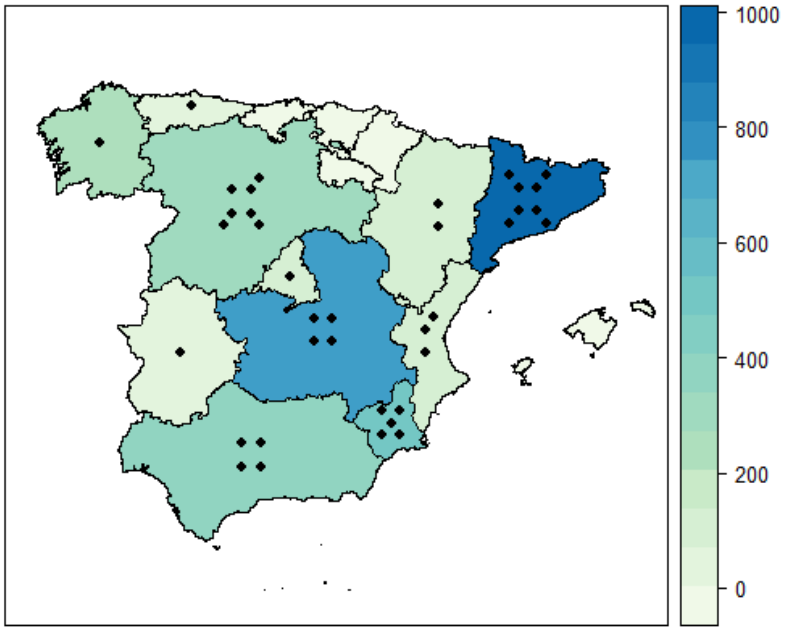


Figure. Number of abattoirs (dots) and samples (color scale) included in the national monitoring program for Salmonella in pigs between 2002 and 2015 (dots do not represent the actual location of the slaughterhouses).

Sampled farms were located in 13 of the 17 Autonomous Communities, among which Cataluña (n=469), Aragón (n=443), Murcia (n=372) and Castilla y León (n=356) contained the highest number of sampled farms (Figure). In most of the years a single sample from one or more pigs of each farm was collected, although a higher number of samples was collected occasionally (Table). The preferred sample collected at the slaughterhouse was feces with the exception of 2009 and 2010, in which both fecal and lymph node samples were collected in most farms, and 2012, when only lymph nodes were collected in most of the farms (Table).

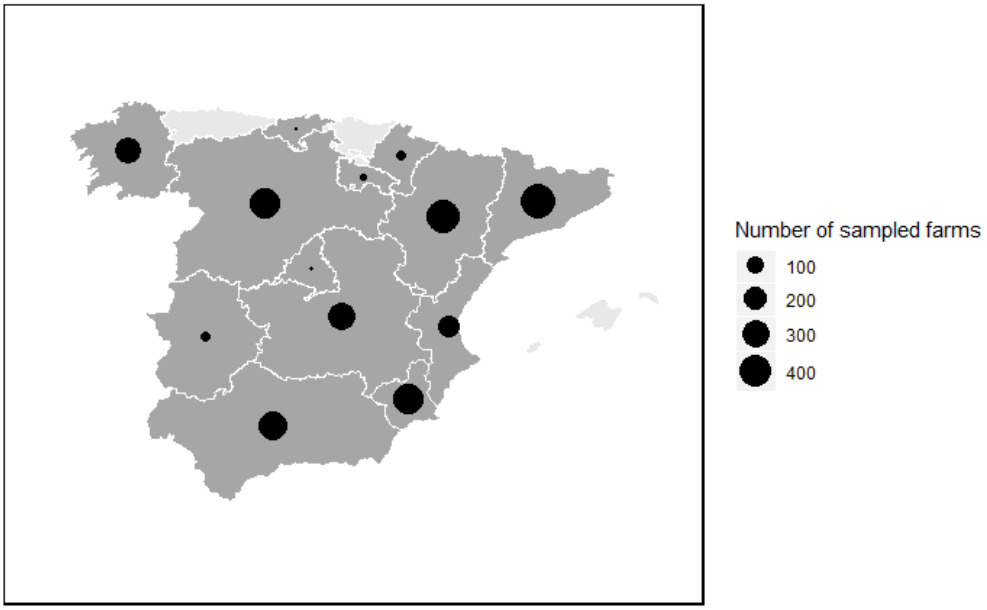


Figure. Number of swine farms sampled as part of the Salmonella monitoring program in each autonomous region in Spain during 2003-2015.

