Describing and mapping of the main existing structures and systematic initiatives and academic activities for surveillance in the EU for zoonoses (transboundary, emerging and re-emerging) in domestic animals and wildlife

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Abstract

The present report describes and maps the main existing structures and systematic initiatives and academic activities for surveillance in the EU for transboundary, emerging and re-emerging zoonoses in domestic animals, wildlife, and the environment, developed by the different sectors, namely human, domestic animal, wildlife and environmental, under One Health approach. This is essential to provide scientific and technical advice and improve future schemes of surveillance. A questionnaire was compiled by MSs and the information collected was complemented by literature reviews about (i) the main existing structures and systematic initiatives or activities, and (ii) academic activities for surveillance in the EU for zoonoses in domestic animals and wildlife. We focused on a 50 zoonotic diseases that were pre-selected for the prioritisation exercise by the One Health working group of EFSA. In total, 21 countries returned the questionnaire. The analysis of zoonotic disease surveillance evidenced that high fragmentation of surveillance programmes occurs in Europe and therefore the main challenge to integrate One Health surveillance is to integrate different surveillance programmes and One Health sectors to progress towards multi-host and multi-sector surveillance programmes. When different sectors oversee the coordination of surveillance programmes, the subsequent integration over the different phases of surveillance is enhanced. A structured approach is needed to determine priorities for surveillance and the approach to be used in European surveillance schemes to achieve a higher benefit-cost ratio with existing or reduced resources. The literature review indicated potential relevance of the hunting sector to participate in surveillance programmes and a bias towards research in vector-borne pathogens and vectors by the academia; experience that can be used to build One health surveillance. Recommendations are provided for further implementation of One health surveillance.

Key words: wildlife, zoonosis, surveillance, One Health

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Summary

Background:

The EU-Commission is setting up a coordinated surveillance system under the One Health (OH) approach for cross-border pathogens that threaten the Union. The present report describes and maps the main existing structures and systematic initiatives, as well as academic activities for surveillance for zoonoses (transboundary, emerging and re-emerging) in domestic animals and wildlife in the EU. This is needed to provide scientific and technical advice and improve future schemes of surveillance. It includes any surveillance activity even if only one sector is involved (human, domestic animals, wildlife and/or environment), excluding foodborne diseases and antimicrobial resistance. A questionnaire on official surveillance was complemented by literature reviews (i) on the main existing structures and systematic activities and (ii) academic activities for surveillance in the EU for zoonoses in domestic animals and wildlife. International surveillance programmes (SPs) targeting transboundary zoonotic and emerging diseases under OH approach worldwide is presented in a separate report. A literature review on zoonotic disease surveillance targeting the environment is also presented in a separate report, together with available methodology.

Methods:

- The questionnaire was distributed through EFSA to Members and Observers of EFSA Animal Health and Welfare Network, and to a list of additional contacts collated by *ENETWILD*. This questionnaire explored (i) the general organization of the SPs, and (iii) the target pathogen and species and methods for surveillance. Data was collected at SP level, normally several of them per country, each coordinated by one or multiple institutions belonging to one of different health sectors (animal health, public health, environmental authorities), with variable objectives and focusing on different pathogens (of different nature and epidemiological characteristics). This heterogeneity was considered to describe and map official SPs in EU.
- LR1: Literature review on the main existing structures and systematic/academic activities for surveillance of zoonoses in domestic animals, wildlife, and human sectors in the EU, allowed to complement the scope of the questionnaire (i.e., not all countries answered the questionnaire, and systematic academic activities are also relevant).
- LR2: Literature review on non-systematic surveillance activities carried out by the academia for surveillance of zoonoses in wildlife in the EU, with the aim of exploring the availability of information on disease surveillance that complements official systematic surveillance.

Results:

- General: The analysis of the questionnaire on official surveillance revealed that the total number of SPs reported in 21 countries which answered the questionnaires is 360. Human sector only SPs and animal sector only SPs predominated, accounting for about two thirds of the total number of SPs, with marked differences among countries. They were followed by far by SPs where both sectors were in charge together of the coordination, and to a lesser extent, other combinations of sectors or with environment-only in charge. These programmes are mainly applied and funded at National level. Peaks in SP establishments occur around major outbreaks.

  Integration and coordination: Surveillance activities can be divided into planning, sampling, analysis, and dissemination phases. The sampling phase is the phase that is the least integrated among sectors (18.9% of SP), and integration increased for planning (24.2%) and

analysis (lab and statistics, 29.4%). The highest collaboration among sectors occurred for dissemination of results (45.0%), which is considered to be also low. "Interest" (collaboration is in favour of stakeholder's interest) and "Legislation" (presence of rules in favour of collaboration) were most frequently indicated as factors for favouring integration, especially by SPs where the sectors share the coordination, while "Economics" (lack of funding for collaboration) was the most important barrier to integration. Different types of institutions were usually involved in the execution of the SPs, especially when multiple sectors were in charge and the animal sector was involved. In contrast, SPs coordinated solely by the human sector usually involved few different types of institutions.

SP objectives: The most frequently reported objectives of the SPs were to "detect new pathogen/diseases or unusual epidemiological events", and "the demonstration of freedom from a particular pathogen/infection". Programmes having these two objectives were commonly programmes coordinated by different sectors.

SP evaluation: Approximately 50% of the SPs included an evaluation process. This evaluation was often an annual event. However, most evaluations were internal, external evaluations were only performed in 11 % of SPs (and less than 1% presented both, internal and external). When asking if results of evaluation were used to revise the SP, the SPs where animal health participated presented the highest rates.

Characteristics of surveillance: 91% of the SPs applied passive surveillance (mostly alone, to a lesser extent combined with active), and only 9% of the SPs were exclusively based on active surveillance. Active surveillance predominated for environment-coordinated programmes (74%), whereas passive surveillance was more frequent for animal (53%) and human (74%) sectors. Combined public-animal-environmental SPs used both (passive and active) relatively frequently (76%). Whereas in some countries one type of surveillance predominated for most pathogens (e.g., passive in Estonia or Greece), other presented a diversified patten, the type of surveillance depending on the pathogen.

Sampling design: The sampling design was predominantly risk based (72.6% of SPs), followed by random (45.8%) and stratified (random) sampling (29%). Risk-based or random sampling predominated in programmes coordinated jointly by multiple sectors (human, animal, and environment), whereas stratified (random) sampling was most frequently reported in SPs coordinated jointly by the human and animal health sectors.

- General characteristics of the listed pathogens and their representation in SPs: Approximately half of the pathogens of the list is vector-borne (47.9%, n=23 pathogens). Among the listed diseases, 64.3% of the bacterial diseases are vector-borne, 44.8% of the viral diseases, and only one of the 4 protozoal diseases, namely *Leishmania* spp. The main vectors associated with the selected pathogens included mosquitoes (20.8%) and ticks (18.8%), followed by fleas, sand flies and trombiculid mites (the later three always in <5% of pathogens). The proportion of vector borne pathogens included was highest in SPs coordinated by the environmental sector and in SPs coordinated jointly by the three sectors; public, animal, and environmental health. The average number of pathogens included per SP separately for each taxon was always less than one. Viral agents were proportionally more present in SPs (53%), followed by bacteria (38%), while protozoa and helminths were less frequent (12 and 8%). *Brucella* spp. were the most frequent pathogen (10.6% of SPs), followed by viral pathogens Influenza A virus (Avian) and rabies. Helminths *Echinococcus* spp. ranked fourth. The number of pathogens included in SP per country according to the taxa was variable, the number of viruses and bacteria correlated positively. A clear spatial pattern was detected for protozoans, being more represented in different species in Southwestern countries. The number of pathogens (of the list) surveyed per SP was positively associated with the number

of institutions involved in the SP. The highest number of pathogens included in SPs occurred in Mediterranean countries, Belgium, The Netherlands, and Scandinavia.

- General characteristics of the listed pathogen´s hosts and their representation in SPs: Among the listed diseases, wild mammals predominated as main **primary hosts/reservoirs**. Rodents were the most represented group (for almost 30% pathogens), followed by other terrestrial wild mammals (21%, mainly ungulates, and to a lesser extent lagomorphs and carnivores) and bats (14.6%). A relevant proportion included both mammals and birds as main hosts (15%) or only birds (14%), i.e., birds may act as primary hosts of almost 30% of the selected list of pathogens. Domestic animals, the environment and humans represented smaller proportions. Concerning the type of host (reservoirs) sampled by SPs, sampling of domestic animal species predominated, followed by wild mammals (both game and non-game species). To a lesser extent, wild birds and the environment were sampled (<10 % SPs). Livestock clearly predominated in SPs where the animal health sector was in charge (alone or coordinated); whereas wildlife was predominant in SPs coordinated jointly by the animal health and environmental sectors, as well as for environment-only sector. Normally, SPs focused on sampling only one single or two groups of hosts (including environment. Sampling the environment and humans were restricted only to some countries.
- Literature review (LR1) addressed the main existing structures and systematic/academic initiatives for surveillance of zoonoses in domestic animals, wildlife, and human sectors in the EU. The main differences and complementary results provided by the literature review *versus* the questionnaire were, first, the hunting sector was the institution most frequently involved. This was followed by official laboratories, research institutions and public health institutions, all similarly high in the ranking). Secondly, there was a higher motivation to evidence trends and improve knowledge compared to official-only surveillance. No relevant differences were evidenced in the ranking of pathogens more frequently included in SPs.
- Literature review (LR2) on surveillance activities carried out by the academia for surveillance of zoonoses in wildlife in the EU. The most frequently reported objectives were to answer research and epidemiological questions, rather than early detection of pathogens. Unlike official surveillance, in academic activities active surveillance alone seems to predominate over passive surveillance or combined surveillance. About the sampled hosts, there was also a predominance of arthropod vectors and vector-borne pathogens (Lyme borreliosis and Tick-borne encephalitis virus, followed by West Nile virus).

Discussion

- Regarding the **questionnaire on official surveillance**, our results refer to SPs in the countries which returned the questionnaire (n=21, from the EU and associated countries), which is considered a good sample rather than a complete census of SPs over Europe. We focused on a list of zoonotic diseases pre-selected for the prioritisation exercise by the OH working group of EFSA. This mapping therefore is a large representation of European SPs, including different health sectors (public, animal, and environmental) and at least one of the listed zoonotic pathogens.

  The **integration between sectors** is not generalized (the relationship "number SPs human-only or animal sectors-only coordinated" to "number SPs where both sectors participated in coordination" was 3.2:1), which is a necessary step to develop OH surveillance for such multi-host transboundary zoonotic pathogens. SPs are mainly applied and funded at the national level, however a OH approach ideally requires an international approach since pathogens, risks and determining factors do not "care" about borders. Therefore, preferably surveillance is planned and coordinated nationally. The integration among sectors was the exception and mainly applied to the last phase: dissemination of results (still at low rate, <50%). Different

sectors worked mainly independently and only came together to disseminate results of surveillance. This may have occurred because joint reporting is either obligatory or requested by national or international institutions. It is particularly worrying that the phase of planning presented low integration among sectors. This is consistent with the fact that among the dishomogeneities occurring in SPs, the one most frequently mentioned was that the number of samples differs. This may also be an issue within a sector between years. Planning, sampling, and analysis are essential steps for integrated OH surveillance. A relevant learnt lesson was that integration among sectors was more frequent when different sectors oversee the coordination. This indicates that involving animal, public and environment health sectors is needed for their subsequent integration over the different phases of surveillance.

Two main factors were referred to as **favouring** (i.e., barrier when not implemented): the "Existence of appropriate legislation", which can be considered an objective factor and a legal liability if implemented, whereas the second, "Interest to collaborate" can be influenced by subjective perceptions from different health sectors and by awareness and knowledge about OH surveillance approach. Therefore, there is still a need to increase the interest on collaboration among sectors. No legislation will succeed if there is no interest to integrate other sectors, and no interest will be fruitful without the appropriate legislative framework to develop proper OH surveillance. The factors were most referred to in SPs where the coordination was mixed between sectors, an opinion that is particularly relevant given their experience in coordination with other sectors.

Within sectors, animal health presented the higher average **number of involved institutions** per SP, whereas the public health sector was the one involving the smaller. This may indicate that animal health, given the higher diversity of hazards (pathogens), host and environments faced, is more used (or requires) to involve different institutions in surveillance, for example, domestic animals and wildlife institutions, respectively. We speculate that this can contribute to explain animal health as more receptive to integrate OH surveillance than other sectors.

The two most frequently **reported objectives** of the SPs were related to disease reporting, early or at the end of outbreaks: "detecting new pathogen/diseases or unusual epidemiological events", and "the demonstration of freedom from a particular pathogen/infection". Both objectives were specially remarked by SPs coordinated by different sectors. It becomes evident that the difficult task of determining pathogen emergence requires multi-actor coordinated SPs to be more effective. It is also worth mentioning that the objective "evaluate control or eradication strategies" was more prevalent in SPs coordinated by different sectors (except the human/animal). Given that most reported SPs only involved one single sector, we conclude that animal and public health seldom work together to control and eradicate zoonosis in spite of their potential to do so. When the environmental sector participated in coordination, this objective was highly reported by SPs, indicating that public health-animal health collaboration may be triggered when environment is relevant to pathogens of animal and medical interest (epidemiology, surveillance, control).

The low rates reported for **evaluation processes** in SPs (approximately 50%, the external evaluation was only performed in 11% of SPs) indicates that this activity must be promoted, and it must be standardized (in a comparable way), but flexible. The attributes to evaluate, for instance, would include the ability of a system to detect an emergent event (sensitivity) while keeping the simplest or timeliness as possible, but also acceptability, predictive value positive and representativeness. It was not the scope of this report to analyse the current evaluation schemes of SP, but it is advisable in order to provide recommendations on their

quality and efficiency, and more importantly, what the SP requirements are, which determines the characteristics to be assessed.

Regarding the main **characteristics of surveillance**, most SPs applied only passive surveillance (60%) or in combination with active surveillance (31.1%), i.e., 91% at least applied passive surveillance (alone nor combined with active). 8.9% of the SPs were exclusively based on active surveillance. Each SP requires its own evaluation in terms of the required passive and/or active surveillance approach. However, considering the specificities of each pathogen group, hosts (reservoirs), potential source, access, and types of samples, and finally, the costs (normally lower for passive surveillance), a general framework could be developed to design best strategies shared among sectors. For instance, we found that active surveillance predominated for environment-coordinated SPs (74%). Interestingly, we evidenced that combined SPs (among sectors) tended to use both passive and active in equilibrated proportions (about 50%), probably arising from the collaborative approach and complementary specialization of sectors. As indicative, combined public-animal-environmental programmes used both (passive and active) in a large proportion (76%).

The **sampling design** predominantly included risk based (72.6% of SPs), followed by random (45.8%) and stratified sampling (29%). Random and risk-based sampling predominated in SPs were multiple sectors (animal, public health, and environment) where co-ordinately in charge, whereas stratified sampling was most frequently reported in SPs jointly coordinated by human and animal health sectors. Since risk-based design requires relevant understanding of the epidemiological context and prior information, we must reflect about if current risk-based sampling (which is highly prevalent) is sound. The collaboration of sectors based on their respective expertise would help to this aim.

About **hosts/reservoirs sampled** in SPs, domestic species apart, the questionnaire evidenced the relevance of wild mammals (both game and nongame species), and to a lesser extent, wild birds, and the environment. Particularly, wildlife was predominant in SPs co-coordinated by animal health and environmental sectors, and the environmental sector alone. However, an important fragmentation of SPs occurs in terms of number of different groups hosts sampled: the average number of different groups of hosts sampled per SP was about 2, even tending to lower values for the animal health and environmental sectors. This is illustrative of the large level of fragmentation of SPs occurring in Europe and the challenge is to integrate different SPs to develop OH surveillance. OH focused surveillance integrates different health sectors (including environment), but also needs to consider multi-pathogen multi-hosts and environment systems as a whole, and this may be constrained by fragmented surveillance, especially if different SPs are not coordinated.

Beyond the fact that the number of pathogens included in surveillance system per country according to the taxa was variable, we remark that the average number of **pathogens** (of the list, separately for each taxon) included per SP was less than one. This is because the number of pathogens included per SP is normally low, and often multiple pathogen taxa are not represented. This is similarly indicative of the degree of fragmentation of SPs in Europe. Multiple host SPs may be benefit at all steps of the process (planning, sampling, analysis, dissemination), both, in terms of logistics and costs, being able to integrate multi-pathogen multi-hosts and environment systems as a whole, if they integrate with other SPs.

I spite of the relevance of wildlife in SPs, they seem still to be unrepresented. A relevant exercise to evaluate and improve future European SPs was to compare the actual sampled

hosts/reservoirs species in SPs and the **primary hosts/reservoirs for the selected pathogens** (even when for some pathogens are not completely known yet). Domestic animals are among those more frequently sampled by SPs, but not preferential main hosts for most pathogens of the list, and the opposite occurs for wildlife. Wild mammals predominated as the main potential reservoirs for the selected list of pathogens. Some of them, such as wild ungulates, are widely distributed all over the continent and are involved in conflicts including shared diseases with livestock and humans. This situation requires a common transboundary approach over Europe. A relevant proportion included wild birds as main hosts (about 30%), many of which are migratory and may carry pathogens all over Europe. This reinforces the need of coordinated SPs in the continent as pathogens "does not care" about borders.

Half of the pathogens here considered are **vector-borne**, and the main vectors included mosquitoes and ticks (to a less extent fleas, sand flies and trombiculid mites). Activities developed on vector surveillance were not included in the scope of the present report. However, the main recommendations here presented should apply to vector surveillance, including the fact that an enormous fragmentation and heterogeneity of SPs occurs over Europe. The surveillance of vectors should be integrated together with pathogens and addressed in coordination by the different health sectors. As indicative, the proportion of vector-borne pathogens included in surveillance systems was higher for the environmental sector as well as in SPs where the three sectors, human, animal, and environmental heath coordinated (jointly) the SP.

- **The literature review (LR1) on the main existing structures and systematic initiatives for surveillance in the EU for zoonoses by domestic animals, wildlife, and human sectors**: A big difference (compared to the questionnaire) is that the hunting sector was the institution most frequently involved in the reviewed SPs. This indicates the potential relevance of the hunting sector to be more involved in SPs.
- **The literature review (LR2) on surveillance activities carried out by the academia for surveillance in the EU for zoonoses in wildlife**: The most frequently reported objectives indicate that there is specific motivation by the academia to estimate the magnitude of a health problem and improve knowledge, compared to official surveillance, which are more interested on detecting pathogen emergence, spread and/or fade out. Unlike official surveillance, in academic activities active surveillance alone seems to predominate over passive surveillance or combined surveillance, which is a necessary approach to test hypotheses and develop experimental and observational designs in the context of research. Interests and/or motivations of the academia were also biased towards vector-borne pathogens and vectors, which complements the scope of official surveillance. Therefore, it is recommendable official surveillance to build on what the academia is doing in relation to vector borne pathogens and vectors, and this vector detection and diagnosis methods.

Conclusions and recommendations:

- The results here presented on the questionnaire refer to SPs from a number of countries which returned the questionnaire (n=21, mostly from the UE), which is a **good sample rather than a complete census of SPs over Europe**, illustrating a large representation of European SPs, including different health sectors (public, animal, and environmental) with at least one of the listed zoonotic pathogens. However, it is advisable to increase the number of countries (questionnaires on official surveillance) to be analysed, although the present report is considered a good sample.
    - The **integration between sectors** was not predominant, and mainly applied to the last phase of SPs (dissemination of results). However, sampling, planning and analysis (lab

and data) are essential steps to the foundations of OH surveillance. The integration among sectors was more frequent when different sectors oversee the coordination, which illustrates the way to progress on coordinated harmonized OH surveillance.

- Two main factors referred to as **favouring** (**or barrier** when not implemented) were "existence of appropriate legislation" and "interest to collaborate", which evidences there still is relevant job to do to: defining an appropriate legislative framework and promoting the interest of collaboration between sectors.
- The difficult **objective** of detecting new pathogen/diseases or unusual epidemiological events, and the demonstration of freedom require multi-actor coordinated SPs to be effectively addressed. Most reported SPs only involved one single health sector, illustrating that animal and public health seldom work together to control and eradicate zoonosis in spite of their potential to do so. Public health-animal health collaboration may be triggered when environment is relevant to pathogens of animal and medical interest.
- The **evaluation of SPs** is not frequently implemented by SPs, which makes evident that an important effort is needed by all health sectors to develop effective evaluation processes.
- While no single surveillance tool, either **active or passive**, is perfect, usually combinations of approaches work best. However, less than one third of SPs combined active and passive surveillance. Each SPs, as well as future European surveillance schemes, requires its own evaluation in terms of the required passive and/or active surveillance approach.
- The **sampling design** predominantly includes risk-based sampling, followed by random and stratified (random) sampling. Risk-based sampling is the one requiring more previous information and therefore current SPs and future European schemes must ensure this strategy is really yielding both higher sensitivity and higher positive predictive value than surveillance conducted randomly across the host populations. The collaboration of sectors based on their respective expertise would help to achieve this aim.
- About hosts/reservoirs, domestic species apart, wild mammals and wild birds, were the most frequently sampled. However, an important **fragmentation of SPs occurs in terms of the nª of different groups hosts sampled**. This illustrates the need to integrate different SPs to achieve proper OH surveillance.
- The **number of pathogens** included per SP is normally low, and often multiple pathogen taxa are not represented, indicating a high degree of fragmentation of SPs and need for future integration.
- Many pathogens here considered are **vector borne**, adding complexity to integral OH surveillance.

- The literature reviews indicated the potential relevance of the hunting sector to be more involved in SPs, and the bias towards borne pathogens and vectors by the academia, which can be used by official surveillance to build OH surveillance upon existing experience.

The main **RECOMMENDATIONS** for further implementing OH surveillance are:

1. The **integration** between sectors (human, animal, and environment health) is a necessary step to develop OH surveillance. Moreover, efforts should be made to plan surveillance and coordinate and integrate approaches at an international level.

a. We recommend that different sectors become involved in the coordination of SPs to facilitate their subsequent integration over the different phases of the surveillance. Since objectives maybe specific to SP and health sectors, surveillance must ensure these specific objectives are met when surveillance is planned as multi-sectorial. Integrated disease and population monitoring is essential to meet this diversity of objectives.

b. No legislation will succeed if interest to integrate other sectors is not motivated, and no interest will be fruitful without the appropriate legislative framework to implement OH surveillance. Multi-sectoral national and international OH surveillance working groups involving the multiple disciplines are essential. They should regularly and frequently meet, and their activities should go beyond merely reporting. They should define policies and plan surveillance in an adaptive way, the objective of the surveillance is a central element for planning and decision-making.

c. Surveillance planning must be addressed from the very beginning by different institutions/sectors. The plan should include:

- Sampling design: risk-based, random, stratified; active vs passive
- What, how, who, when
- Documentation and data management
- Synergies: technical (diagnosis), facilities, access to samples
- Communication

d. For effective detection of pathogen emergence multi-actor coordinated SPs are required. Public health-animal health collaboration can be triggered when the environment is relevant to pathogens of animal and public health interest.

2. Future OH European surveillance is an opportunity to implement critical evaluation of programmes. SP evaluation processes must be promoted, and they should be conducted in a standardized and comparable way. At the same time, flexibility on the planning, implementation, and evaluation of health interventions and programmes should be considered assessing their effectiveness within a common European OH framework. We recommend an analysis of the evaluation of surveillance systems, including recommendations on quality and efficiency, and most importantly, to define the SP requirements and objectives to be able to determine the characteristics to be assessed.

3. Considering the specificities of each pathogen group, hosts (reservoirs), potential source, access, types of samples and costs (normally lower for passive surveillance), a general framework need be developed to design best strategies (active and passive surveillance) shared among sectors.

4. The sampling design of the reviewed SPs predominantly included risk-based sampling (vs random and random stratified), which requires relevant prior knowledge.

a. Therefore, a structured approach is needed to determine priorities for surveillance and the approach to be used in European surveillance schemes to achieve a higher benefit-cost ratio with existing or reduced resources.

b. Transnational research and collaboration of sectors/countries based on their respective expertise would help to this aim (data and expertise sharing).

c. High quality (spatially precise) information for livestock at European level is needed to assess risks (such as the interface with wildlife) and subsequent risk-based

sampling. However, this information is not available at European level at sufficient resolution and must be openly shared by countries.

   d. Wildlife population monitoring (integrated surveillance) is also essential to develop risk-based surveillance.

5. A high fragmentation of SPs occurs in Europe and therefore the challenge to integrate OH surveillance is to integrate different SPs. OH focused surveillance must integrate different health sectors (including environment), but also needs to consider multi-pathogen multi-hosts and environment systems as a whole. Integration of SPs does not necessarily mean the complete convergence/fusion of SPs but planning them in coordination to making them comparable and synergic.
6. The low number of pathogens included per SP indicates a high fragmentation of SPs. We recommend progressing towards multiple-host SPs, which will be beneficial at all steps of the process in terms of logistics, costs, and elucidating determining factors. Integration of all sectors with international focus is required. The surveillance of a higher number of pathogens (which may well apply to vectors too) may need to involve larger and diverse number of institutions and again, requires different sectors to join for coordinating the SPs.
7. Comparison of the actual sampled hosts and the primary known reservoir species for the selected pathogens is needed to evaluate and improve future European SPs. Overall, a first exercise revealed that wildlife, the main reservoir host for most zoonotic pathogens, is underrepresented in current SPs. Wildlife under-represented in current surveillance schemes, particularly mammals, namely rodents and bats, and to a less extent, wild ungulates, and carnivores, should be included in SPs.
   a. There is need to involve more wildlife and environmental institutions to increase feasibility of surveillance. These institutions have the technical ability, knowledge and expertise to develop active and passive surveillance and can also provide means and logistics, which, however, need improvement.
   b. Concerning passive surveillance, wildlife disease professionals can assess clinical signs and pathology, the preliminary clinico-pathological diagnosis guides the correct selection of samples/organs and of pathogens to be tested. Testing of animals found dead or with clinical sigs provides a higher chance of detecting pathogens. Passive surveillance is very important for the early detection of new diseases/pathogens.
   c. Regarding active surveillance, the hunting sector, as well as wildlife management and environmental agencies have access to samples from apparently healthy animals, which may carry subclinical/inapparent infections.
   d. For all the above, guidelines/protocols, means and reliable diagnostic tests are needed.
8. The recommendations above should apply also to vector surveillance, including the fact that an enormous fragmentation and heterogeneity of SPs for vectors may occur. The surveillance of vectors for specific pathogens should be integrated with surveillance of animals and humans, thus, should be designed and coordinated among the different health sectors.

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1. General Introduction

1.1. Background and Terms of Reference as provided by the requestor

This contract was awarded by EFSA to Universidad de Castilla-La Mancha, contract title: Wildlife: collecting and sharing data on wildlife populations, transmitting animal disease agents, contract number: OC/EFSA/ALPHA/2016/01 – 01.

The terms of reference for the present report (specific contract 10, task 7. *Ad hoc* requests in systematic literature review, scientific and technical advice on targeted wildlife surveillance), are, as indicated in deliverable 2.2: "Describing and mapping of the main existing structures and systematic initiatives/academic activities for surveillance in the EU for zoonoses (transboundary, emerging and re-emerging) in domestic animals, wildlife, and the environment".

The designated methods for compiling the information were literature reviews and a questionnaire survey on surveillance activities for zoonotic disease in the EU, as well as in neighbouring areas or countries where relevant, e.g., the Balkans. The focus was to be on surveillance activities for zoonotic emerging pathogens in domestic animals, wildlife, vectors, and environmental samples. The request was to exclude the surveillance activities on food-borne zoonotic diseases and antimicrobial resistance. Documented surveillance activities could be performed by one or several of the four One Health (OH) sectors, which are the human, domestic animal, wildlife, and environment sectors. The questionnaire survey should be designed to gather information on surveillance activities for zoonotic disease from all OH sectors in each surveyed country.

The deliverable had to consist of a scientific report with description of the research methods applied and the resulting overview of official and academic surveillance activities that target transboundary zoonotic and emerging hazards in domestic animals, wildlife, and the environment in the EU.

1.2. Scope of the report

The *ENETWILD* consortium (www.enetwild.com) implemented an EFSA funded project whose main objective has been the harmonization and collection of information regarding the geographical distribution and abundance of wildlife and wildlife diseases throughout Europe.

The EU-Commission has allocated specific resources for EU Member states (MS) for setting up a coordinated surveillance programmes (SPs) under the OH approach for cross-border pathogens that threaten the Union. In this context, the tasks requested by EFSA to ENETWILD under specific contract 10 are to identify, describe and learn lessons from existing coordinated/collaborative disease surveillance.

The present report describes and maps the main existing structures and systematic initiatives/academic activities for surveillance in the EU for zoonoses (transboundary, emerging and re-emerging) in domestic animals, wildlife, and the environment. To this end:

- Information on official surveillance frameworks in Europe was obtained from the different countries through a questionnaire that *ENETWILD* developed in agreement with EFSA. The questionnaire aimed at mapping national SPs in Europe for 50 zoonotic diseases listed by EFSA. These SPs could be performed in animals or the environment by one or several of the OH sectors, i.e., the human health, domestic animal, wildlife, or environment sector. Foodborne zoonoses and antimicrobial resistance surveillance activities were excluded from this study.

- To describe official surveillance frameworks in Europe, *ENETWILD* elaborated, in agreement with EFSA, a questionnaire aimed at collecting information at the national level was used. The target of this questionnaire survey was to collate information on all OH sectors, i.e., human health, domestic animals, wildlife, environment in EU MS and associated countries, with focus on either health hazards where wildlife is directly involved i.e., wildlife zoonotic disease surveillance or other hazards not directly involving wildlife, for example surveillance of zoonotic diseases in domestic animals. This questionnaire was not intended for veterinary authorities only. This includes all national wildlife and domestic animal zoonotic disease SPs in Europe (excluding only foodborne zoonoses and antimicrobial resistance) including at least one of the list pathogens. It includes any surveillance activity focusing on zoonotic/emerging pathogens in animals (domestic animals, wildlife) as well as surveillance activities in the environment (environmental samples and vectors), even if only one sector is involved (human, domestic animals, wildlife, environment).
- The questionnaire was complemented by literature reviews:
    - on the main existing structures and systematic/academic initiatives academic activities for surveillance in the EU for zoonoses (transboundary, emerging and re-emerging) **in domestic animals and wildlife**,
    - on **academic activities** for surveillance in the EU for zoonoses in **in domestic animals and wildlife**.

2. Questionnaire survey on official zoonotic disease surveillance activities in the EU and neighbouring countries

2.1. Methods

2.1.1. The questionnaire

The questionnaire was divided into two parts and presented into separate sheets (as an Excel document, see Annex 1[2]).

- Sheet 1: PART 1 – **surveillance**. This part explores the general organization of the SP
- Sheet 2: PART 2 – **pathogens**. This part aims to identify target pathogen and species and methods for surveillance

There were 5 types of answer formats: cells could be filled with 1) a "Drop-down menu", 2) a "Multiple drop-down menu", 3) year format, 4) 0-1 answer, and finally, 5) free text. We asked to stick to the answer type to facilitate the analysis process. In case it would be not possible to answer the question, or the answer is unknown, we asked to leave it empty.

Distribution of the questionnaire

The questionnaire was distributed by EFSA to Members and Observers of EFSA Animal Health and Welfare Network. This was done in the context of the above mentioned EFSA mandate for scientific and technical assistance for a coordinated SP under the OH approach for cross-border pathogens that threaten the Union ('OH system'), and it was supported by the Direct Grant CP-g-22-04.01. Both the mandate and the direct grant programme had been presented in June 2022 at the AHAW (Animal Health and Welfare) Network meeting.

It was communicated to these network that this mandate (term of reference A.1.) requested EFSA to design the OH SP and that one specific task of this ToR was to 'perform a mapping of the main existing structured and systematic initiatives for surveillance in the EU for zoonoses in animals and the environment'. The task was to identify already existing structures, initiatives, and tools on which the OH SP can build, in terms of including them in or adapting them to the OH SP, and capturing the lessons learnt from implementing them.

EFSA introduced the network ENETWILD, as the contractor in charge to prepare the questionnaire for the collection of relevant information on the existing structures and systematic initiatives in the EU for surveillance of zoonoses (transboundary; emerging and re-emerging; non-foodborne, non-AMR) in domestic animals, wildlife, and the environment. The Members and Observers of EFSA Animal Health and Welfare Network would probably need to collaborate with different colleagues in their respective countries, and therefore, EFSA's Focal Points were included, copied in the emails, as well as colleagues from countries that have contacted EFSA because their country intends to apply for a direct grant, who might be able to help in putting all the necessary information together. EFSA added a list of additional contacts collated by ENETWILD that could also be helpful for the task.

EFSA asked to return the completed questionnaire by 15th September 2022, this deadline that was later extended to 6th October. A webinar was organized by *ENETWILD* to present and solve

[2] https://doi.org/10.5281/zenodo.7446484

questions aimed at Members and Observers of EFSA@s Animal Health and Welfare Network, and other potential responders on September 5th, 2022.

2.1.2. Data analysis

Data was collected per SP, normally several per country, each coordinated by one or multiple institutions belonging to one of different health sectors (animal health, public health, environmental authorities, or in coordination), with variable objectives and focusing on different pathogen/s (of different nature and epidemiological characteristics). All this heterogeneity is considered to describe and map official SPs in EU at different levels: SP level (n=360); and Country level (n=21 countries). This report pays special attention to describing the main characteristics of the SPs as a function of the OH sector in charge of the respective SP (human, domestic animal, wildlife, environment, or several of these) and the Country of origin.

First, we present general information on the SPs in the countries that answered the questionnaire. Thereafter, following the structure of the questionnaire, we organise the presentation of results like this:

- **Coordination** of the SP
- **Integration among sectors** (animal health, human health, environmental health) within the SP
- Participating **Institutions**
- **Geographical** and **temporal** coverage
- **Objectives**
- **Evaluation** of the SP (is the performance of the programme evaluated?)
- **Pathogens** and target **hosts** (or reservoirs, including the environment, and both, potential and sampled), and the main **epidemiological characteristics** of interest for risk assessment and surveillance
- **Characteristics of surveillance**, such as target hazards, sampling design, type of samples.

2.1.3. The pathogens

Part 2 included a list of zoonotic diseases pre-selected for the prioritisation exercise by the OH working group of EFSA (see Table 1). Therefore, this survey refers to European SPs including at least one of the listed zoonotic pathogens:

Table 1. List of 50 zoonotic pathogen species/genera pre-selected for the prioritisation exercise by the OH working group of EFSA.

Target pathogens	Caused disease
Bacillus anthracis	Anthrax
Brucella (*B. abortus, melitensis, suis*)	Brucellosis (*B. abortus, melitensis, suis*)
Chikungunya virus	Chikungunya fever
SARS-Coronavirus type 2	COVID-19
Crimean-Congo haemorrhagic fever virus	Crimean-Congo haemorrhagic fever
Cryptosporidium spp.	Cryptosporidiosis
Eastern equine encephalitis virus	Eastern equine encephalitis
Ebola virus disease virus	Ebola virus disease
Echinococcus spp. (*E. granulosus*, *E. multilocularis*)	Echinococcosis (*E. granulosus, E. multilocularis*)
Erysipelothrix rhusiopathiae	Erysipelothricosis
Giardia spp.	Giardiasis
Burkholderia mallei	Glanders
Hantavirus	Hantavirus infection
Rickettsia helvetica	Helvetica spotted fever
Hendra virus	Hendra virus infection
Hepatitis E virus	Hepatitis E
Influenza A virus (Avian)	Influenza, avian
Influenza A virus (Swine)	Influenza, swine
Japanese encephalitis virus	Japanese encephalitis
Lassa virus	Lassa fever
Leishmania spp.	Leishmaniosis
Leptospira spp.	Leptospirosis
Borrelia burgdorferi	Lyme borreliosis
Lymphocytic choriomeningitis virus	Lymphocytic choriomeningitis
Marburg virus	Marburg virus disease
Rickettsia conorii	Mediterranean Spotted Fever
MERS-Coronavirus	MERS
Monkeypox virus	Monkeypox
Rickettsia typhi	Murine typhus
Nipah virus	Nipah virus infection
Omsk haemorrhagic fever virus	Omsk haemorragic fever
Yersinia pestis	Plague
Possawan virus	Possawan virus infection
Coxiella burnetii	Q-fever
Rabies virus	Rabies
Rift Valley fever virus	Rift Valley fever
SARS-Coronavirus type 1	SARS
Orientia tsutsugamush	Scrub typhus
Shuni virus	Shuni virus infection
Sindbis virus	Sindbis fever
St. Louis encephalitis virus	St. Louis encephalitis
Thogoto virus	Thogoto virus infection
Tick-borne encephalitis virus	Tick-borne encephalitis
Toxoplasma gondii	Toxoplasmosis

Francisella tularensis	Tularemia
Usutu virus	Usutu virus infection
Venezuelan equine encephalitis virus	Venezuelan equine encephalitis
Wesselsbron virus	Wesselsbron virus infection
West Nile virus	West Nile fever
Western equine encephalitis virus	Western equine encephalitis

Subsequently, we detail the list of pathogens and their main characteristics of relevance for the purposes of describing and mapping the official zoonosis surveillance frameworks in Europe in this report.

2.2. Results

2.2.1. General

The total number of SPs in 21 countries according to questionnaires is 360, distributed as indicated in Table 2 and Figure 1.

Table 2. The total number of SPs in 21 countries according to questionnaires (n=360).

Country	Number of SPs
Austria	16
Belgium	46
Cyprus	3
Czech Republic	1
Denmark	4
Estonia	13
Finland	8
France	3
Germany	31
Greece	5
Ireland	3
Italy	56
Latvia	26
Netherlands	75
Norway	3
Portugal	6
Slovak Republic	19
Slovenia	3
Spain	11
Sweden	27
Turkey	1
Total	360

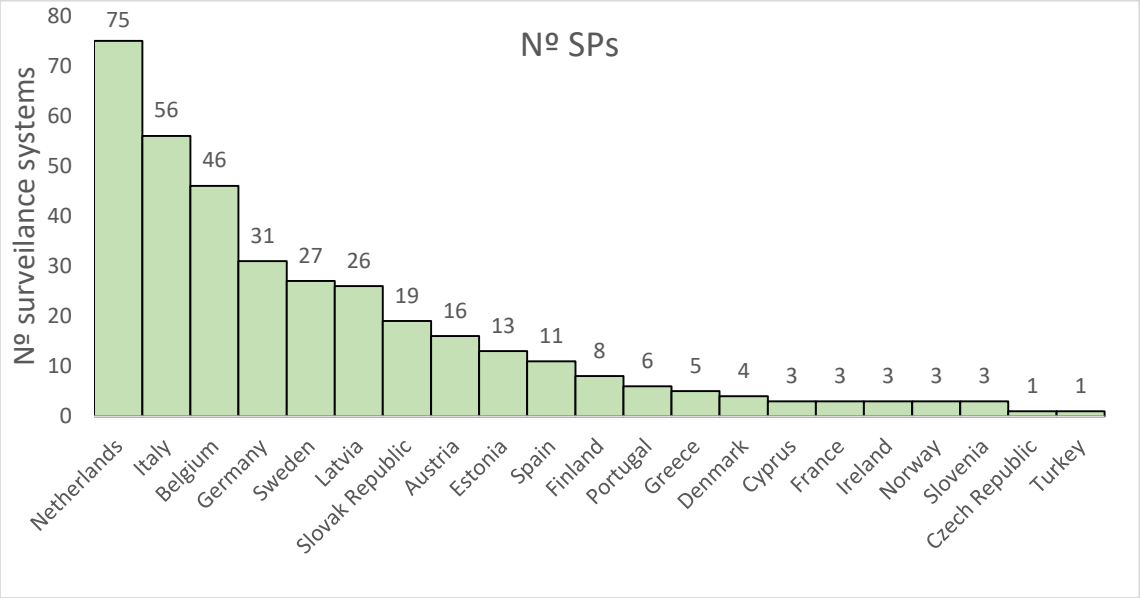


Figure 1. Number of SPs in 21 countries according to questionnaires (ranked).

Coordination is understood as different sectors participating in the organization and implementation of activities. Regardless of that, the sector/s in charge can be one or several. The analysis of the number of SPs by sector in charge (type of health organization in charge, Figure 2, i.e., the sector/s responsible of the SP) indicates that mostly either the Human sector or the Animal sector is in charge, each variant accounting for about one third of the total. These variants are followed by SPs where the Human and Animal sectors were in charge together of the coordination, without (n=51) or with the Environment sector (n=29). To a lesser extent, other combination of sectors or Environment authorities only (n=7) were in charge.

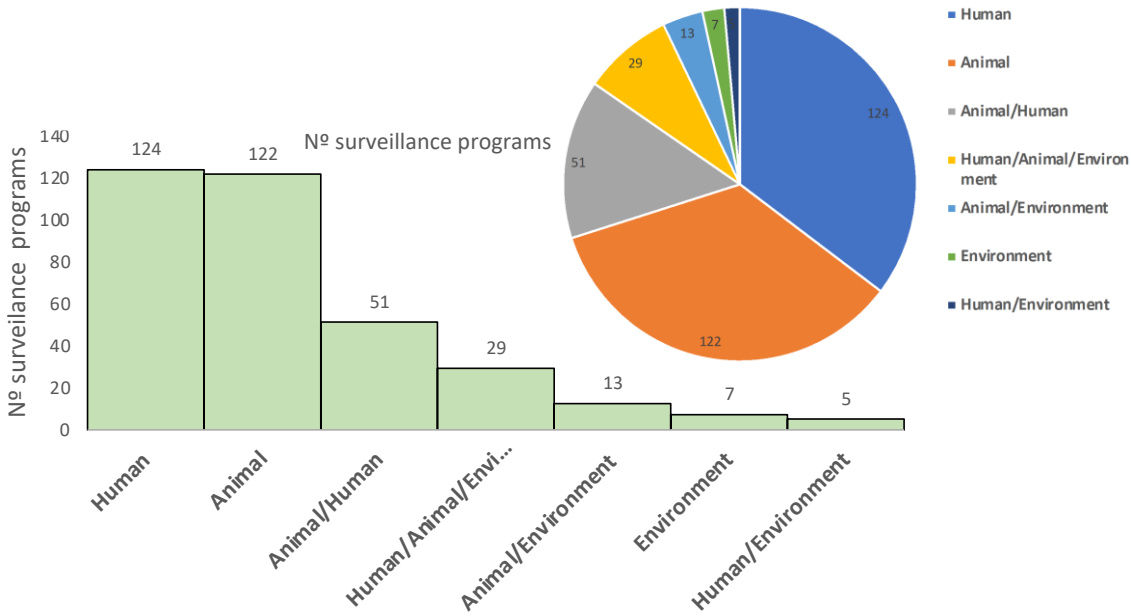


Figure 2. Number of SPs by sector (type of health organization/s in charge).

If we analyse the number of SPs as a function of the Country, there were marked differences in the relative contribution of the different sectors to coordination of the SP (Figure 3). This is illustrated in the next figure, where the total and relative frequency (n) of SPs is indicated by country and sector (the respective sectors involved, alone or in coordination with others). We note that no information from the human sector was received from Belgium (Flanders), and this general would not be explained by the result of whether the questionnaire reached the human sector.

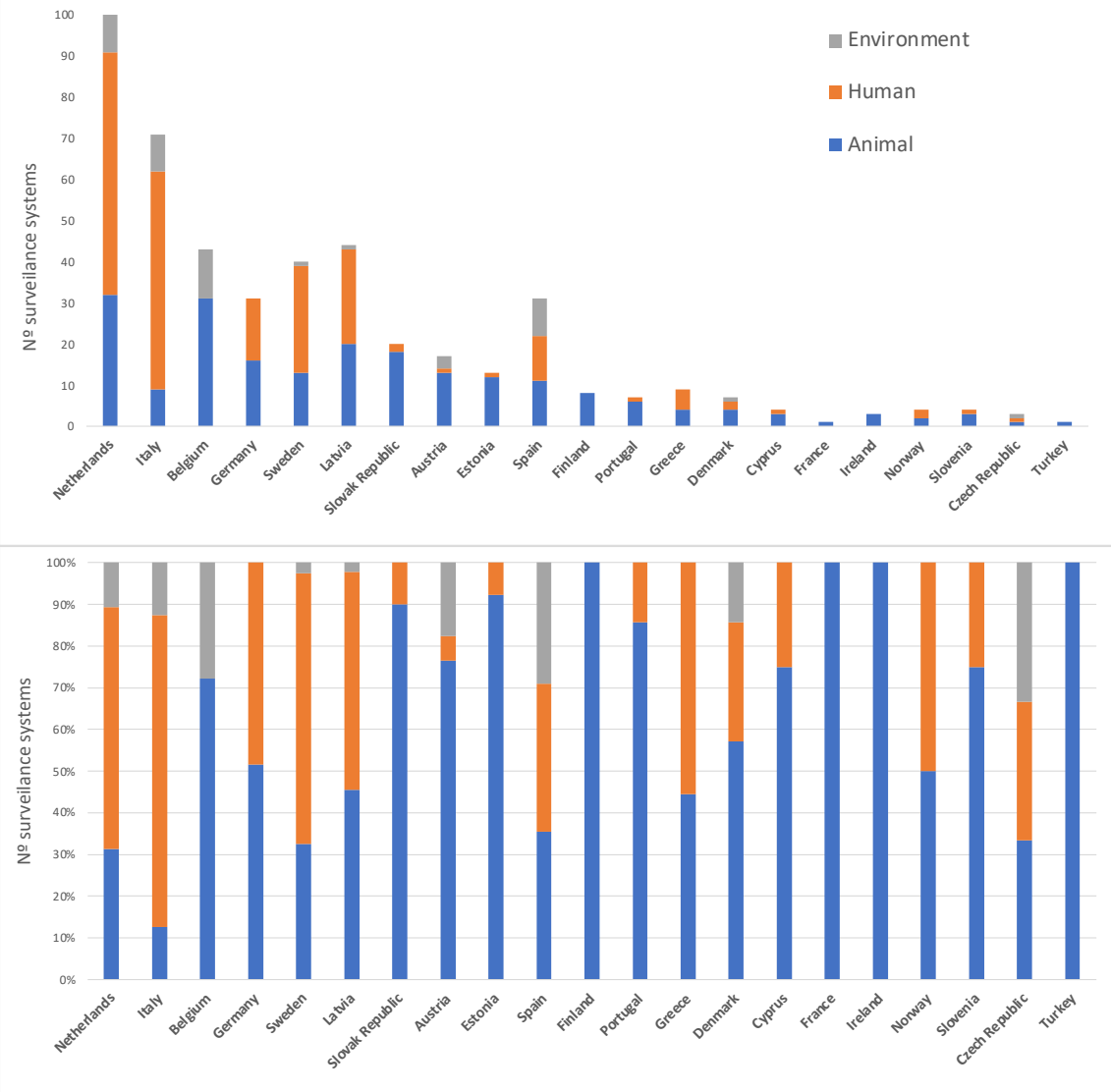


Figure 3. (a) Number of SPs by sector (type of health organization in charge) as a function of the Country (the frequency of SPs where the respective sectors in charge of coordination, alone or in coordination with others). (b) The same information is showed as relative contribution of different sectors within country.

As for the **origin of funding**, the proportion and number of SPs are summarized in Figure 4, being mainly national (82.5%).

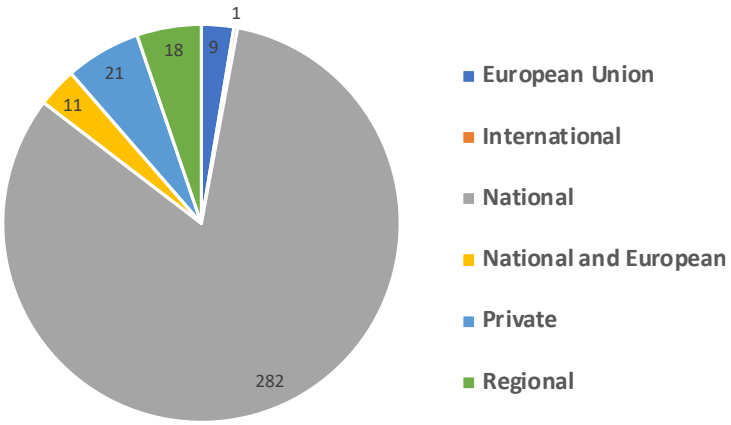


Figure 4. The origin of funding (the proportion and number) of SPs.