Table. Number of samples and farms included in the Salmonella monitoring program in swine in 2002-2015, and number of samples and farms from which Salmonella enterica was recovered.

Year	Number of samples	Number of farms	Number of positive samples	Number of positive farms	Sample type	Prevalence (95% Confidence Interval)
2002	277	254	45	45	Faeces	17.7% (13.0–22.4)
2003	293	285	62	62	Faeces	21.8% (17.0–26.6)
2004	161	150	91	85	Faeces	56.2% (48.3–64.1)
2005	388	192	173	109	Faeces	44.3% (37.3–51.3)
2006	189	188	99	99	Faeces	52.4% (45.3–59.5)
2007	224	220	79	78	Faeces	34.8% (28.5–41.1)
2008	170	169	66	66	Faeces	38.8% (31.5–46.1)
2009	561	287	211	151	Faeces and lymph nodes	35.9% (30.2–41.6)
2010	421	234	138	107	Faeces and lymph nodes	31.8% (25.6–38.0)
2011	236	231	84	84	Lymph nodes and feces	35.7% (29.5–41.9)
2012	163	163	48	48	Faeces	29.4% (22.4–36.4)
2013	230	229	69	69	Faeces	30.0% (24.1–35.9)
2015	384	384	139	139	Faeces	36.2% (31.4–41.0)

Overall the period prevalence of Salmonella at the farm level in 2002-2015 was 35.0% (95% CI: 33.3-36.7). However, this number varied considerably over time, ranging between 17.7% (2002) and 56.2%

(2004). After 2006 the farm-level prevalence has however remained relatively constant between 30 and 40% (Figure). In the three years in which lymph node were included as part of the program the prevalence was slightly higher although differences were not statistically significant (Figure).

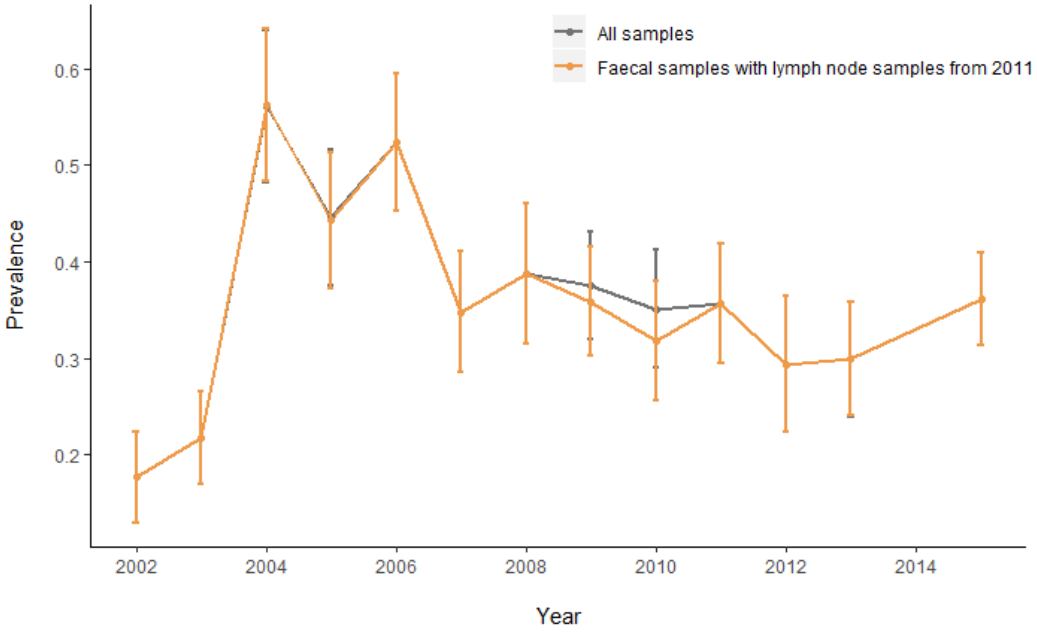


Figure. Proportion of Salmonella positive farms among those sampled as part of the Salmonella monitoring program in Swine in 2002-2015. The Salmonella farm-level prevalence was also different depending on the region, with values ranging between 23.3 (Castilla la Mancha) to 42.5% (Murcia) for regions in which at least 200 samples were collected (Figure).