This information is shown also by country and sector in the Annex 2[3] (sheet "origin of funding")

2.2.2. Coordination of the surveillance programs (SPs)

The coordination of the SPs was done by one single Institution in 54.8% of the cases, while the remaining 45.2% was coordinated by at least two different institutions (Figure 5). There were marked differences among countries.

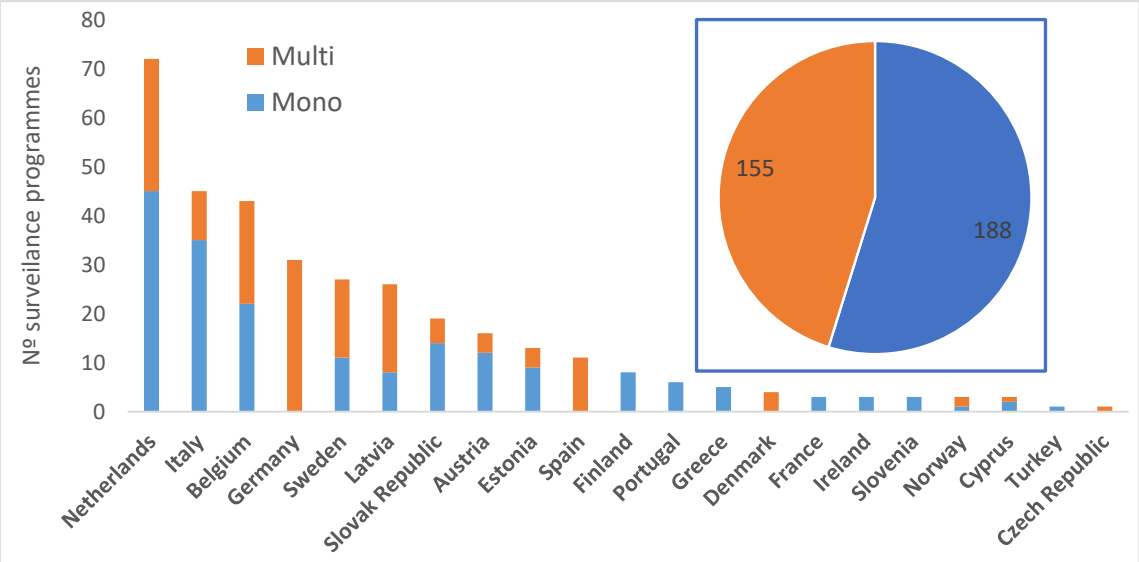


Figure 5. The sectoral graphs show the coordination of the SPs (by one single institution o "mono" and by multiple institutions or "multi") (relative frequency and number, n=360). This information is also shown by country.

[3] https://doi.org/10.5281/zenodo.7446484

2.2.3. Integration among health sectors (animal, human, environmental) within the SPs

The integration/collaboration during the different phases (from planning to dissemination) of SPs are increasingly indicated in the following graph. The alternatives were:

- Integration/collaboration during **planning** phase among Human Health, Animal Health, or Environmental Agencies
- Integration/collaboration during **sampling** phase among Human Health, Animal Health, or Environmental Agencies
- Integration/collaboration during **testing and analysis of data** among Human Health, Animal Health, or Environmental Agencies
- Integration during **dissemination** activities among Human Health, Animal Health, or Environmental Agencies

While the phase of sampling is the one with less integration among sectors (Figure 6, 18.9% of SPs), it increased for planning (24.2%) and analysis (lab and statistics, 29.4%). The highest collaboration occurred for dissemination of results (45%).

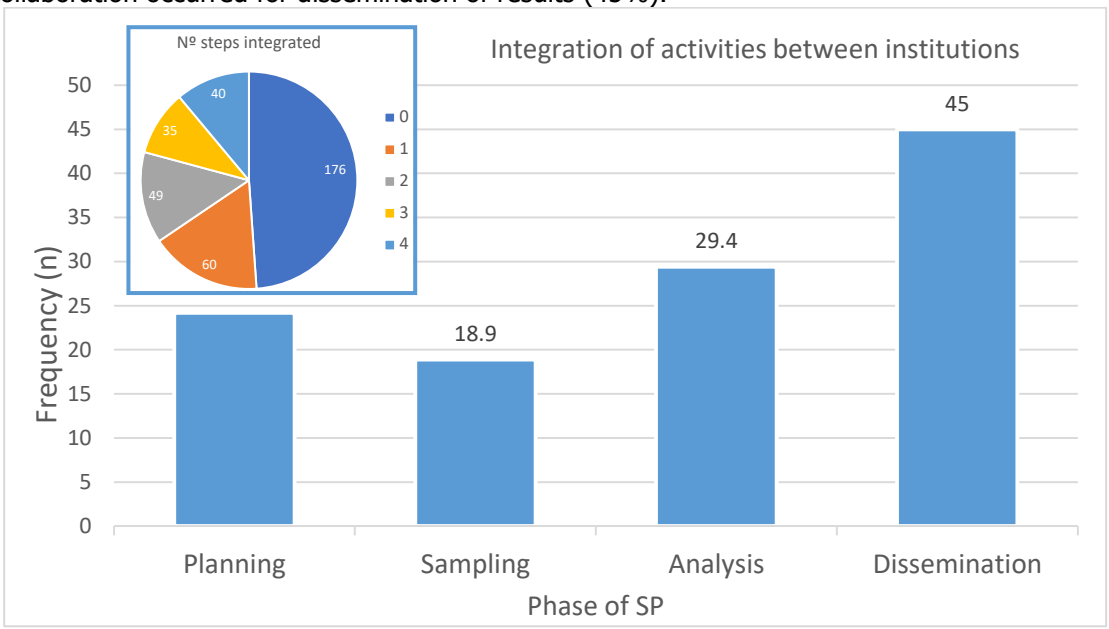


Figure 6. The integration/collaboration during the different phases (from planning to dissemination) of SPs by different sectors.

We analysed which health sectors tended to integrate more frequently with others. We show the relative contribution of different sectors to integration (considering only when some degree of integration occurred, at least in one step), in the Figure 7 for the different phases of surveillance. The charts indicate that integration is more frequent when multiple sectors oversee the coordination, and when Environment is involved. Therefore, having different sectors in charge of coordination is essential for SP integration over the different phases of surveillance, and integration may be more natural when the pathogen is vector-borne or involves another environmental phase.

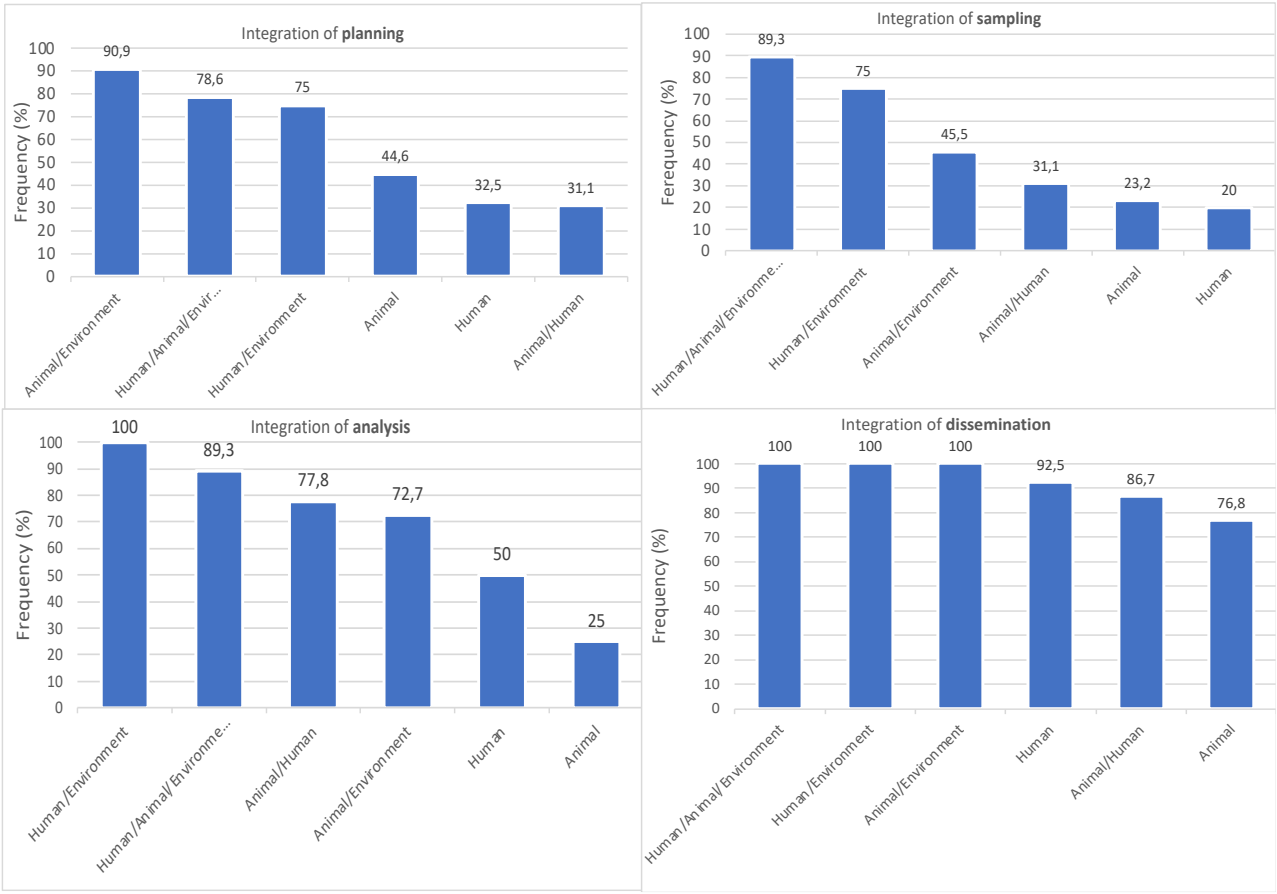


Figure 7. The relative contribution (frequency as %) of different sectors in charge of coordination to the different phases of implementation of SPs (planning, sampling, analysis, and dissemination) when some degree of integration occurred (at least in one step).

As for the **favouring factors for collaboration, the alternatives were:**

Economics	Presence/lack of funding for collaboration
Facilities	Presence/lack of tools (e.g., online platform, meetings, common database)
Interest	Collaboration is in favour / against the stakeholders' interests
Initiatives	Presence/lack of initiatives favouring collaboration (shared research projects)
Legislation	Presence/lack of rules in favour of collaboration
Personnel in charge	Presence/lack of personnel that organizes or manages collaboration

The Figure 8 indicates that "Interest" and "Legislation" were considered the most relevant (or most frequently answered by respondents). Looking in more detail (figures b and c), it was evident that "Interest" and "Legislation" were especially remarked as relevant by SPs (respondents) where the coordination is mixed between sectors.

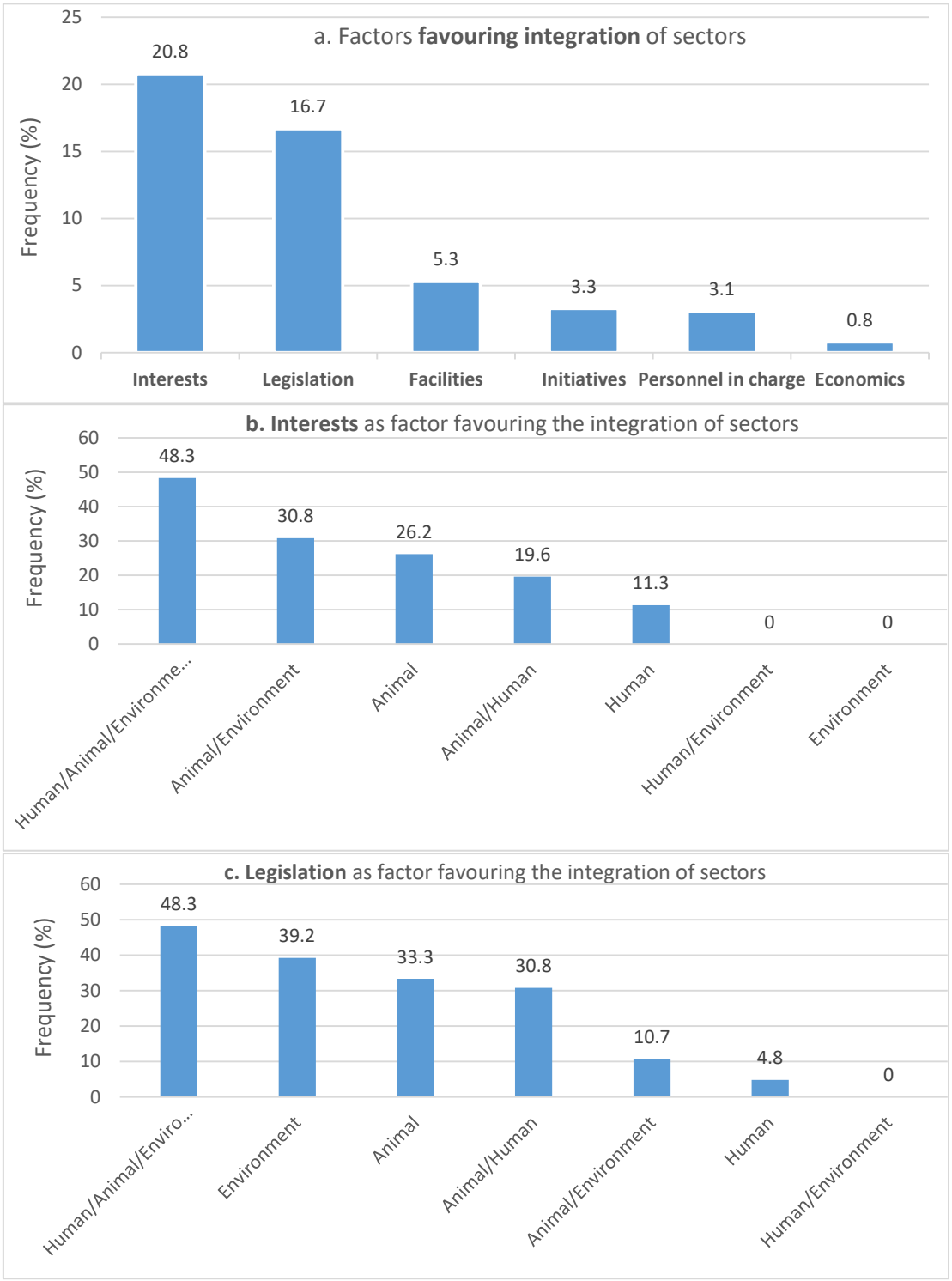


Figure 8. (a) Frequency (%) of factors identified as favouring the integration of sectors in SPs. (b) and (c) show in more details to "Interest" and "Legislation" according to the sectors in charge of the respective SPs. Note the differences in scales of Y-axes.

Other factors mentioned by respondents included the collaboration agreements with environmental protection agencies, and the presence of the human and environmental sectors in the same institution.

In relation to the identified barriers for collaboration (the potential answers where the same, Figure 9) the Economics barrier (a) was specially remarked, and this was more frequent for SPs integrating the animal and the environment sectors (b).

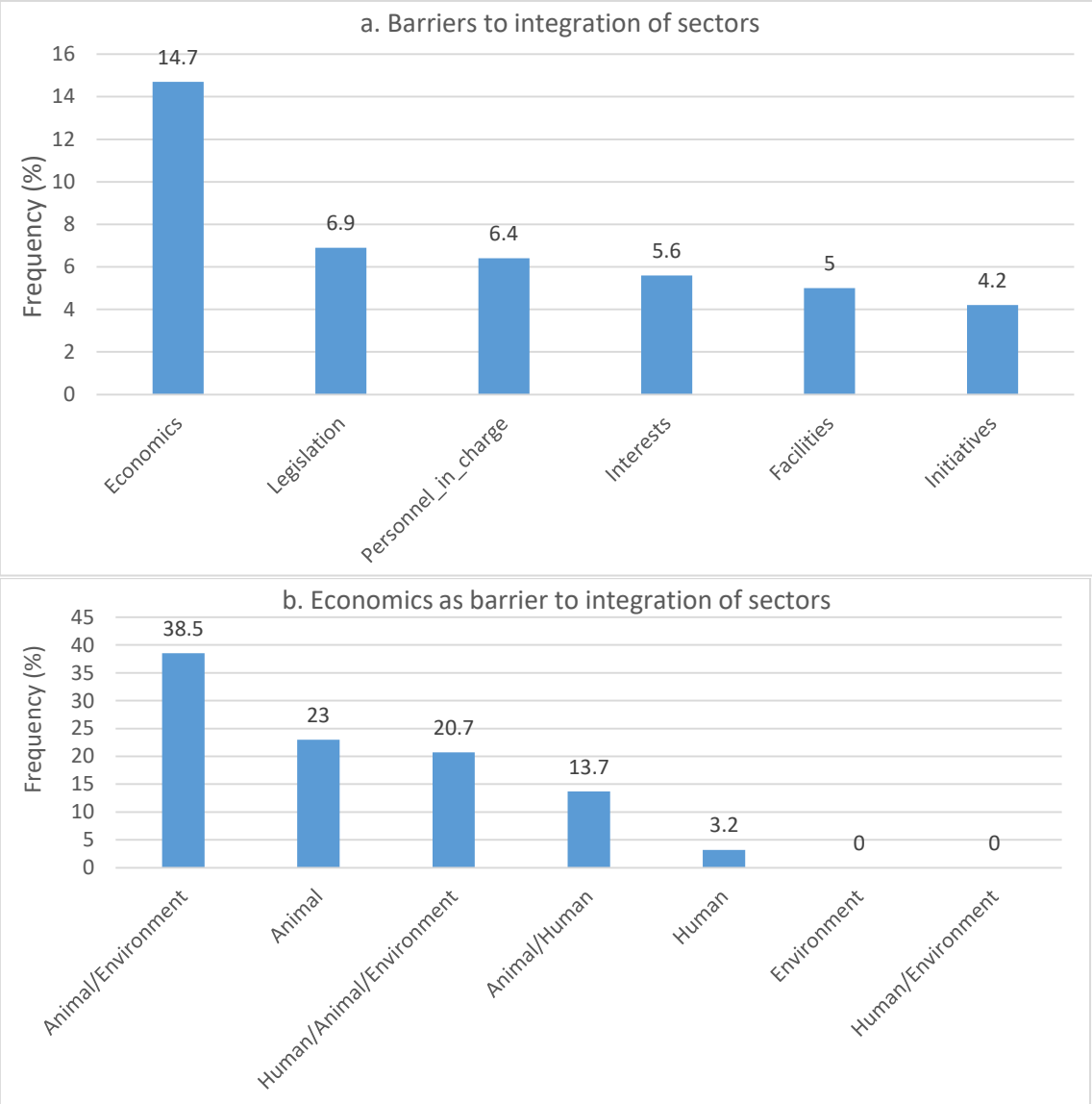


Figure 9. Frequency of identified barriers for collaboration (a). The bottom graph (b) refers frequencies of "Economics" barrier as a function of the sectors coordinating surveillance. Note the differences in scales of Y-axes.

2.2.4. Participating Institutions

The institutions participating in official surveillance according to this questionnaire are diverse and represent different sectors, as it is displayed in Figure 10.

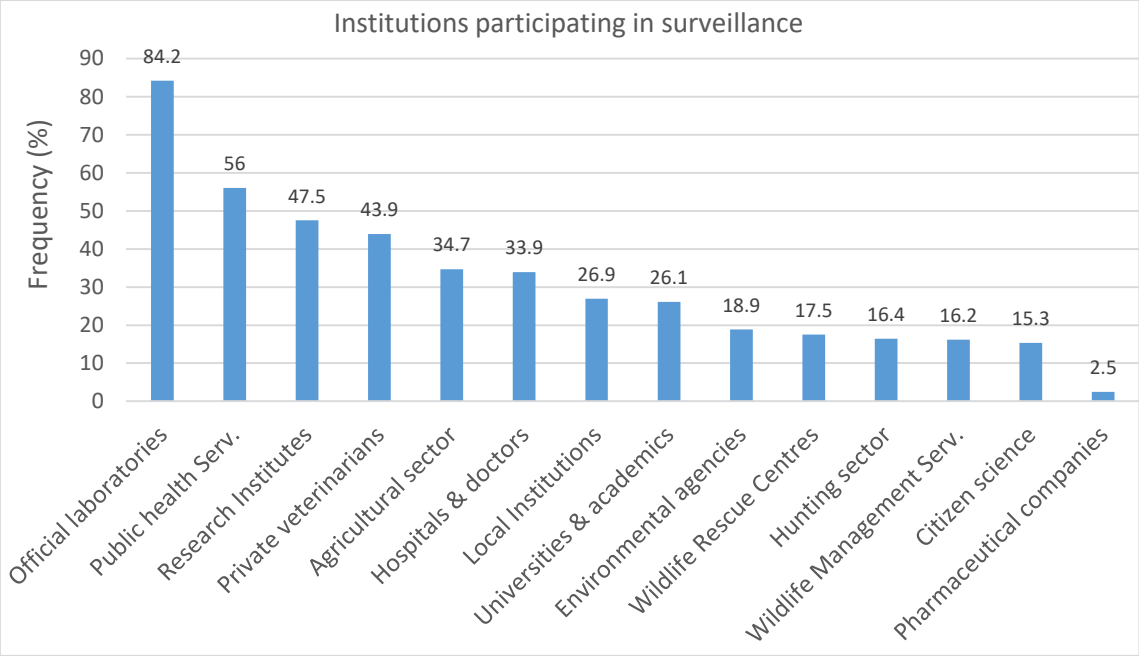


Figure 10. Contribution (frequency) to the SPs (n=360) of the different types of Institutions.

Official laboratories were the institutions most frequently involved in SPs. Public Health Services ranked the second, and Research Institutes third. Pharmaceutical companies ranked the lowest (involved in 2.5% of SPs). Citizen science initiatives, an increasingly applied approach to disease surveillance, still ranks low (15.3%) but compares with other Institutions/sectors, such as wildlife rescue centres or the hunting sector. Other institutions not detailed in Figure 10 but mentioned by respondents included: companies operating WWTPs (wastewater treatment plant) in individual districts, National Food Agencies, private laboratories, zoos, and environmental associations.

The average number of types of institutions participating in an SP was 4.4, but the number could reach up to 14 types (Figure 11a). There was a wide variation among countries (ranging from on average 1.5 to 12 types of institutions per SP). Usually, many different types of institutions were involved in SPs that included several sectors in charge and involved the animal sector (Figure 11b), while the diversity of institutions involved was least for SPs where the human sector was in charge alone (Figure 11c).

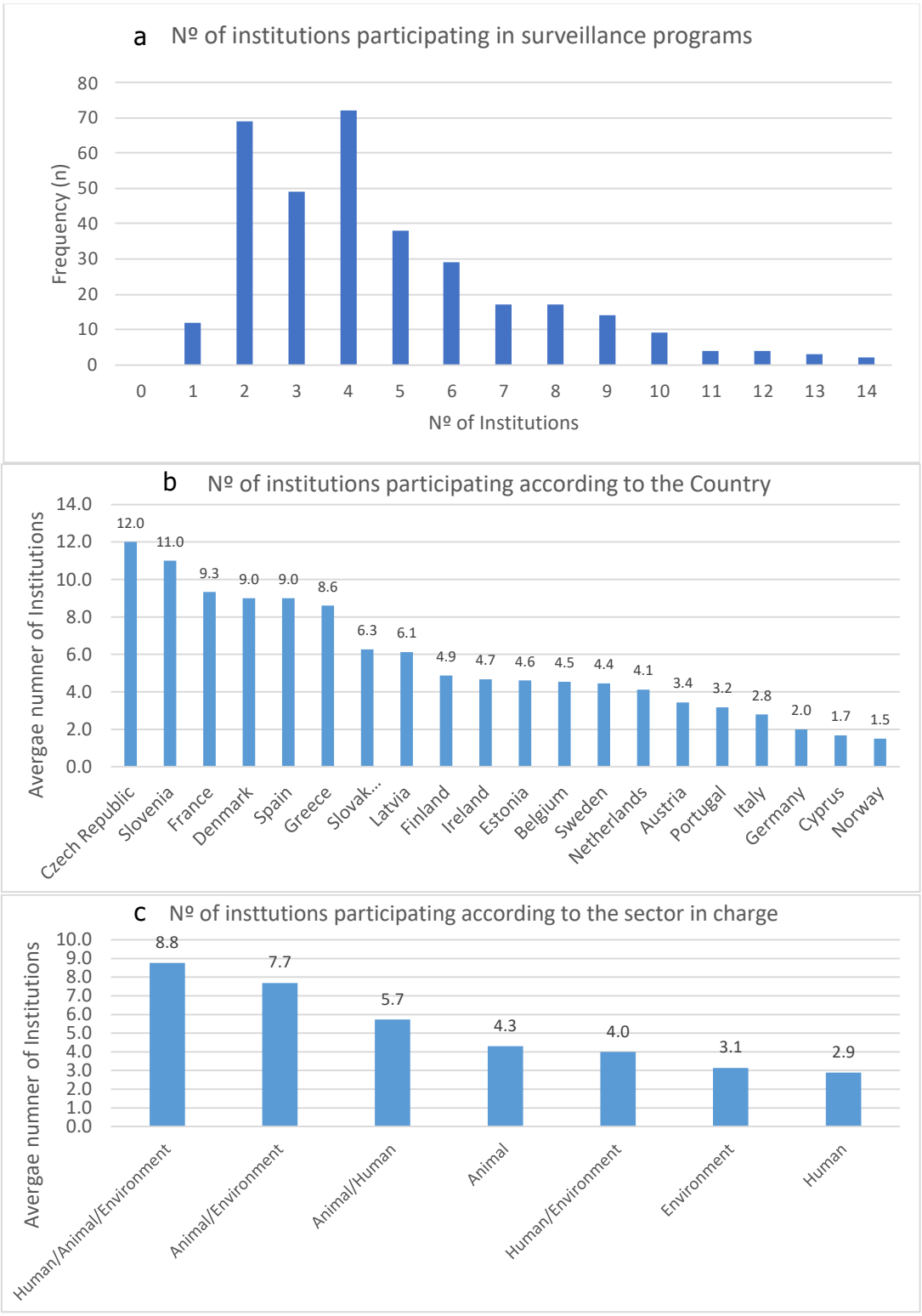


Figure 11. (a) The average number of types of institutions participating in an SP overall, and (b) per country and (c) per sectors in charge. Note the differences in scales of Y-axes.

2.2.5. Geographical and temporal coverage

The sectoral graph (Figure 12) indicates that most SPs operated at national level (87.9%), followed by subnational or regional programmes (9.3%). Only 2.8% operated at supranational level. Particularly supranational level programmes referred to: Covid-19 in Mustelidae, Brucellosis in ruminants and swine, surveillance of *Echinococcus* spp (human), Avian Influenza Surveillance (poultry and wild birds), Cryptosporidiosis (human), Giardiasis (humans), Toxoplasmosis (humans) and Hepatitis E (veterinary and human-animal interface).

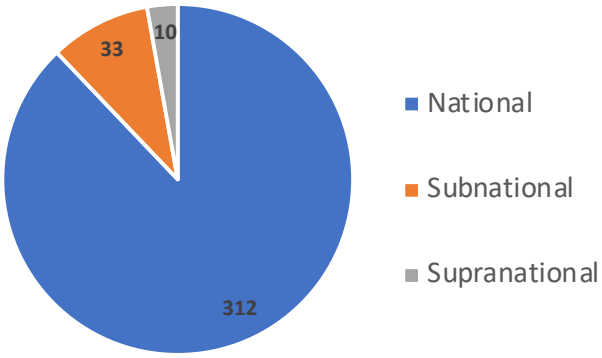
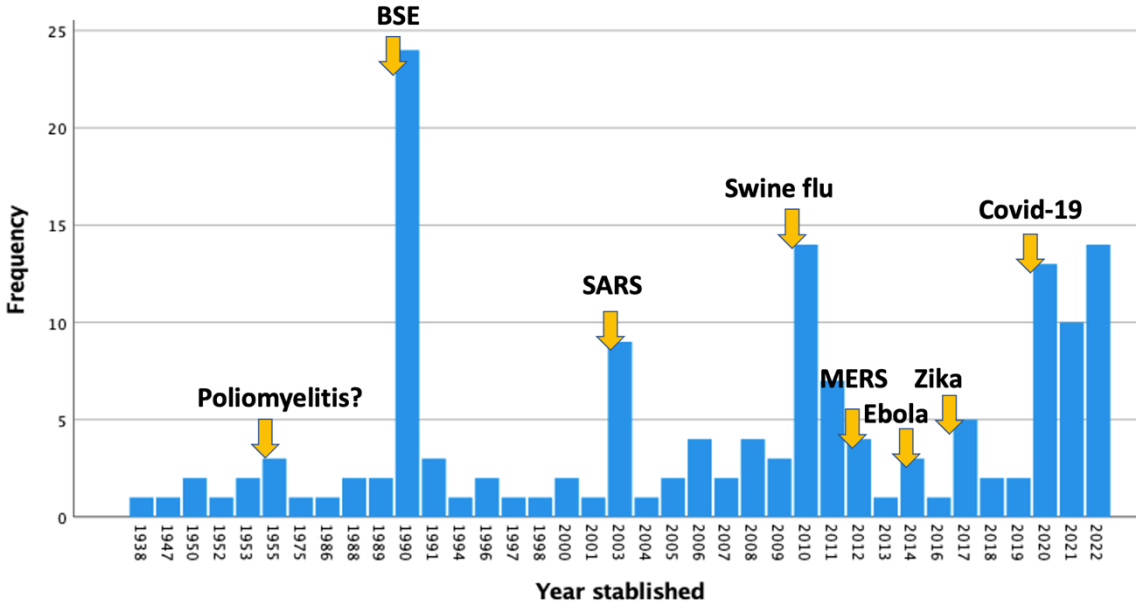


Figure 12. Sectoral graph indicating the spatial coverage of SPs.

The frequency of establishment of SPs (number by year) is represented in Figure 13 (top), together with relevant outbreaks. The creation of many SPs since 2020 is remarkable. In total, 79.10 % of the SP data are digitalized according to respondents (Figure 13 bottom).



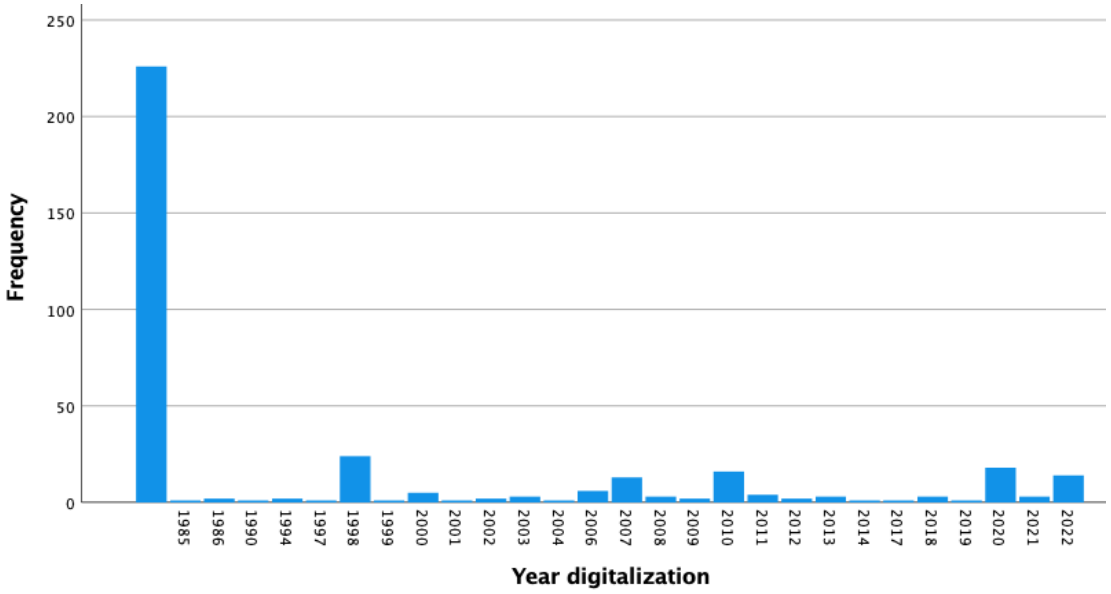


Figure 13. Top: Timeline indicating the frequency of establishment of SPs (number by year). Relevant outbreaks are indicated. Bottom: Timeline indicating the year of digitalization of the SP.

Respondents were asked to identify dishomogeneities occurring at temporal and spatial resolutions during SPs. Seven options were suggested (box):

Sampling effort	The number of samples differs from one territory to the other
Target species	Target species includes any group of the three domains (animal species, humans, environmental samples). The system addresses different species in different territories
Time	The system does not cover the same temporal interval in all territories
Pathogen	Although under the same system, not all pathogens are targeted in all territories
Sampling method	Different methods are applied for diagnosis, varying through territories
Spatial resolution	The system presents differences in data centralization among territories (e.g., municipality collected data vs province collected data)
Other (specify in Notes)	…

The answers to these options are summarized in Figure 14. In most cases, it was reported that the number of samples differed from one territory to the other (20.6%). To a less extent (<5%) other causes of homogeneities were reported. Apart from these, other causes that were mentioned by respondents included: national does not per se mean 100% coverage, certain areas are known to be free of a given pathogen and surveillance will only be performed whenever positive cases are detected, surveillance depends on awareness, dishomogeneity in data quality, territories may differ in sampling representativeness, regionalized health care system (e.g., Italy) and national surveillance activities are organized in a bottom up way with identification of cases by medical facilities to the local health units that report to regional authorities who in turn report cases, registration on voluntary bases in which physician from eligible centres enrol patients by informed consent, response differs per region/year.

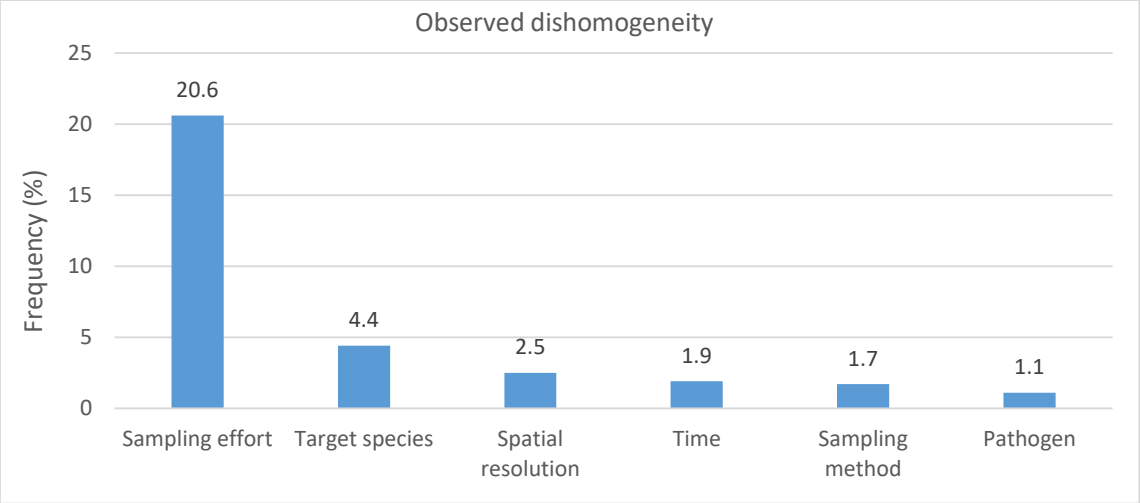


Figure 14. Frequency of dishomogeneities occurring at temporal and spatial resolutions during SPs (N=360).

2.2.6. Objectives of the SPs

The alternatives about the objectives of the monitoring programme given to respondents were:

- Estimate the magnitude of a health problem
- Trends monitoring to improve knowledge
- Detect new pathogen/diseases or unusual epidemiological events
- Document the distribution and spread of a health event
- Evaluate control or eradication strategies
- Demonstrate freedom from a particular pathogen/infection
- Trends monitoring to support intervention
- Others

The most frequently reported objective of the SPs was to detect new pathogen/diseases or unusual epidemiological events (in 38.6% of programmes, see Figure 15) followed by the demonstration of freedom from a particular pathogen/infection. This indicates that objectives to evaluate appearance and to confirm disappearance of pathogens predominate over SPs in our sample. The next four objectives were nearly equally distributed: "Document the distribution and spread of a health event", "Estimate the magnitude of a health problem", "Trends monitoring to improve knowledge" and Trends monitoring to support intervention (disease management)". Finally the least frequent (17.2%) was "To evaluate control or eradication strategies".

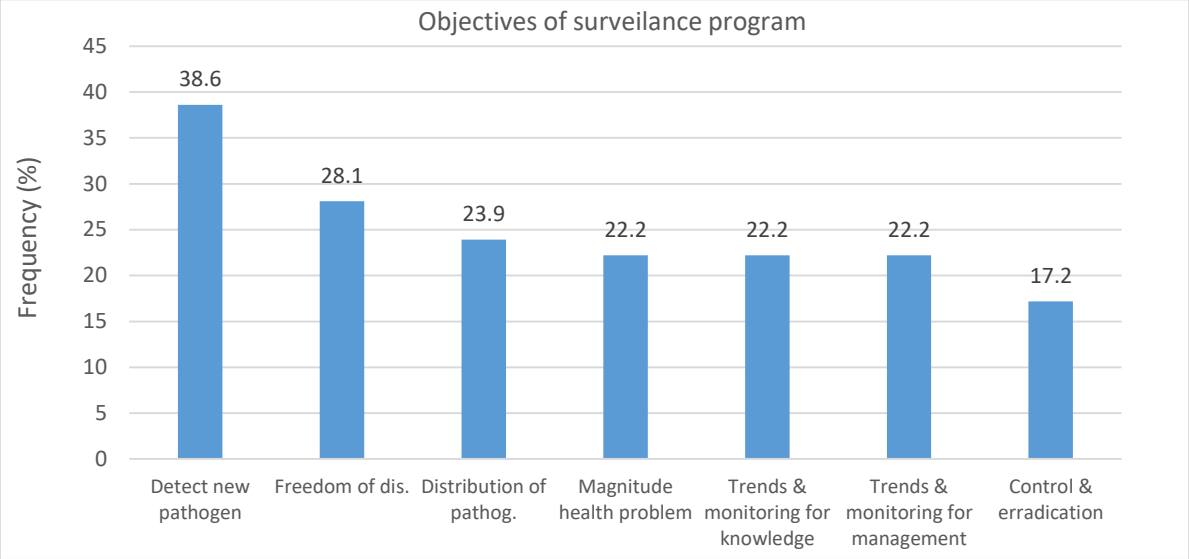


Figure 15. Frequency of different objectives (non-mutually exclusive) of the SPs (N=360).

When focusing on the most reported objective ("Detect new pathogen/diseases or unusual epidemiological event") relative to sectors in charge of coordination of SPs (Figure 16), interestingly, it was shown that it was highly prevalent in SPs coordinated by multiple sectors. This implies that a multisector coordinated approach is often taken for detecting new pathogens or emerging diseases and unusual epidemiological events. Similar results were observed for the objective "Demonstrate freedom from a particular pathogen/infection".

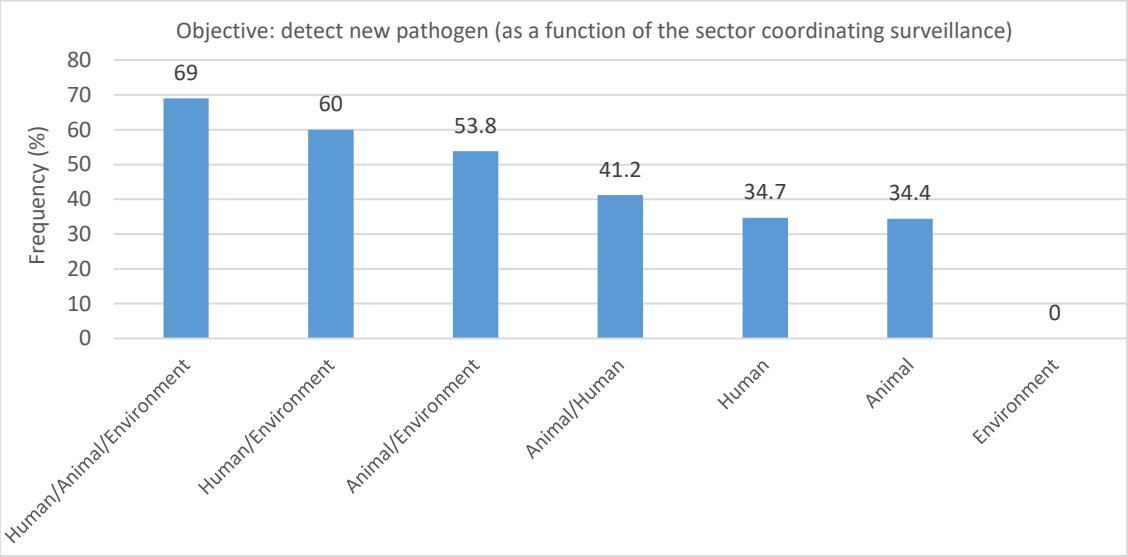


Figure 16. Frequency of reporting of the objective "Detect new pathogen/diseases or unusual epidemiological event" according to sectors in charge of coordination of SPs.

It is also worth mentioning that the objective "Evaluate control or eradication strategies" was more prevalent in SPs co-coordinated by Environment and other sectors (see Figure 17). Possibly this is related to the upcoming of eDNA detection techniques in surveillance.

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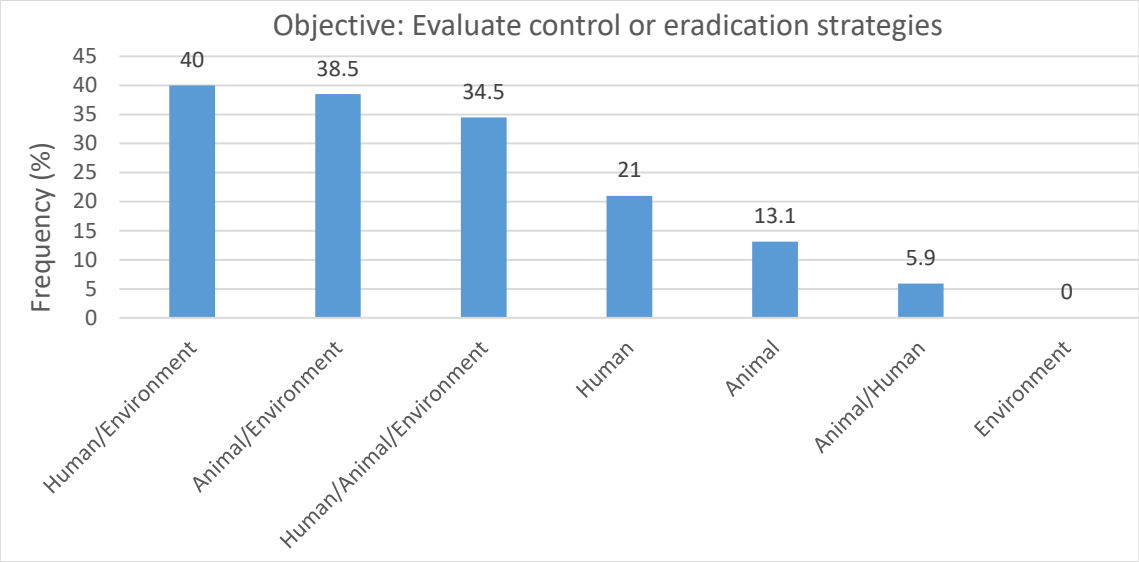


Figure 17. Frequency of reporting of the objective "Evaluate control or eradication strategies" according to sectors in charge of coordination of SPs.

2.2.7. Evaluation of the SPs

It is relevant to know if the implemented SPs are evaluated once implemented. The possible answers were:

Internal or External evaluation	
Internal evaluation	Evaluation carried out within the Coordinating Institution
External evaluation	Evaluation carried out outside of the Coordinating Institution
No evaluation	

Approximately 50% of the SPs presented an evaluation process (see Figure 18 left). The external evaluation was only performed in 11 % of SPs, and less than 1% presented both (internal and external). When evaluated, the frequency is normally annual (Figure 18 right).

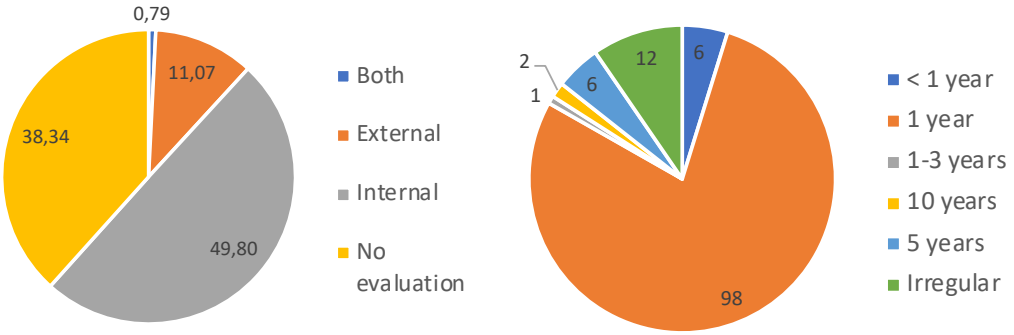


Figure 18. Existence (left) and frequency (right, n is indicated) of an evaluation process for the SP.

The respondents were asked whether the aspects evaluated included (Figure 19):

- The results of evaluation are used to update/improve the system itself

- International standards for sampling and analysis are applied
- Data sharing among institutions is present and clearly organized
- Report to stakeholders is present

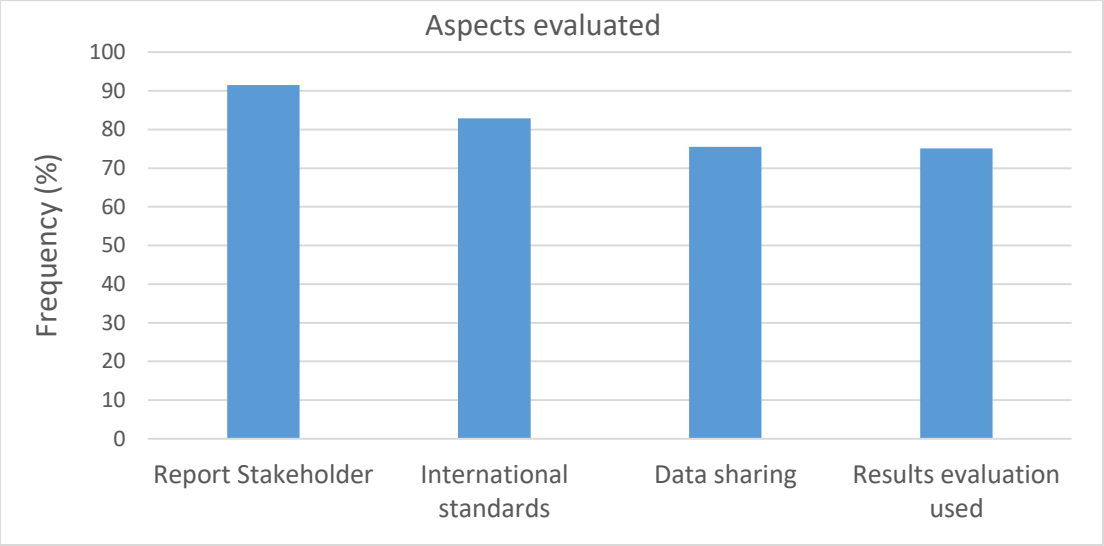


Figure 19. Aspects evaluated in SPs.

The results showed that the above-mentioned aspects were included in 70% to 90% of the SP evaluations (Figure 19). Several respondents indicated (as notes) that their programmes only would be evaluated in case of pathogen detection. When asking if results of evaluation are used (according to sector in charge), the sector where animal health participated presented the higher rates (Figure 20), except for the Animal/human sector. Human sector-only coordinated programmes presented the lowest rate of evaluation.