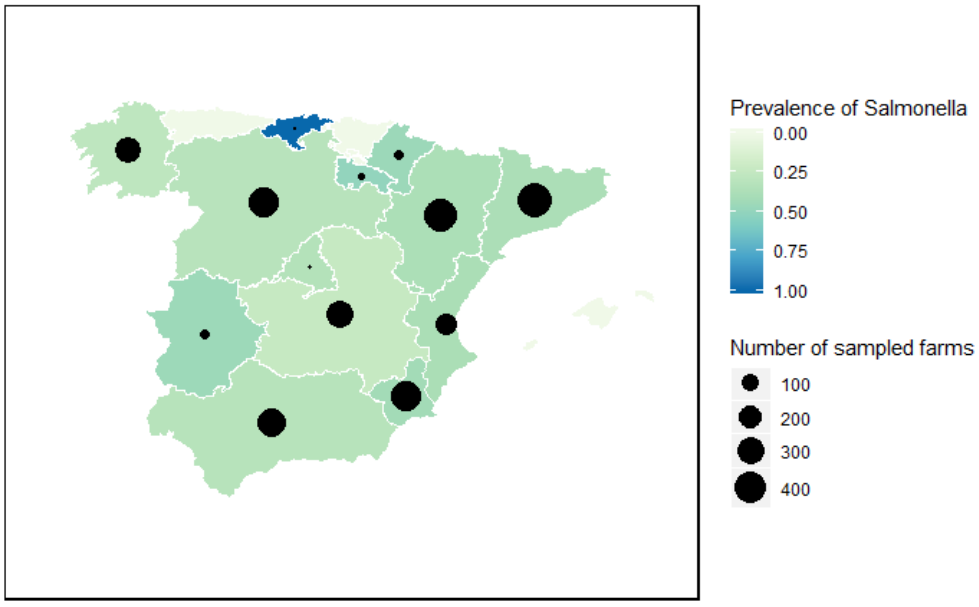


Figure. Prevalence of Salmonella positive farms (color scale) and number of farms sampled in the Salmonella monitoring program between 2003 and 2015.

The number of Salmonella serovars identified each year ranged from 10 in 2003 to 22 in 2011. Next Figure shows the proportion of isolates belonging to the most common serovars found, namely

Typhimurium (n=276), Rissen (n=251), Derby (n=194), 4,[5],12:i:- (Monophasic, n=101), and Bredeney (n=54; Figure.

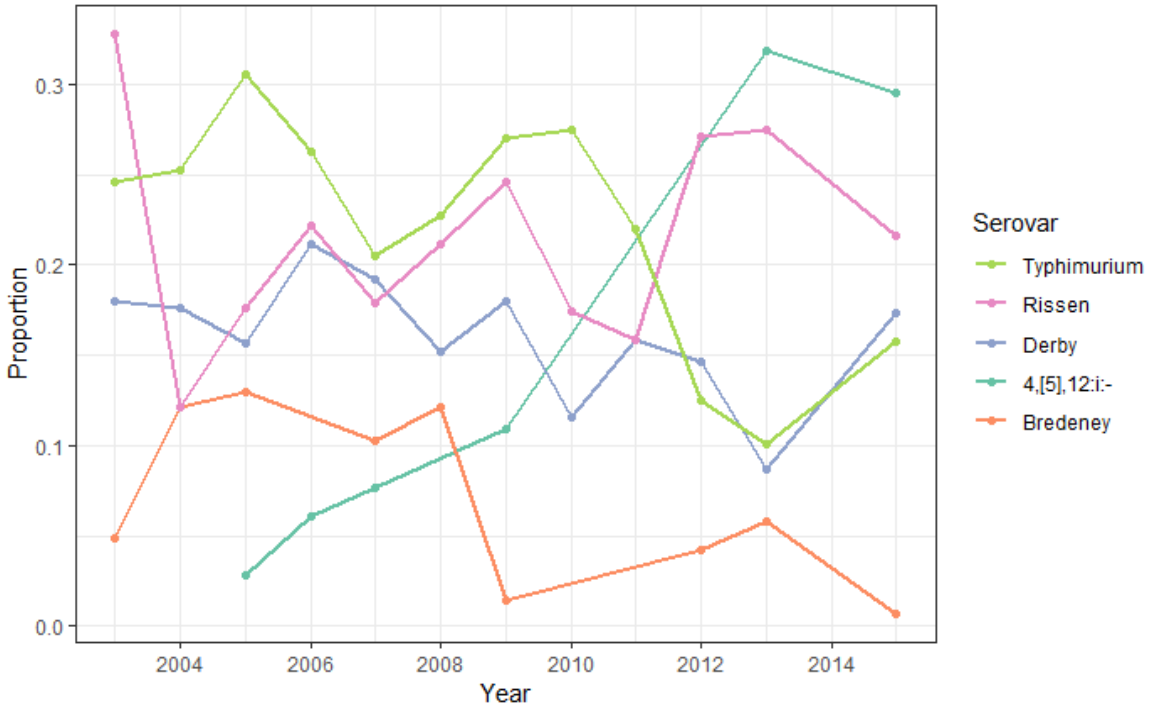


Figure. Proportion of Salmonella isolates belonging to the most common serotypes found in 2002-2015.