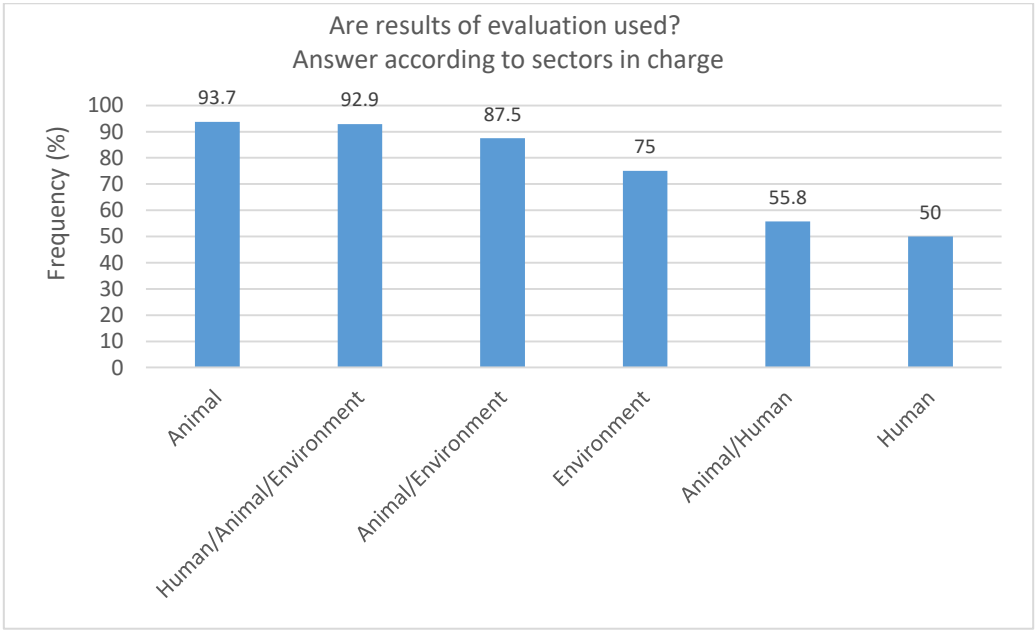


Figure 20. Proportion of SPs evaluated according to sector in charge (human/environment not presented since n=1).

2.2.8. Characteristics of surveillance

2.2.8.1. Active *vs* passive surveillance

Figure 21 displays the frequency of passive and active surveillance (or combined) applied by SPs. Active surveillance means investigator-initiated provision of health-related data, while passive surveillance refers to observer-initiated provision of health-related data.

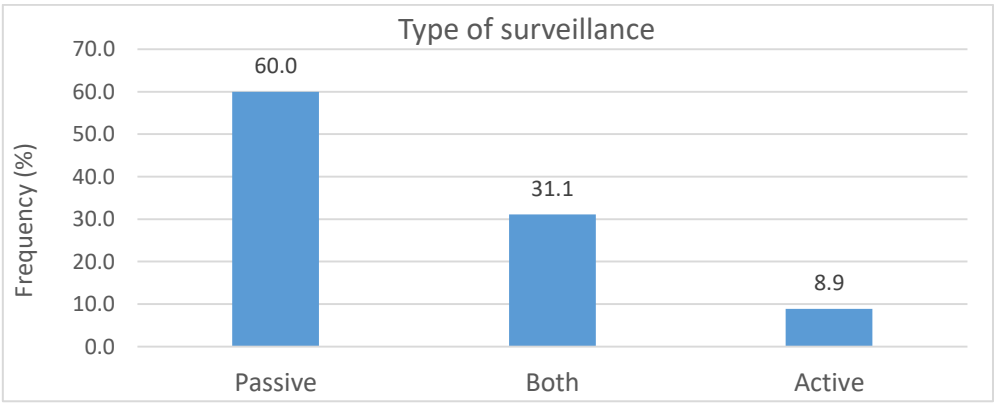


Figure 21. Frequency of passive and active surveillance (or combined) applied by SPs

Characteristics of surveillance: Most SPs applied only passive surveillance (60%) or in combination with active surveillance (31.1%), i.e., 91% applied passive surveillance (alone or combined with active). Only 8.9% of the SPs were exclusively based on active surveillance. Regarding surveillance typology as a function of the sectors in charge of SPs (Figure 22), it is evident that active surveillance predominates in environment-coordinated programmes (74%), whereas passive surveillance is more relatively frequent for animal (53%) and only-human (74%) sectors. It is also noteworthy that combined human-animal-environmental programmes used combined surveillance (passive and active) in a large proportion (76%). The distribution of active and passive SPs according to countries is presented in the Annex 3[4] and in the maps of the Figure 23.

[4] https://doi.org/10.5281/zenodo.7446484

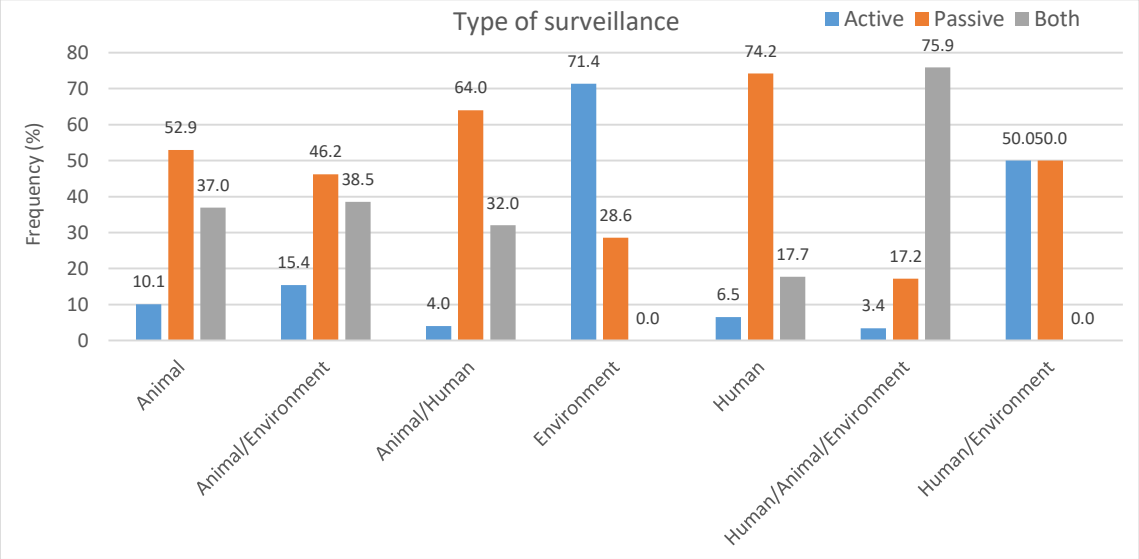


Figure 22. Frequency of surveillance typology (passive, active surveillance, or combined) as a function of the sectors in charge of SPs.

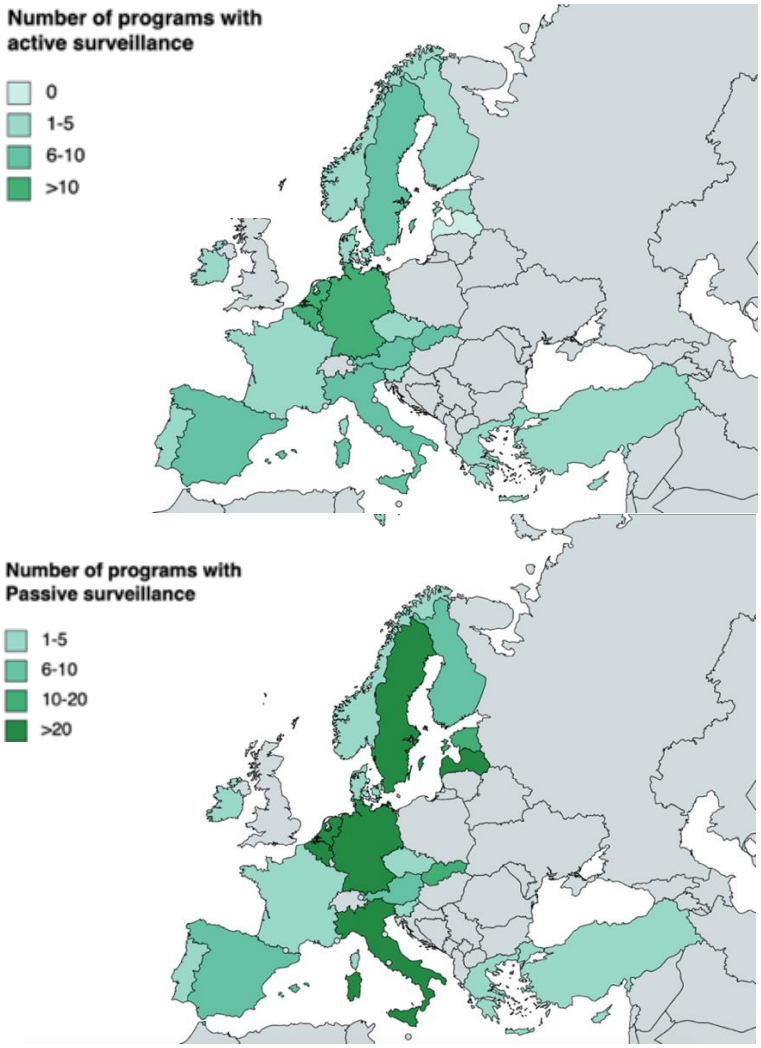


Figure 23. Distribution of active (alone or combined, top) and passive (alone or combined, bottom) SPs (N=169 active, 385 passive SPs) according to countries.

As for active surveillance, in absolute terms, the countries where a higher number of SP incorporating this approach are Germany, the Netherlands, and Belgium while for passive surveillance Northern Europe (Sweden, Latvia) and Italy also did.

The Table 3 indicates the presence of (only) active, (only) passive or both surveillance approaches per pathogen and country. Whereas in some countries one type of surveillance predominated for most pathogens (e.g., passive in Estonia or Greece, also see Figure 23), other presented a diversified patten, the type of surveillance depending on the pathogen. The following maps (Figure 24) indicates the presence of (only) active, (only) passive or both surveillance approaches per pathogen and country.

Table 3. Presence of (only) active, (only) passive or both surveillance approaches per pathogen country (presented as a combination of 0-1 values active/passive/both. Shuni virus, Thogoto virus and Wesselsbron virus were not reported as surveyed by any SP in any country.

Pathogen	Austria	Belgium	Cyprus	Czech Republic	Denmark	Estonia	Finland	France	Germany	Greece	Ireland
Bacillus anthracis		0/1/0			0/1/0	0/1/0			0/1/0	0/1/0	
Borrelia burgdorferi	1/0/0	1/0/0			0/1/0	0/1/0				0/1/0	
Brucella spp.		0/0/1	0/0/1	1/0/0	0/1/0	0/0/1	0/0/1	0/0/1	0/0/1	0/1/0	0/0/1
Burkholderia mallei		0/1/0			0/1/0	0/0/1				0/1/0	
Chikungunya virus		0/1/0				0/1/0				0/1/0	
Coxiella burnetii	0/0/1	0/0/1			0/1/0	0/1/0		0/0/1	0/1/0	0/1/0	
Crimean-Congo haemor. fever		0/1/0				0/1/0				0/1/0	
Cryptosporidium spp.		0/1/0				0/1/0		0/1/0			
Eastern equine encep. virus		0/1/0			0/1/0	0/1/0				0/1/0	
Ebola virus disease virus		0/1/0			0/1/0	0/1/0			0/1/0	0/1/0	
Echinococcus spp.		0/0/1		0/0/1		0/1/0	0/0/1	0/1/0	0/1/0	0/1/0	1/0/0
Erysipelothrix rhusiopathiae								0/1/0			
Francisella tularensis	1/0/0	0/1/0		0/1/0	0/1/0	0/1/0	0/1/0		0/0/1	0/1/0	
Giardia spp.						0/1/0		0/1/0	0/1/0		
Hantavirus						0/1/0			0/1/0	0/1/0	
Hendra virus						0/1/0					
Hepatitis E virus	0/1/0								0/1/0		
Influenza A virus (Avian)	0/0/1	0/0/1	0/0/1	1/0/0	0/0/1	0/0/1	0/1/0	0/1/0	0/0/1	0/1/0	0/0/1
Influenza A virus (Swine)		0/1/0			0/1/0	0/1/0		0/1/0		0/1/0	
Japanese encephalitis virus		0/1/0			0/1/0	0/1/0				0/1/0	
Lassa virus		0/1/0				0/1/0			0/1/0		
Leishmania spp.								0/1/0		0/1/0	
Leptospira spp.	0/0/1	0/1/0			0/1/0	0/1/0		0/1/0	0/1/0	0/1/0	
Lymphocytic choriom. virus											
Marburg virus						0/1/0			0/1/0	0/1/0	
MERS-Coronavirus						0/1/0				0/1/0	
Monkeypox virus	0/1/0	0/1/0			0/1/0	0/1/0				0/1/0	

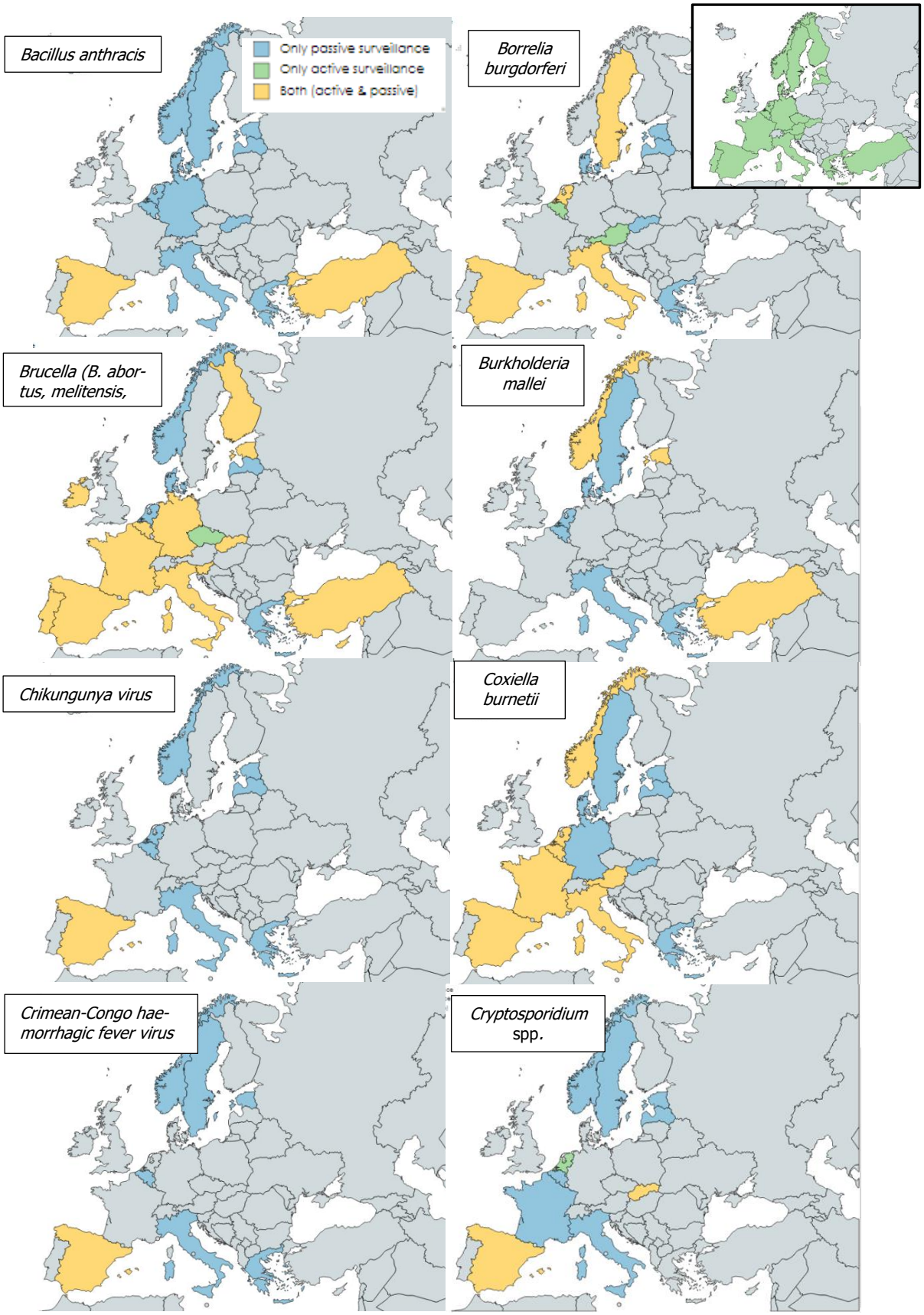
Pathogen	Austria	Belgium	Cyprus	Czech Republic	Denmark	Estonia	Finland	France	Germany	Greece	Ireland
Nipah virus					0/1/0	0/1/0				0/1/0	
Omsk haemorrhagic fever virus						0/1/0				0/1/0	
Orientia tsutsugamushi											
Possawan virus infection											
Rabies virus	0/1/0	0/1/0	1/0/0	0/0/1	0/1/0	0/0/1	0/0/1	0/1/0	0/1/0	0/0/1	
Rickettsia conorii	1/0/0									0/1/0	
Rickettsia helvetica						0/1/0		0/1/0			
Rickettsia typhi	1/0/0									0/1/0	
Rift Valley fever virus		0/1/0			0/1/0	0/1/0				0/1/0	
SARS											
SARS-Coronavirus type 1						0/1/0			0/1/0	0/1/0	
SARS-Coronavirus type 2	0/1/0	0/0/1			0/0/1	0/0/1	0/0/1	0/1/0		0/1/0	
Sindbis virus						0/1/0				0/1/0	
St. Louis encephalitis virus											
Tick-borne encephalitis virus		0/0/1				0/1/0				0/1/0	
Toxoplasma gondii		0/1/0				0/1/0		0/0/1		0/1/0	
Usutu virus		0/0/1			0/1/0			0/1/0		0/1/0	
Venezuelan equine encep. virus		0/1/0			0/1/0	0/1/0					
West Nile virus	0/0/1	0/1/0		1/0/0	0/1/0	0/1/0		0/1/0		0/0/1	
Western equine encep. virus					0/1/0	0/1/0					
Yersinia pestis		0/1/0				0/1/0		0/1/0	0/1/0	0/1/0	

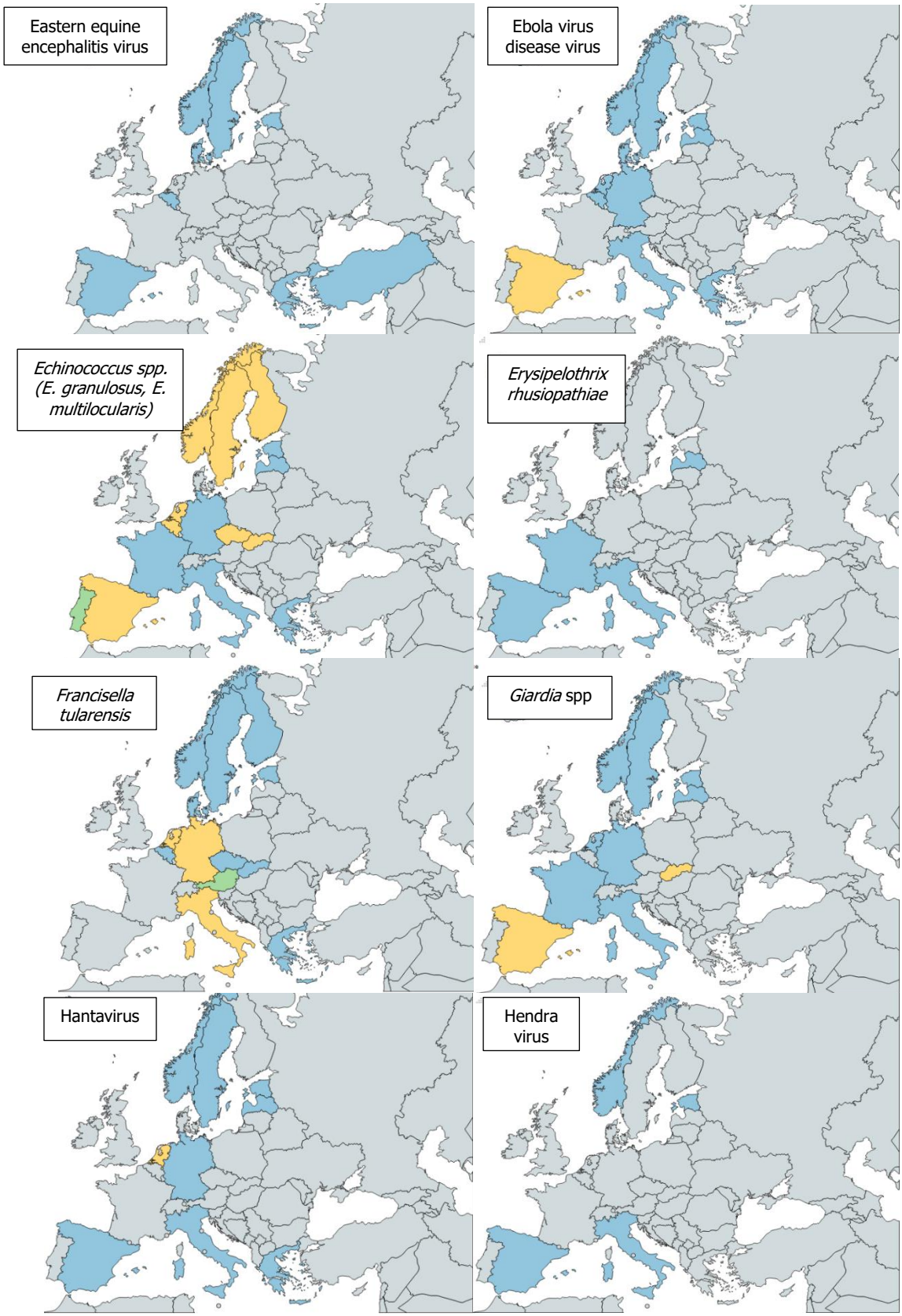
Table 3 (cont.).