These distribution of these serovars was however heterogeneous spatially, with certain serovars being particularly abundant in farms located in certain areas in Spain (i.e, S. Typhimurium in Castilla y Leon and Galicia, S. Rissen in Extremadura or S. Derby in Andalucia) (Figure).

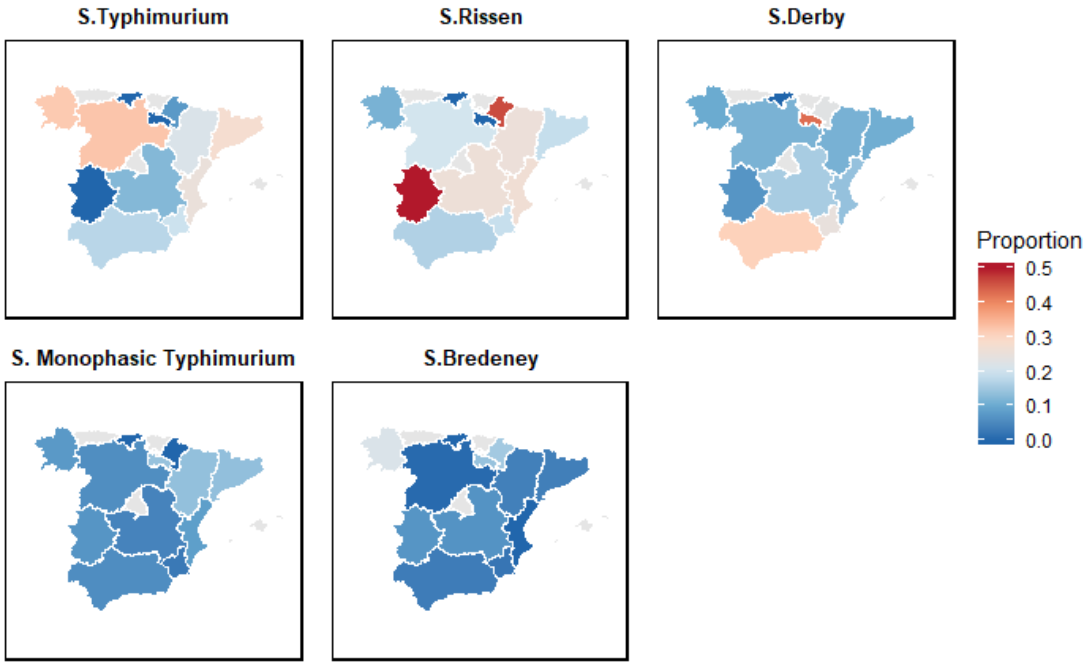


Figure. Proportion of isolates from each region that belonged to the top five serovars found in swine samples through the national monitoring program in Spain in 2002-2015.

4. Conclusions

Degree of achievement: Deliverable D.4.1. has been achieved. Additional spatio-temporal analysis will be performed next year.

Scientific and technical dissemination activities:

- Martínez et al, 2018. Monitoring systems of salmonella in Spain to assess a "one health" approach towards a potential risk to humans from ingestion of contaminated pork meat. IMED. Vienna, Austria. 9-11 November 2018.
- Garrido-Estepa, M., Latasa, P., Ordóñez-León, G.Y.; Martínez-Avilés, M; de la Torre, A; García-Comas, L. 2018. Clinical aspects of non-Typhi, non-Paratyphi Salmonella related hospitalisations in Spain: trends, comorbidities, risk factors for worse prognosis and hospital costs. Eur J Clin Microbiol Infect Dis (2018). https://doi.org/10.1007/s10096-018-3433-1. Open access article.

Main conclusions: Spatial patterns have not been previously included nor considered in national surveillance programs in Spain up to now. The use of this simple, spatial approach has proven to be a successful and useful tool for identifying priority geographical areas for implementing Salmonella surveillance programs.