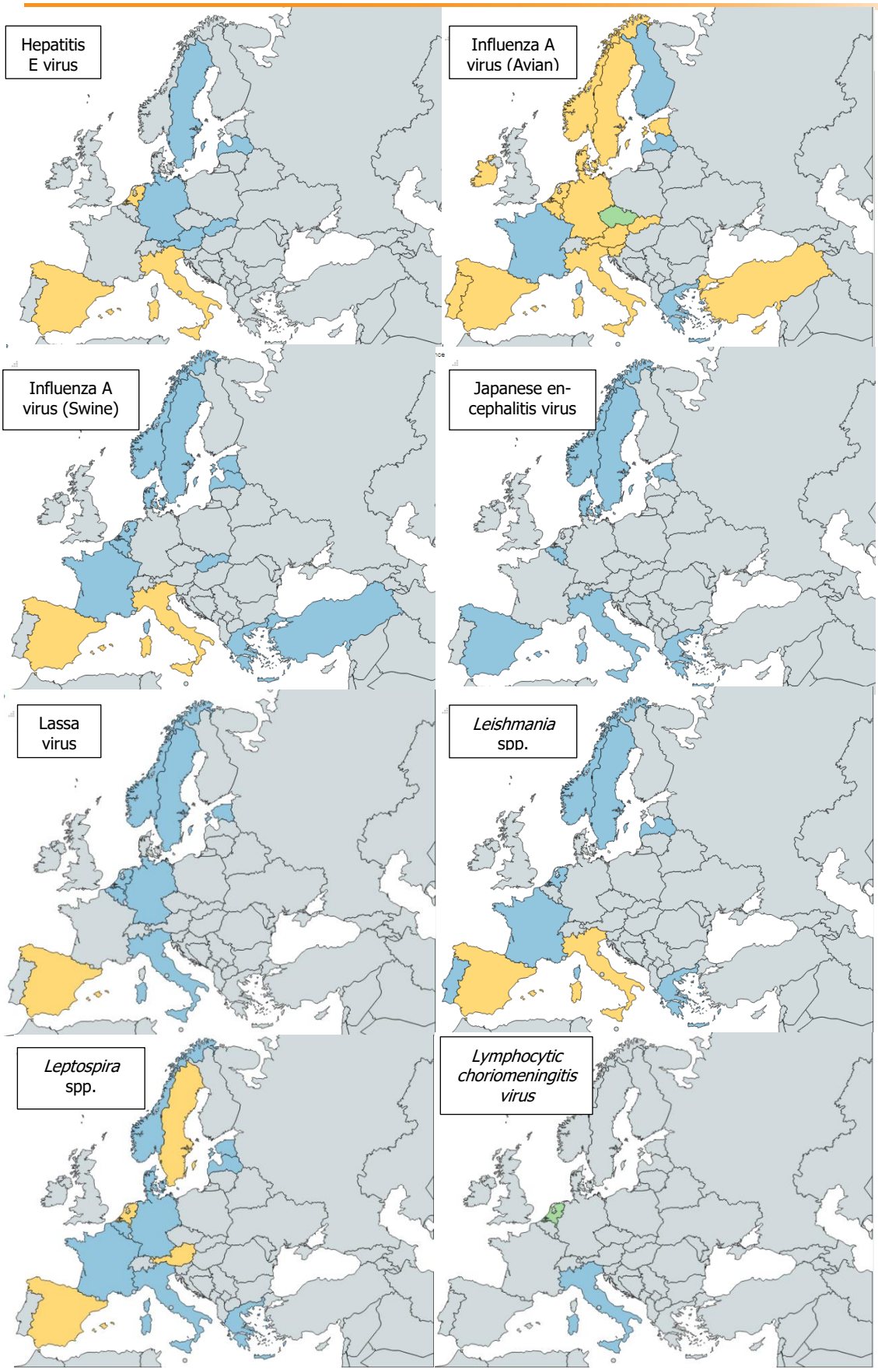
Pathogen	Italy	Latvia	Netherlands	Norway	Portugal	Slovak Republic	Slovenia	Spain	Sweden	Turkey
Bacillus anthracis	0/1/0	0/1/0	0/1/0	0/1/0		0/1/0		0/0/1	0/1/0	0/0/1
Borrelia burgdorferi	0/0/1	0/1/0	0/0/1			0/1/0		0/0/1	0/0/1	

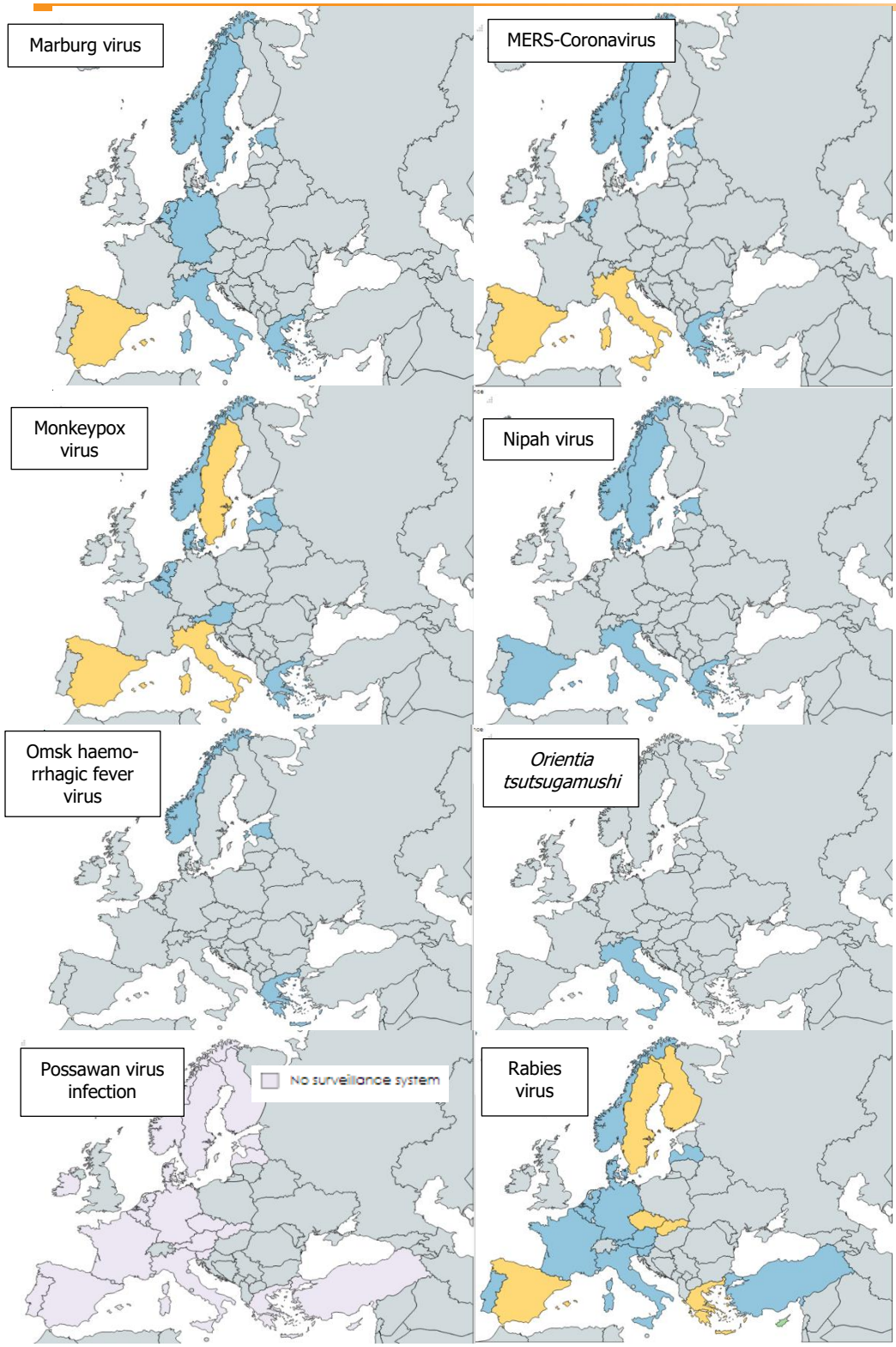
Brucella spp.	0/0/1	0/1/0	0/1/0	0/1/0	0/0/1	0/0/1	0/0/1	0/0/1		0/0/1
Burkholderia mallei	0/1/0		0/1/0	0/0/1					0/1/0	0/0/1
Chikungunya virus	0/1/0	0/1/0	0/1/0	0/1/0				0/0/1		
Coxiella burnetii	0/0/1	0/1/0	0/0/1	0/0/1		0/1/0		0/0/1	0/1/0	
Crimean-Congo haemorrhagic fever	0/1/0		0/1/0	0/1/0				0/0/1	0/1/0	
Cryptosporidium spp.	0/1/0	0/1/0	1/0/0	0/1/0		0/0/1		0/0/1	0/1/0	
Eastern equine encephalitis virus				0/1/0				0/1/0	0/1/0	0/1/0
Ebola virus disease virus	0/1/0	0/1/0	0/1/0	0/1/0				0/0/1	0/1/0	
Echinococcus spp.	0/1/0	0/1/0	0/0/1	0/0/1	1/0/0	0/0/1		0/0/1	0/0/1	
Erysipelothrix rhusiopathiae	0/1/0	0/1/0						0/1/0		
Francisella tularensis	0/0/1		0/0/1	0/1/0		0/1/0			0/1/0	
Giardia spp.	0/1/0	0/1/0	0/1/0	0/1/0		0/0/1		0/0/1	0/1/0	
Hantavirus	0/1/0	0/1/0	0/0/1	0/1/0				0/1/0	0/1/0	
Hendra virus	0/1/0			0/1/0				0/1/0		
Hepatitis E virus	0/0/1	0/1/0	0/0/1			0/1/0		0/0/1	0/1/0	
Influenza A virus (Avian)	0/0/1	0/1/0	0/0/1	0/0/1	0/0/1	0/0/1	0/0/1	0/0/1	0/0/1	0/0/1
Influenza A virus (Swine)	0/0/1	0/1/0	0/1/0	0/1/0		0/1/0		0/0/1	0/1/0	0/1/0
Japanese encephalitis virus	0/1/0			0/1/0				0/1/0	0/1/0	
Lassa virus	0/1/0		0/1/0	0/1/0				0/0/1	0/1/0	
Leishmania spp.	0/0/1	0/1/0	0/1/0	0/1/0	0/1/0			0/0/1	0/1/0	
Leptospira spp.	0/1/0	0/1/0	0/0/1	0/1/0				0/0/1	0/0/1	
Lymphocytic choriom. virus	0/1/0		1/0/0							
Marburg virus	0/1/0		0/1/0	0/1/0				0/0/1	0/1/0	
MERS-Coronavirus	0/0/1		0/1/0	0/1/0				0/0/1	0/1/0	
Monkeypox virus	0/0/1	0/1/0	0/1/0	0/1/0				0/0/1	0/0/1	
Nipah virus	0/1/0			0/1/0				0/1/0	0/1/0	
Omsk haemorrhagic fever virus				0/1/0						
Orientia tsutsugamushi	0/1/0									

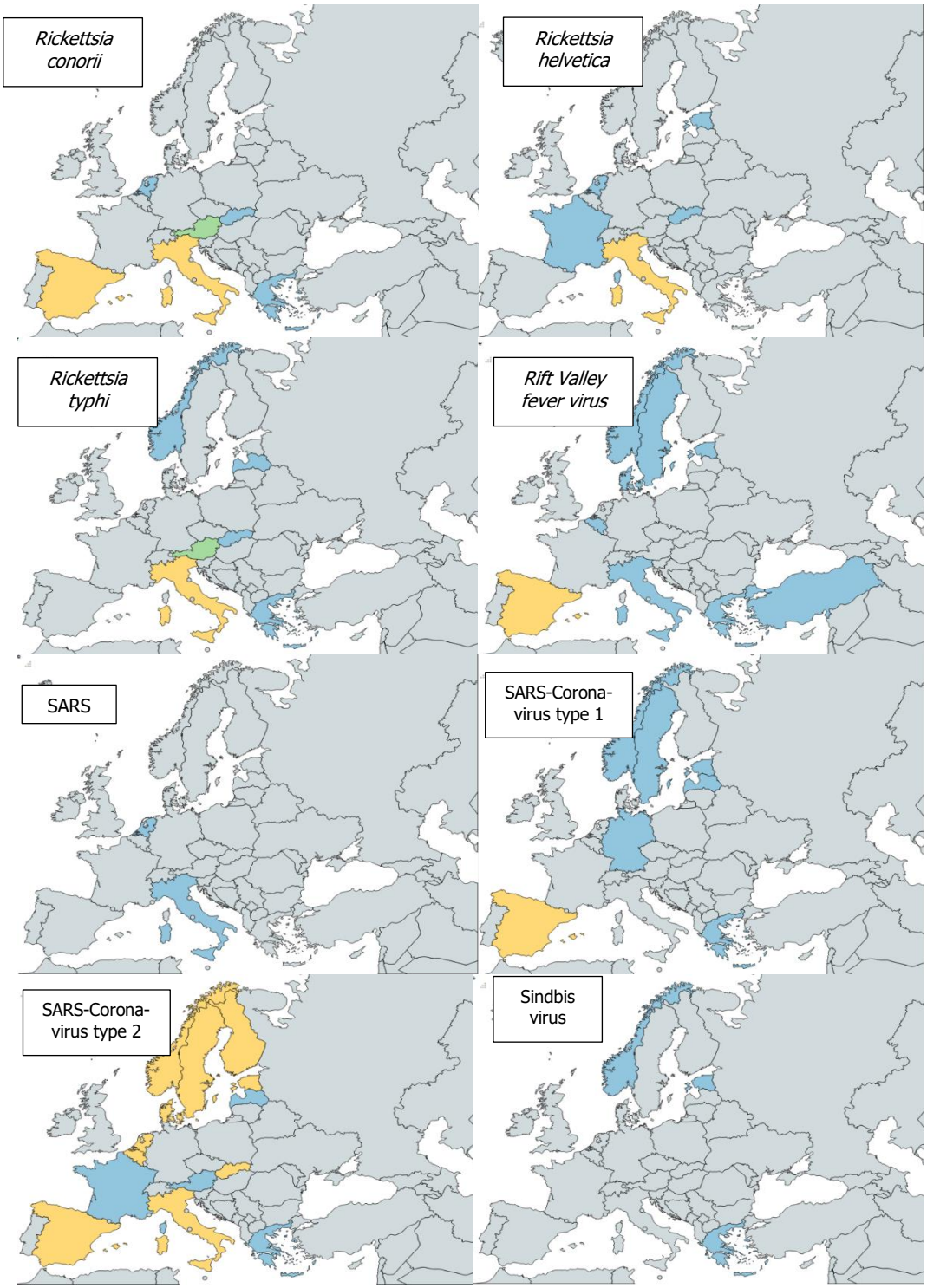
Pathogen	Italy	Latvia	Netherlands	Norway	Portugal	Slovak Republic	Slovenia	Spain	Sweden	Turkey
Possawan virus infection										
Rabies virus	0/1/0	0/1/0	0/1/0	0/1/0	0/1/0	0/0/1	0/1/0	0/0/1	0/0/1	0/1/0
Rickettsia conorii	0/0/1		0/1/0			0/1/0		0/0/1		
Rickettsia helvetica	0/0/1		0/1/0			0/1/0				
Rickettsia typhi	0/0/1	0/1/0		0/1/0		0/1/0				
Rift Valley fever virus	0/1/0			0/1/0				0/0/1	0/1/0	0/1/0
SARS	0/1/0		0/1/0							
SARS-Coronavirus type 1		0/1/0		0/1/0				0/0/1	0/1/0	
SARS-Coronavirus type 2	0/0/1	0/1/0	0/0/1	0/0/1		0/0/1		0/0/1	0/0/1	
Sindbis virus				0/1/0						
St. Louis encephalitis virus								0/1/0		
Tick-borne encephalitis virus	0/0/1	0/1/0	0/0/1	0/1/0		0/1/0		0/1/0	0/1/0	
Toxoplasma gondii	0/0/1	0/1/0	0/0/1			0/0/1		0/0/1		
Usutu virus	0/0/1		0/0/1	0/1/0		0/1/0		0/1/0	0/1/0	
Venezuelan equine encep. virus				0/1/0				0/1/0	0/1/0	0/1/0
West Nile virus	0/0/1	0/1/0	0/0/1	0/1/0		0/1/0		0/0/1	0/1/0	
Western equine encep- virus				0/1/0				0/1/0	0/1/0	0/1/0
Yersinia pestis	0/1/0	0/1/0	1/0/0	0/1/0				0/0/1	0/1/0	











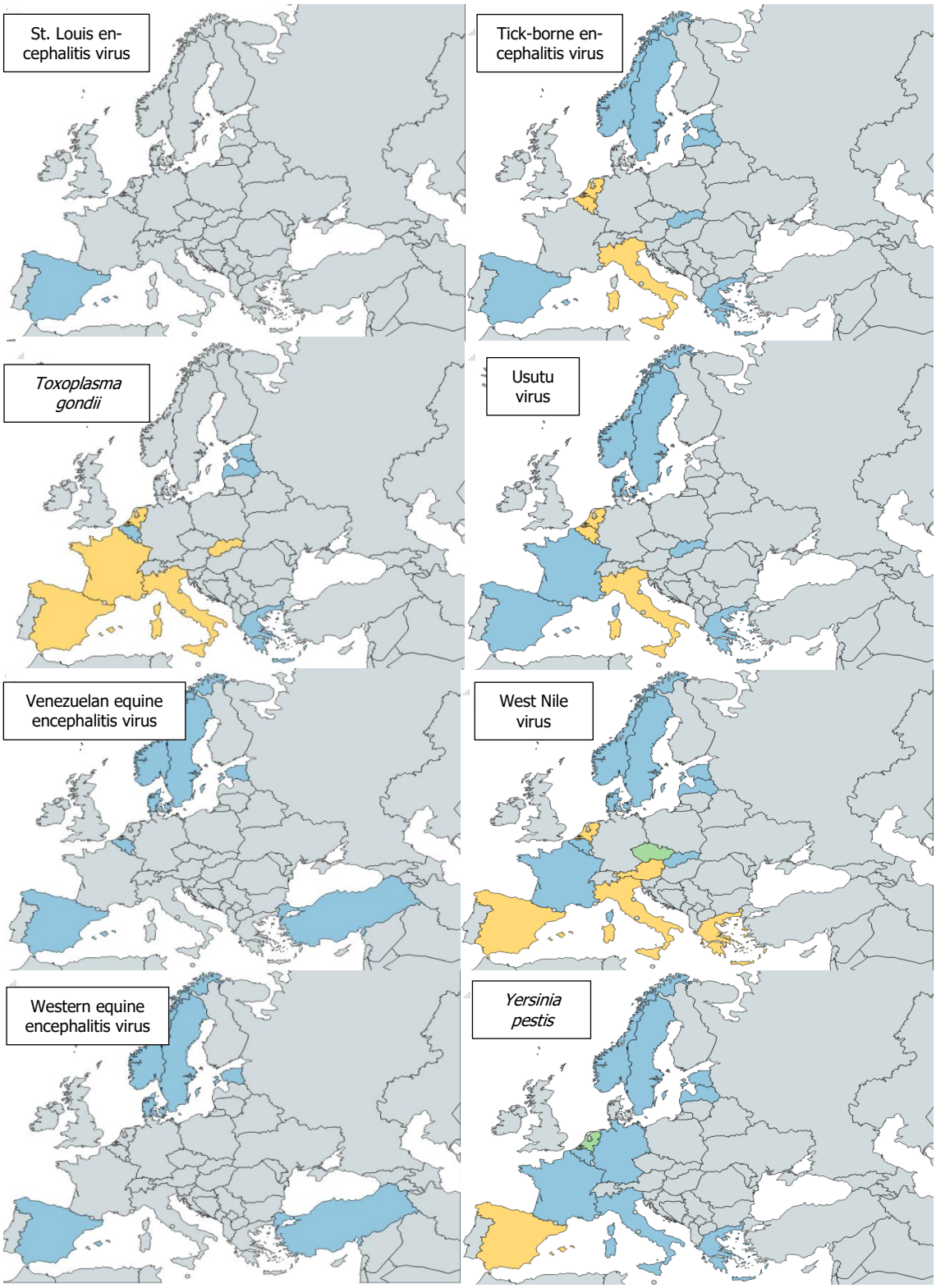


Figure 24. Presence of (only) active, (only) passive or both surveillance approaches per pathogen in European countries. Shuni virus, Thogoto virus and Wesselsbron virus were not reported as surveyed by any SP in any country.

2.2.8.2. Sampling design

The sampling design (Figure 25) predominantly includes risk based (72.6% of SPs), followed by random (45.8%) and stratified (random) sampling (29%).

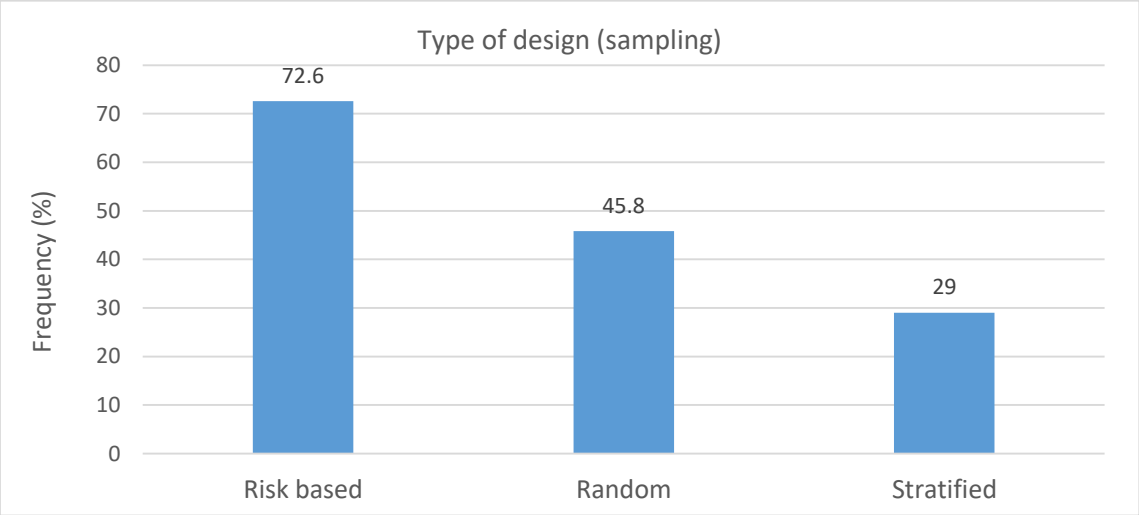


Figure 25. Frequency (%) of sampling design (non-mutually exclusive) of SPs.

Random and risk-based sampling predominated in programmes where multiple sectors (human, animal, and environment) were in charge together (Figure 26a,b), whereas stratified sampling (c) was most frequently reported in SPs jointly coordinated by human and animal health sectors.

Figure 27 shows the proportion (%) of SPs per country applying random sampling and risk-based sampling grouped in categories, showing that no clear spatial patterns are present.

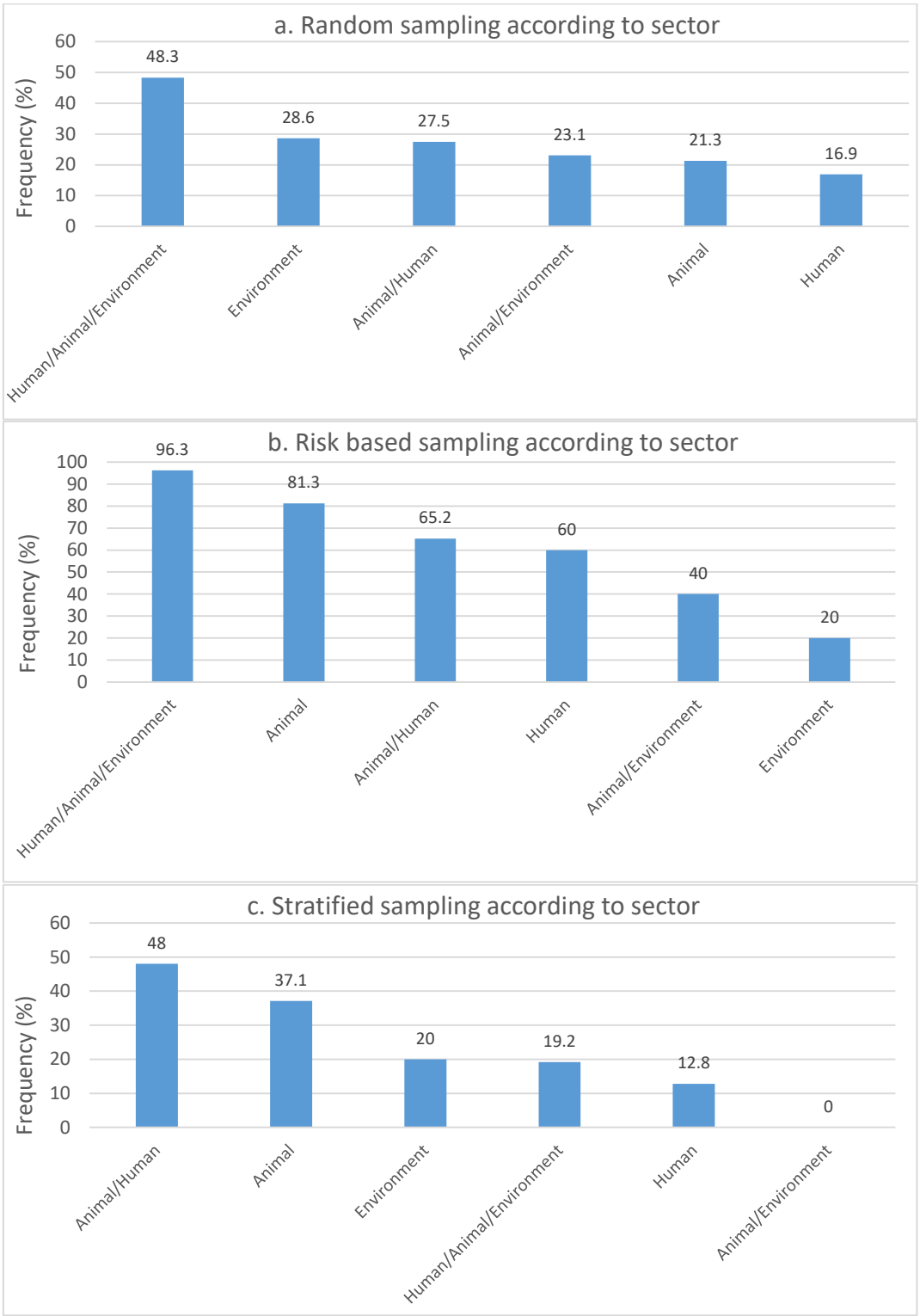


Figure 26. Proportion of sampling design (non-mutually exclusive) of SPs according to sectors in charge. Note different scales in Y-axes.

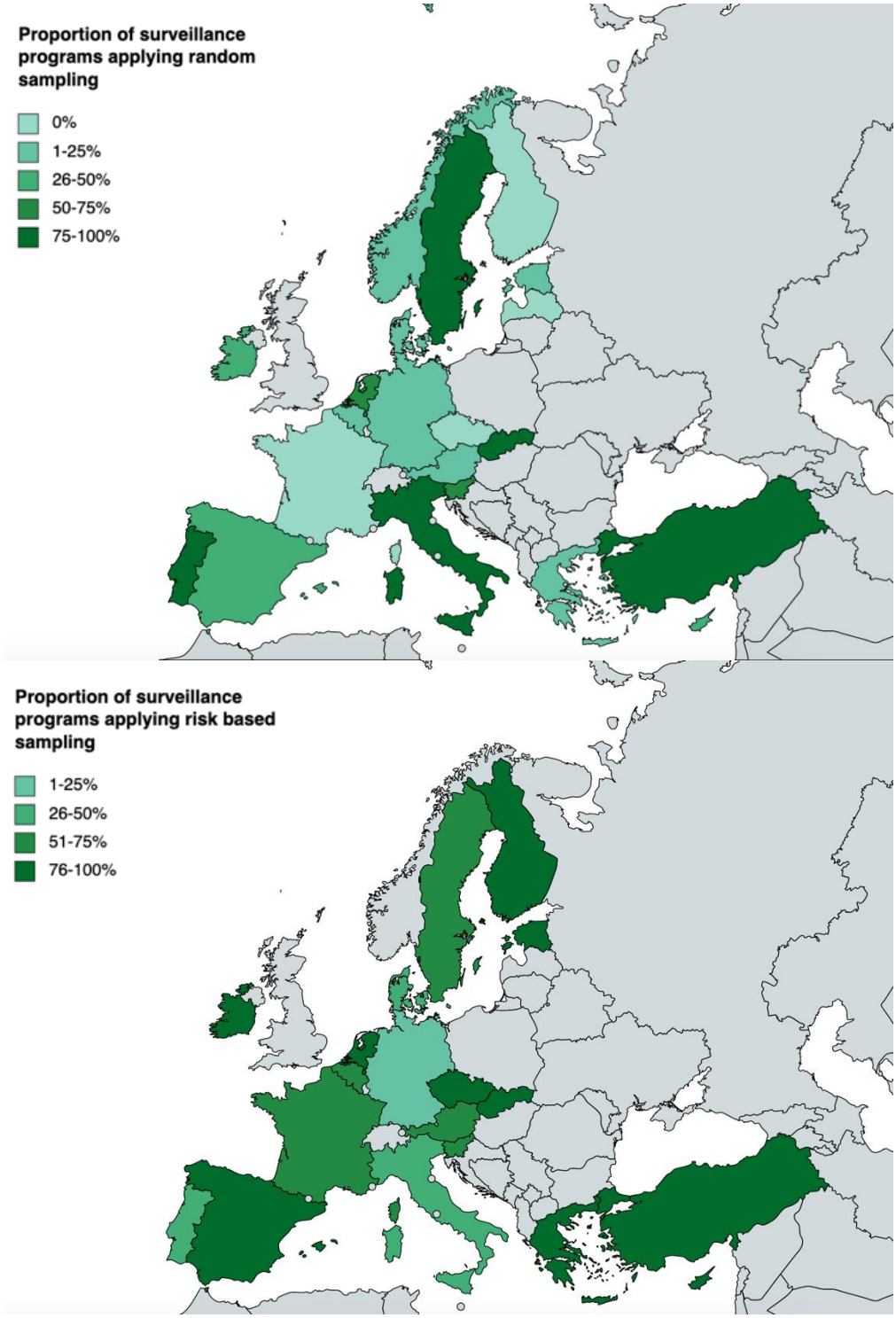


Figure 27. The top map displays the proportion (%) of SPs per country applying **random** sampling, and **risk-based** sampling can be seen at the bottom, grouped into categories for visualizing.

2.2.8.3. Type of samples (hosts/reservoirs)

In total, 80 % of SPs reported they store and archive samples. The sampled subject was classified in one of the following groups:

- Humans
- Vectors
- Environment
- Pets
- Livestock
- Wild mammal & game spp., includes ungulate, lagomorph, some carnivore species (e.g., red fox)
- Wild bird & game spp.
- Wild mammal non-game spp., includes other carnivore, bat and rodent species
- Wild bird non-game spp.

Figure 28 indicates that domestic species predominated across SPs, followed by wild mammals (both game and non-game spp). To a less extent, wild birds and the environment were sampled (<10 SPs). Human were rarely included in SPs under the circumstances requested in this questionnaire and for the selected list of pathogens.

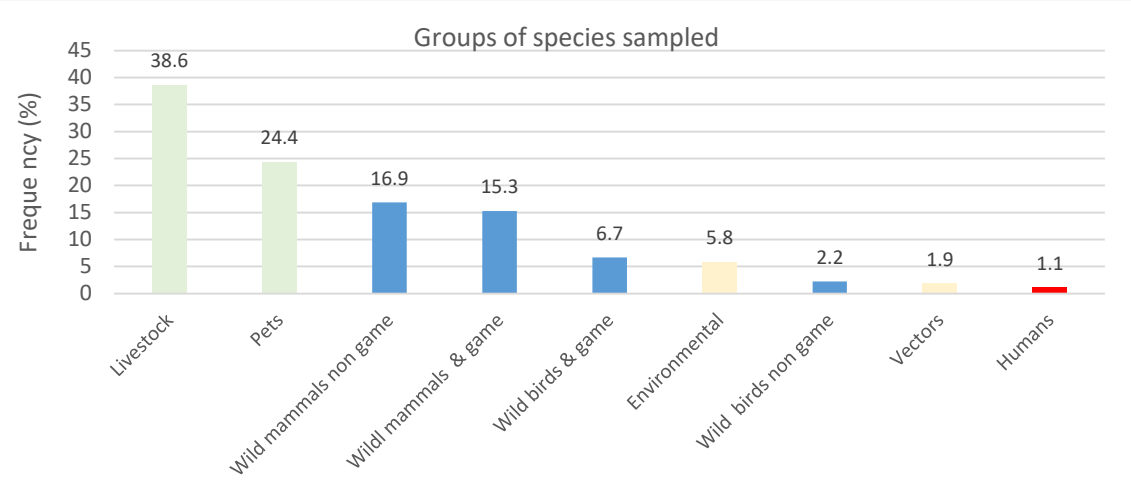


Figure 28. Frequency of sampled hosts (incl. environment).

The evaluation of the frequency of sampled hosts (incl. environment) as a function of the sector in charge of coordination (Figure 29) indicates that: (i) livestock clearly predominated in SPs where the animal health sector was in charge (alone or co-ordinately); (ii) wildlife was predominant in SPs co-ordinately in charge by animal health and environment sectors, and environment sector alone.

The Figure 30 shows the different host species sampled (presence, individually per graph) per country, as well as the number of different host groups sampled per SP. Wild mammals (game and non-game species) were the groups more frequently present in SPs at country level over Europe, followed by wild birds (mainly game species), livestock and pets. The environment and humans were restricted only to some countries. The number of different groups sampled ranged between 2 and 3 in most countries.

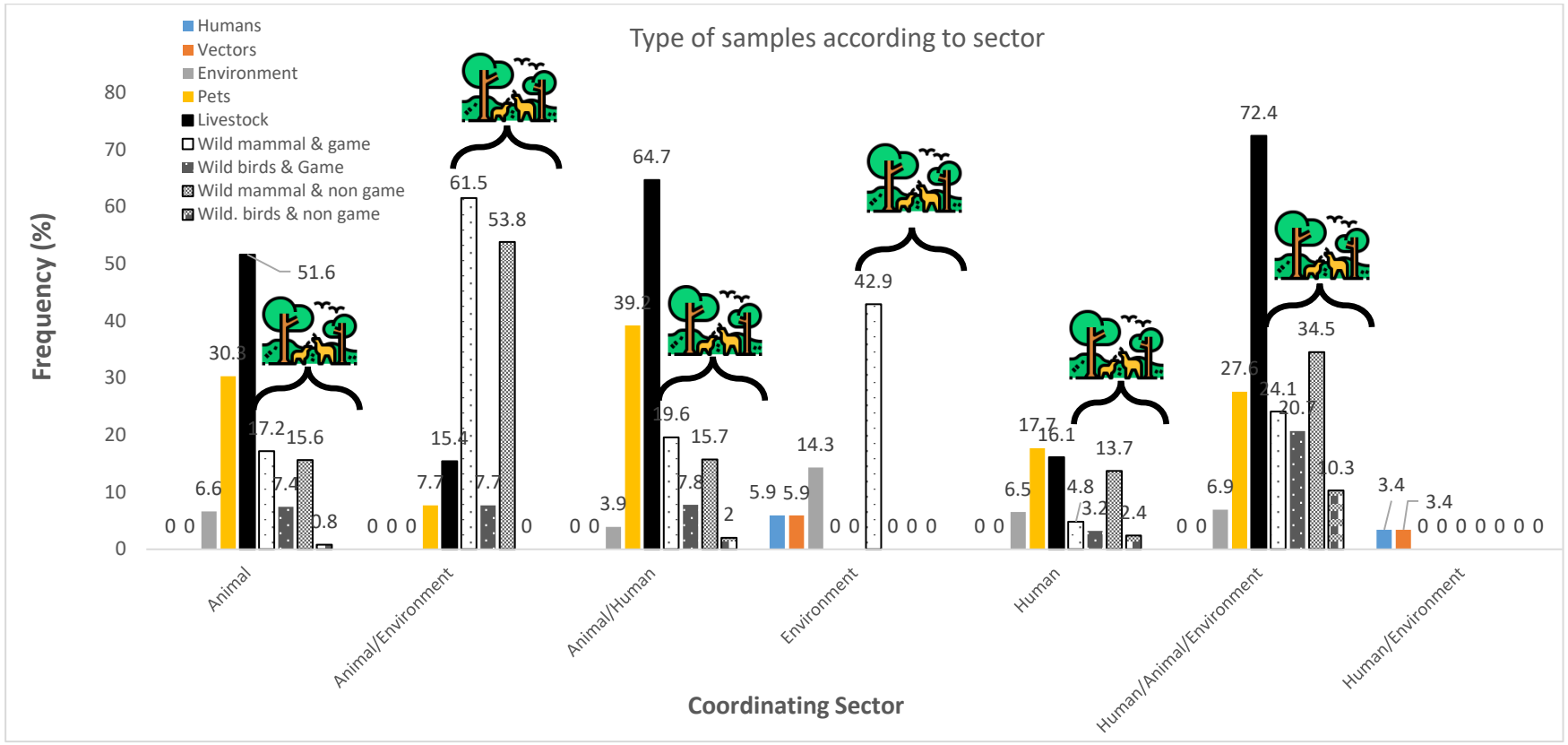


Figure 29. The frequency of sampled hosts (incl. environment) in SPs as a function of the sector in charge of coordination. The icon on top of bars refers to wildlife.

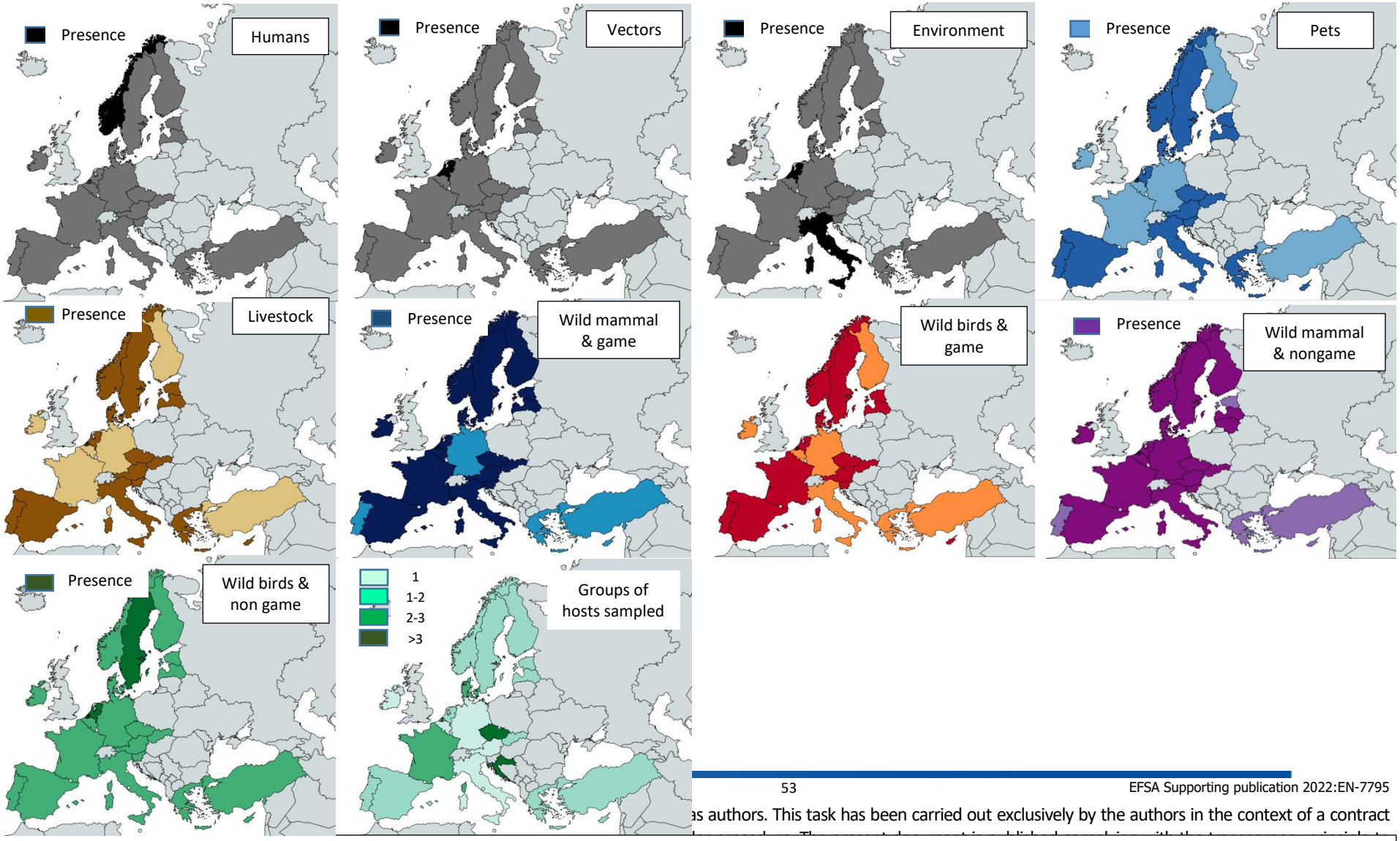


Figure 30. Types of hosts sampled (presence, individually per graph) and average number of different host groups sampled by SP and Country.

Figure 31 shows the number of different groups hosts sampled per SP, predominating programmes where one single group was sampled (top). The average number of different groups of hosts sampled per SP (bottom figure) was about 2, tending to lower values for the animal health and environmental sectors.

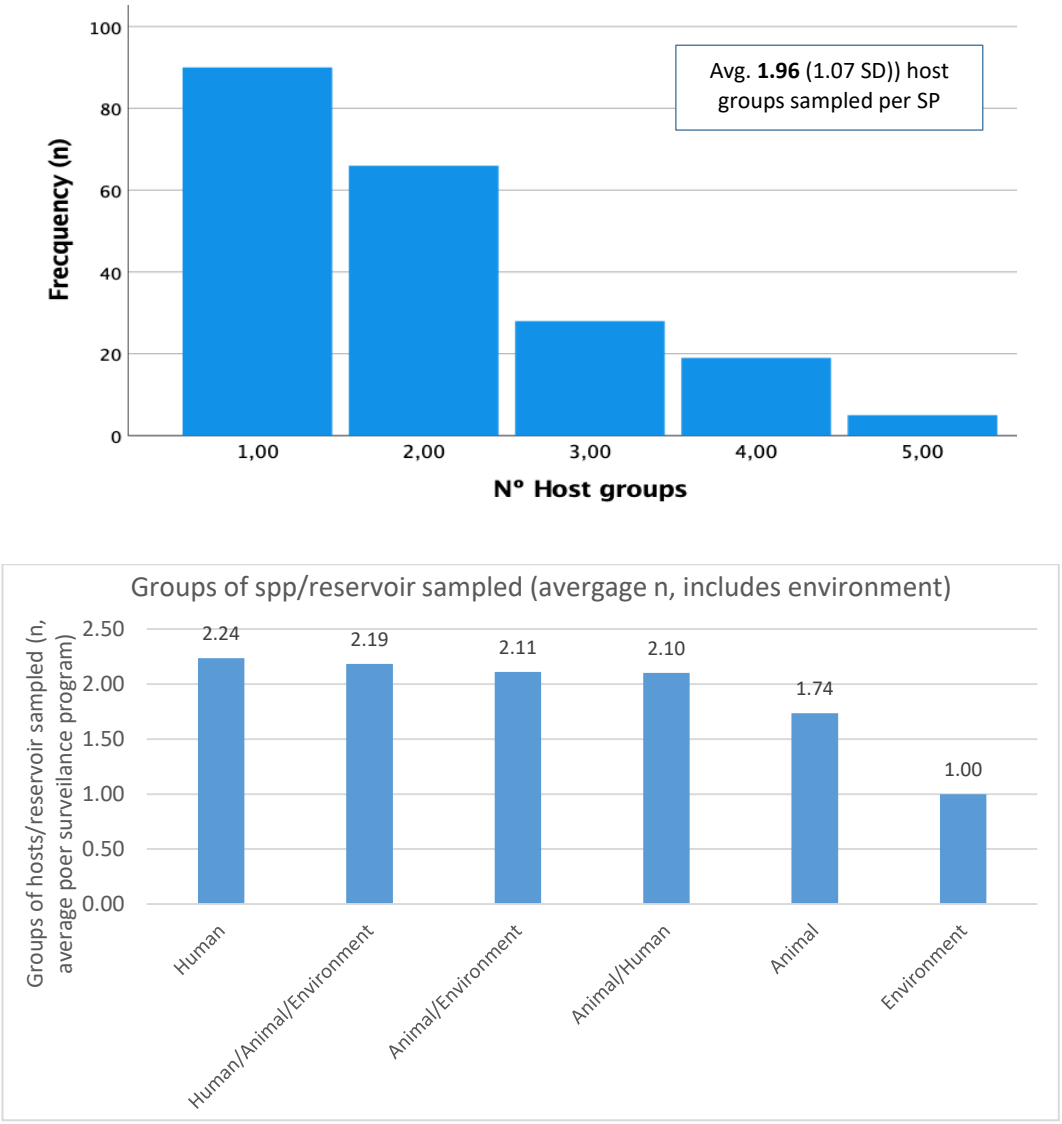


Figure 31. Number of hosts sampled per SP (top: frequency distribution and average values). The bottom graph displays the average number of hosts sampled per SP separately for each sector in charge of coordination.

2.2.8.4. Main characteristics of the prioritized pathogens

The Table 4 details the list of pathogens (n=48) and their main characteristics of relevance for the purposes of describing and mapping the official European zoonosis SPs in this report. In this list, viral agent predominates (n=30, Figure 32), followed by bacteria (n=13), protozoa (n=4, *Toxoplasma gondii*, *Leishmania*, *Giardia* and *Cryptosporidium*), and helminths (n=1, *Echinococcus* spp).

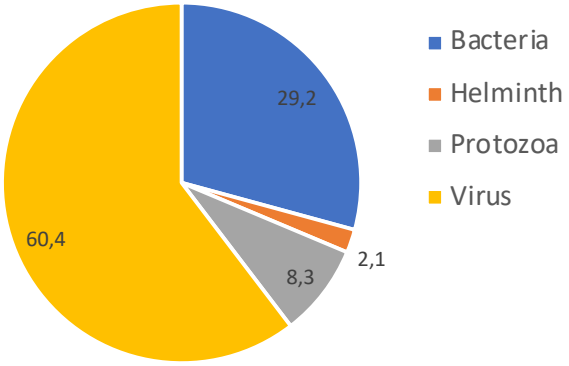


Figure 32. Proportions of viral agent (n=29), bacteria (n=14), protozoa (n=4, *Toxoplasma gondii*, *Leishmania*, *Giardia* and *Cryptosporidium*), and helminths (n=1, *Echinococcus* spp) included in the list pre-selected by EFSA OH WG.

The primary hosts/reservoirs of the selected pathogens were summarized (Figure 33). Rodents were the most represented primary hosts/reservoirs (for almost 30% pathogens), followed by other terrestrial wild mammals (21%, mainly ungulates, and to a less extent lagomorphs and carnivores) and bats (14.6%). Therefore, wild mammals predominated as main potential reservoirs for the selected list of pathogens (approx. 80%). A relevant proportion included both mammals and birds as main hosts (15%) or only birds (14%), which means that birds may act as primary hosts of almost 30% of the selected list of pathogens. Domestic animals, the environment and humas represented smaller proportions and even in one case the main host remains undetermined (for *Rickettsia helvetica*). For more details on hosts, see Annex 2[5] sheet "Pathogens", where not only primary but also a wide range of hosts are summarized.

[5] https://doi.org/10.5281/zenodo.7446484

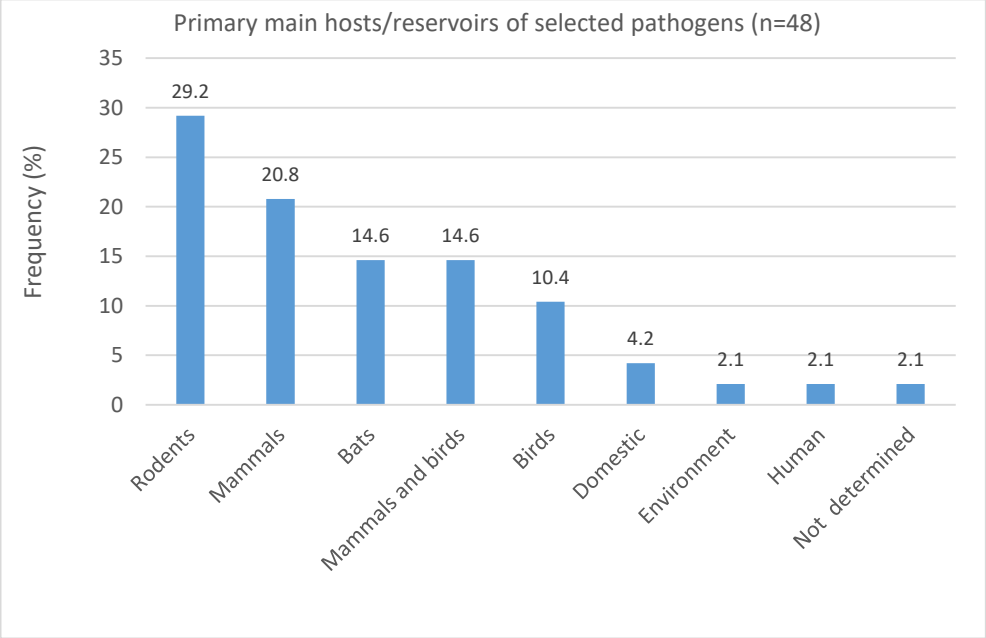


Figure 33. Primary hosts /reservoirs of the selected pathogens.

Approximately half of the pathogens in the list can be considered vector borne (47.9%, n=23 pathogens, see Figures 35 and 36; Table 4), largely predominating among bacteria taxa (64.3%, Figure 34), and being almost half of viruses (44.8%), whereas only *Leishmania* spp was vector borne among selected protozoa.

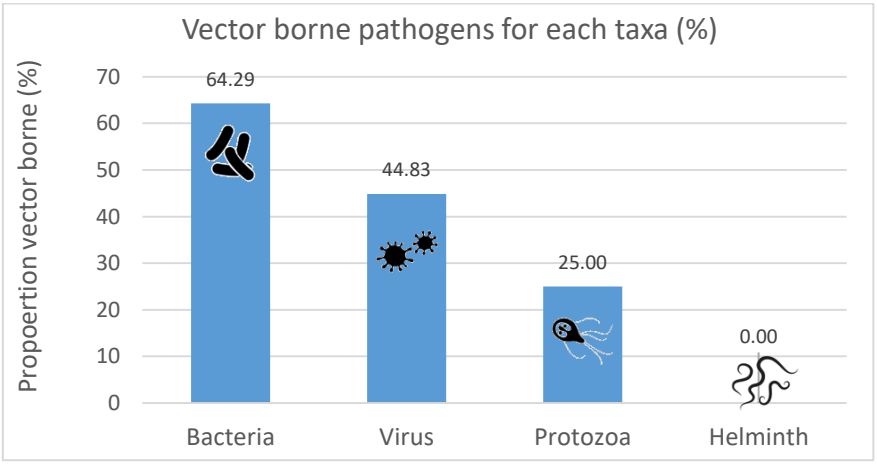


Figure 34. Proportions of vector borne pathogens for each main taxa.

The main vectors (Figure 35, Table 4) associated with the selected pathogens included (n=48) mosquitoes (20.8%) and ticks (18.8%), followed by fleas, sand flies and trombiculid mites (the later three always in <5% of pathogens). Considering only the vector-borne selected pathogens (n=23), frequencies were approximately two-fold (43.4% mosquitoes, 39.1% ticks, always <10% for other vectors) (see Figure 35).

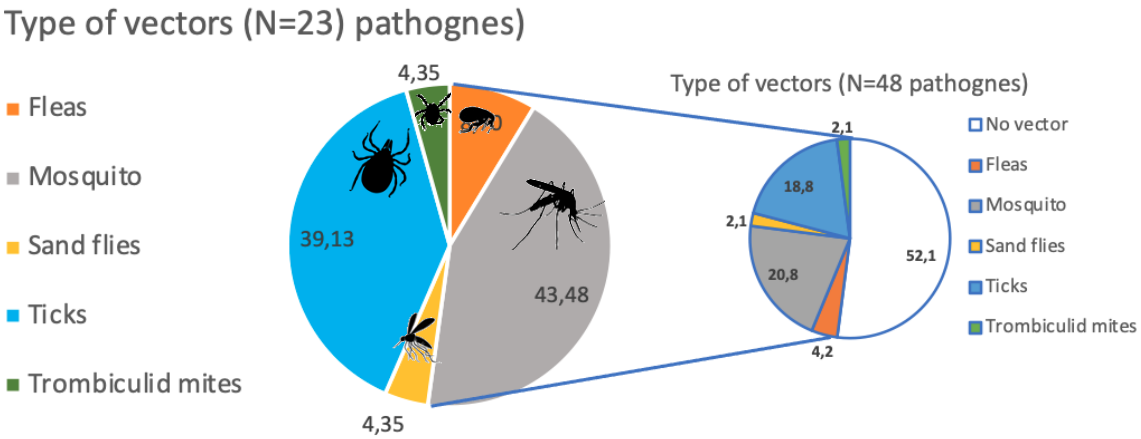


Figure 35. The main vectors of the selected pathogens (right, n=48). Frequencies are also calculated considering only vector borne pathogens (left, n=23).

The most prevalent types of zoonosis among the selected pathogens were metazoonosis (which requires a vector) and direct zoonosis (Figure 36). Cyclozoonosis were only represented by *Echinococcus* spp and *Toxoplasma gondii*, whereas *B. anthracis* was considered a saprozoonosis.

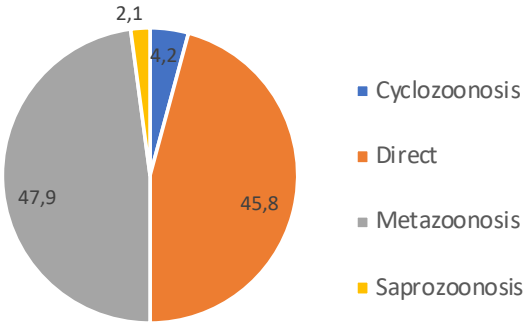


Figure 36. Types of zoonosis of the selected pathogen according to life cycle and source of pathogen for the hosts (n=48).

Table 4. Main characteristics of relevance for the purpose of describing and mapping the official zoonosis surveillance frameworks in Europe in this report. More details are provided in an annex. Shuni virus, Thogoto virus and Wesselsbron virus were not reported as surveyed by any SP in any country, and are not included.

Pathogen	Type pathogen	Vector borne	Main (primary) reservoirs	Main vectors	Domestic cycle	Peri-domestic cycle	Sylvatic cycle	Per-dom. & dom.	Peri-dom. & sylvatic	Peri-dom. & domestic & sylvatic	Pathogen life cycle
Bacillus anthracis	Bacteria	No	Environment		No	Yes	Yes	No	Yes	No	Saprozoonosis
Borrelia burgdorferi	Bacteria	Yes	Rodents	Ticks (*Ixodes*)	No	No	Yes	No	No	No	Metazoonosis
Brucella (B. abortus, melitensis, suis)	Bacteria	No	Wild and domestic ungulates, hares		Yes	No	Yes	No	No	No	Direct
Burkholderia mallei	Bacteria	No	Domestic equids		Yes	No	No	No	No	No	Direct
Chikungunya virus	Virus	Yes	Human (wild primates)	*Aedes*	No	No	Yes	No	No	No	Metazoonosis
Coxiella burnetii	Bacteria	Yes	Mammals, birds	Ticks	Yes	No	Yes	No	No	No	Metazoonosis
Crimean-Congo haemorrhagic fever virus	Virus	Yes	Wild and domestic mammals	Ticks	Yes	No	Yes	No	No	No	Metazoonosis
Cryptosporidium spp.	Protozoa	No	Environment, vertebrates (cattle)		Yes	No	Yes	No	No	No	Direct
Eastern equine encephalitis virus	Virus	Yes	Horse, birds	Culex and *Culiseta* mosquitoes	Yes	No	Yes	No	No	No	Metazoonosis
Ebola virus disease virus	Virus	No	Fruit bats (primates and other wild mammals)		No	No	Yes	No	No	No	Direct
Echinococcus spp. (E. granulosus, E. multilocularis)	Helminth	No	Wild and domestic canids, ungulates, and rodents		Yes	No	Yes	No	No	No	Cyclozoonosis
Erysipelothrix rhusiopathiae	Bacteria	No	Environment, a wide variety of wild and domestic animals, birds, and fish		Yes	No	Yes	No	No	No	Direct
Francisella tularensis	Bacteria	Yes	Rodents, Lagomorpha	Ticks	No	No	Yes	No	No	No	Metazoonosis
Giardia spp.	Protozoa	No	Environment, wild and domestic mammals, and birds		Yes	No	Yes	No	No	No	Direct

Hantavirus	Virus	No	Wild rodents		No	No	Yes	No	No	No	Direct
Hendra virus	Virus	No	Fruit bats		No	No	Yes	No	No	No	Direct
Hepatitis E virus	Virus	No	Human, wild and domestic suids		Yes	No	Yes	No	No	No	Direct
Influenza A virus (Avian)	Virus	No	Wild waterfowl, domestic poultry		Yes	No	Yes	No	No	No	Direct
Influenza A virus (Swine)	Virus	No	Wid and domestic suids		Yes	No	Yes	No	No	No	Direct
Japanese encephalitis virus	Virus	Yes	Vertebrate hosts, primarily pigs (wild boar, pigs) and wading birds	Mosquitoes (*Culex tritaeniorhynchus*)	No	No	Yes	No	No	No	Metazoonosis
Lassa virus	Virus	No	Rodents (multimammate rat *Mastomys natalensis*)		No	No	Yes	No	No	No	Direct
Leishmania spp.	Protozoa	Yes	*L. infantum*: Wild and domestics mammals: lagomorphs, carnivores (other such as hedgehogs)	Sand flies	No	No	Yes	No	No	No	Metazoonosis
Leptospira spp.	Bacteria	No	Rodents		No	Yes	Yes	No	Yes	No	Direct
Lymphocytic choriomeningitis virus	Virus	No	Wild and domestic rodents (*Mus musculus)*		No	No	Yes	No	No	No	Direct
Marburg virus	Virus	No	Fruit bats (primates and other wild mammals)		No	No	Yes	No	No	No	Direct
MERS-Coronavirus	Virus	No	Dromedary camels		Yes	No	Yes	No	No	No	Direct
Monkeypox virus	Virus	No	Primates, rodents		No	No	Yes	No	No	No	Direct
Nipah virus	Virus	No	Fruit bats		No	No	Yes	No	No	No	Direct

Omsk haemorrhagic fever virus	Virus	Yes	Wild rodents	Ticks	No	No	Yes	No	No	No	Metazoonosis
Orientia tsutsugamushi	Bacteria	Yes	Wild rodents (mainly Rattus, also peri-urban)	Trombiculid mites	No	No	Yes	No	No	No	Metazoonosis
Possawan virus infection	Virus	Yes	Wild rodents (also shrews, medium size mammals)	Ticks (*Ixodes, Haemaphysalis* spp)	No	No	Yes	No	No	No	Metazoonosis
Rabies virus	Virus	No	Red Foxes, bats		No	No	Yes	No	No	No	Direct
Rickettsia conorii	Bacteria	Yes	Dogs (Lagomorpha)	*Rhipicephalus sanguineus*	No	Yes	Yes	No	Yes	No	Metazoonosis
Rickettsia helvetica	Bacteria	Yes	Natural vertebrate reservoir host remains to be determined	*Dermacentor reticulatus* and other ticks (*I. ricinus*)	No	No	Yes	No	No	No	Metazoonosis
Rickettsia typhi	Bacteria	Yes	Rodents: *Rattus*	Oriental rat flea (*Xenopsylla cheopis*)	No	Yes	Yes	No	Yes	No	Metazoonosis
Rift Valley fever virus	Bacteria	Yes	Domestic ruminants and camels (wildlife reservoirs such as rodents, wild ruminants or bats may also contribute)	Mosquitoes (mainly *Aedes* and *Culex* spp.)	No	No	Yes	No	No	No	Metazoonosis
SARS	Virus	No	Probably bats		No	No	Yes	No	No	No	Direct
SARS-Coronavirus type Yes	Virus	No	Probably bats		No	No	Yes	No	No	No	Direct
SARS-Coronavirus type 2	Virus	No	Probably bats		No	No	Yes	No	No	No	Direct
Sindbis virus	Virus	Yes	Birds (Grouse and passerines)	*Culex* and *Culiseta* mosquitoe	No	No	Yes	No	No	No	Metazoonosis

St. Louis encephalitis virus	Virus	Yes	Birds (Passeriformes and Columbiformes)	Mosquitoes *Culex*	No	Yes	Yes	No	Yes	No	Metazoonosis
Tick-borne encephalitis virus	Virus	Yes	Rodents (also insectivores and carnivores)	*Ixodes* ticks	No	No	Yes	No	No	No	Metazoonosis
Toxoplasma gondii	Protozoa	No	Environment, wild and domestic Felidae, warm-blooded vertebrates		Yes	Yes	Yes	Yes	Yes	Yes	Cyclozoonosis
Usutu virus	Virus	Yes	Wild birds	Mosquito *Culex*	No	No	Yes	No	No	No	Metazoonosis
Venezuelan equine encephalitis virus	Virus	Yes	Wild rodents (equines)	Mosquitoes *Culex*	No	No	Yes	No	No	No	Metazoonosis
West Nile virus	Virus	Yes	Wild birds	Mosquitoes *Culex*	Yes	Yes	Yes	Yes	Yes	Yes	Metazoonosis
Western equine encephalitis virus	Virus	Yes	Horse, birds	*Culex* and *Culiseta* mosquitoe	Yes	No	Yes	No	No	No	Metazoonosis
Yersinia pestis	Bacteria	Yes	Wild rodents	Fleas	No	No	Yes	No	No	No	Metazoonosis

2.2.8.5. The pathogens included in SPs

As indicative of how fragmented SPs are, the average number of pathogens of the priority list (Figure 37), separately for each taxon (viruses, bacteria, protozoa, helminths) included per SP, was less than one.

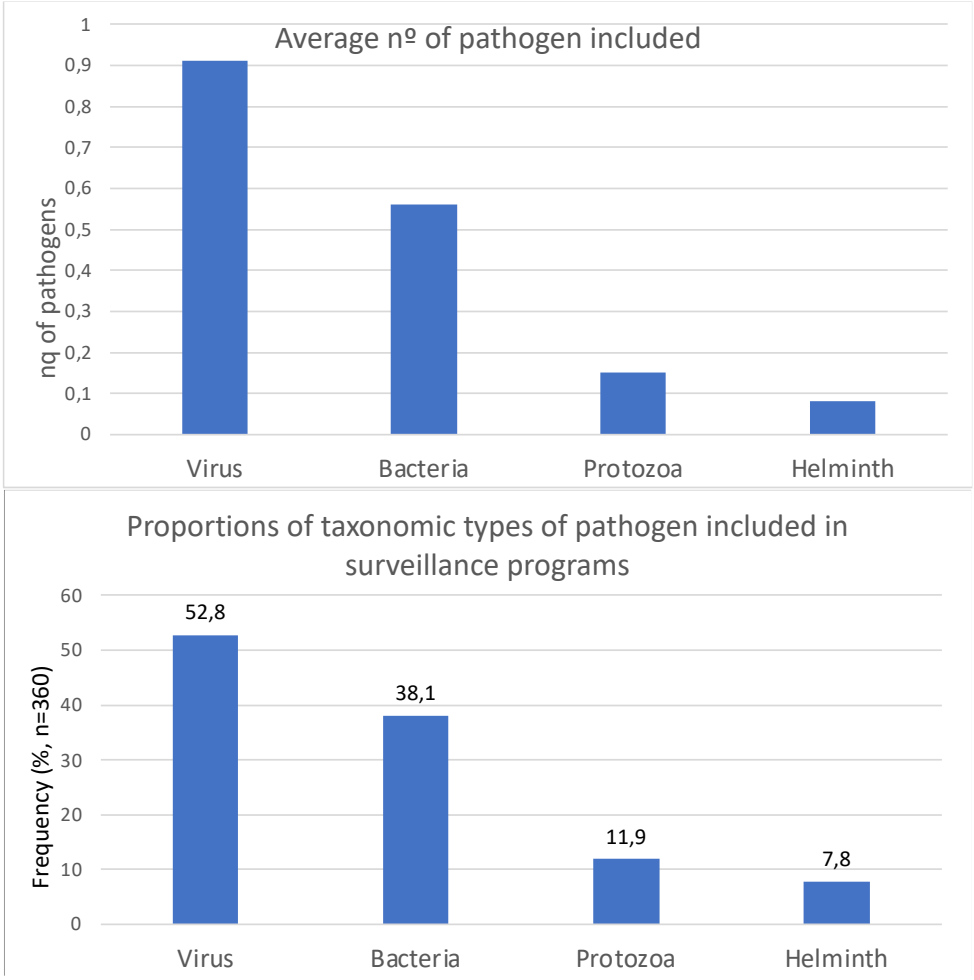


Figure 37. Average number of pathogens separately for each taxa, included per single SP (top) and proportions (bottom).

Figure 38 presents how frequently (%) each pathogen (among those of the priority list) was included in the SPs reported in the questionnaires (n=360). The main taxonomic groups (virus, bacteria, protozoan, helminths) are indicated in different colours. *Brucella* spp were the most frequently included pathogen (10.6% of SPs), followed by viral pathogens Influenza A virus (Avian) and Rabies. Helminths (represented by *Echinococcus* spp) ranked fourth. Shuni virus, Thogoto virus and Wesselsbron virus were not reported as surveyed by any SP in any country. The number of pathogens included in SPs per country according to the taxa are represented in Figure 39. This number was variable, and those having the higher number of viruses and bacteria positively correlated. A clear spatial pattern was detected for protozoans, being more represented different species in Southwestern Countries. As the only representative of helminths, surveillance for *Echinococcus* spp, was present in all country except Austria, Slovenia, and Turkey.

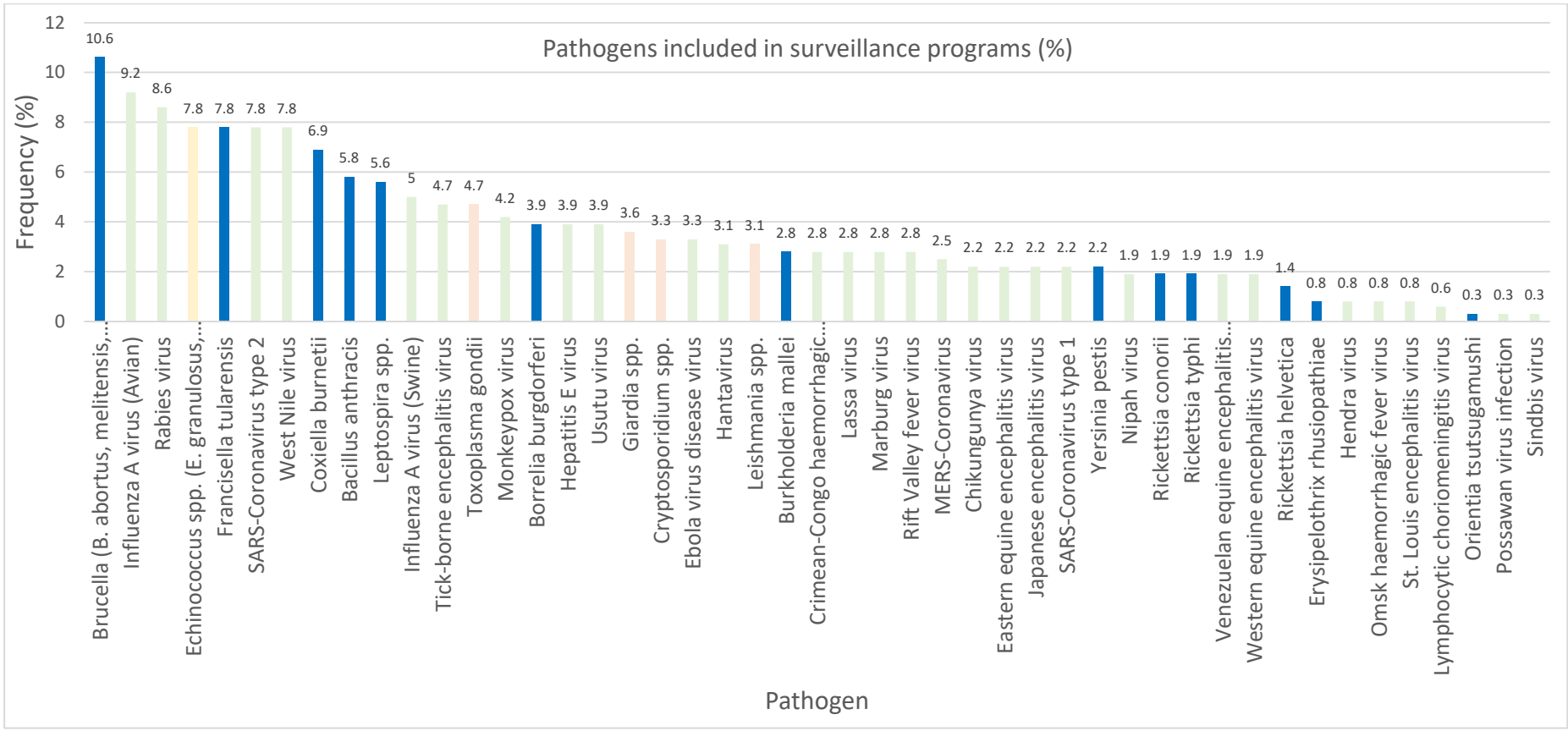


Figure 38. This Figure represents the frequency (%) each pathogen of the list (N=48) that was included in the SPs (n=360). Shuni virus, Thogoto virus and Wesselsbron virus were not reported as surveyed by any SP in any country. SARS is included as a different category since several SPs did not distinguish SARS-Coronavirus type 1 and 2. Blue: Bacteria. Green: Virus. Orange: Protozoa. Yellow: Helminths.

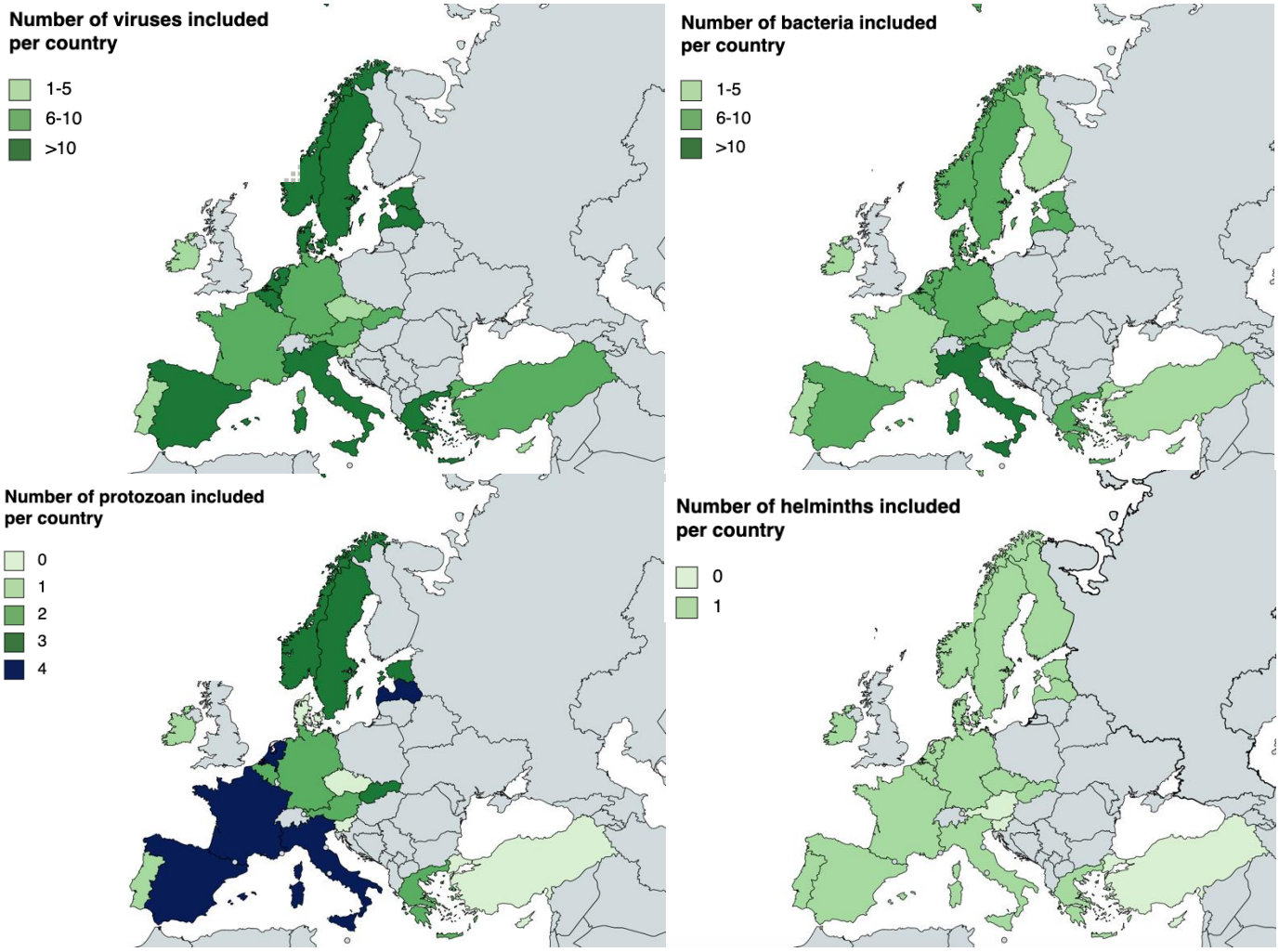


Figure 39. Number of pathogens included in SP per country according to taxa.

The number and proportions of vector-borne pathogens included in SP per country evidence a highly variable scenario over Europe (Figure 40). The countries that had the most SPs for the vector-borne pathogens on the list were Belgium, the Netherlands and Italy (Figure 40, top map), but this was in proportion to general surveillance effort for the selected pathogens (Figure 40, middle map, and graph bottom),

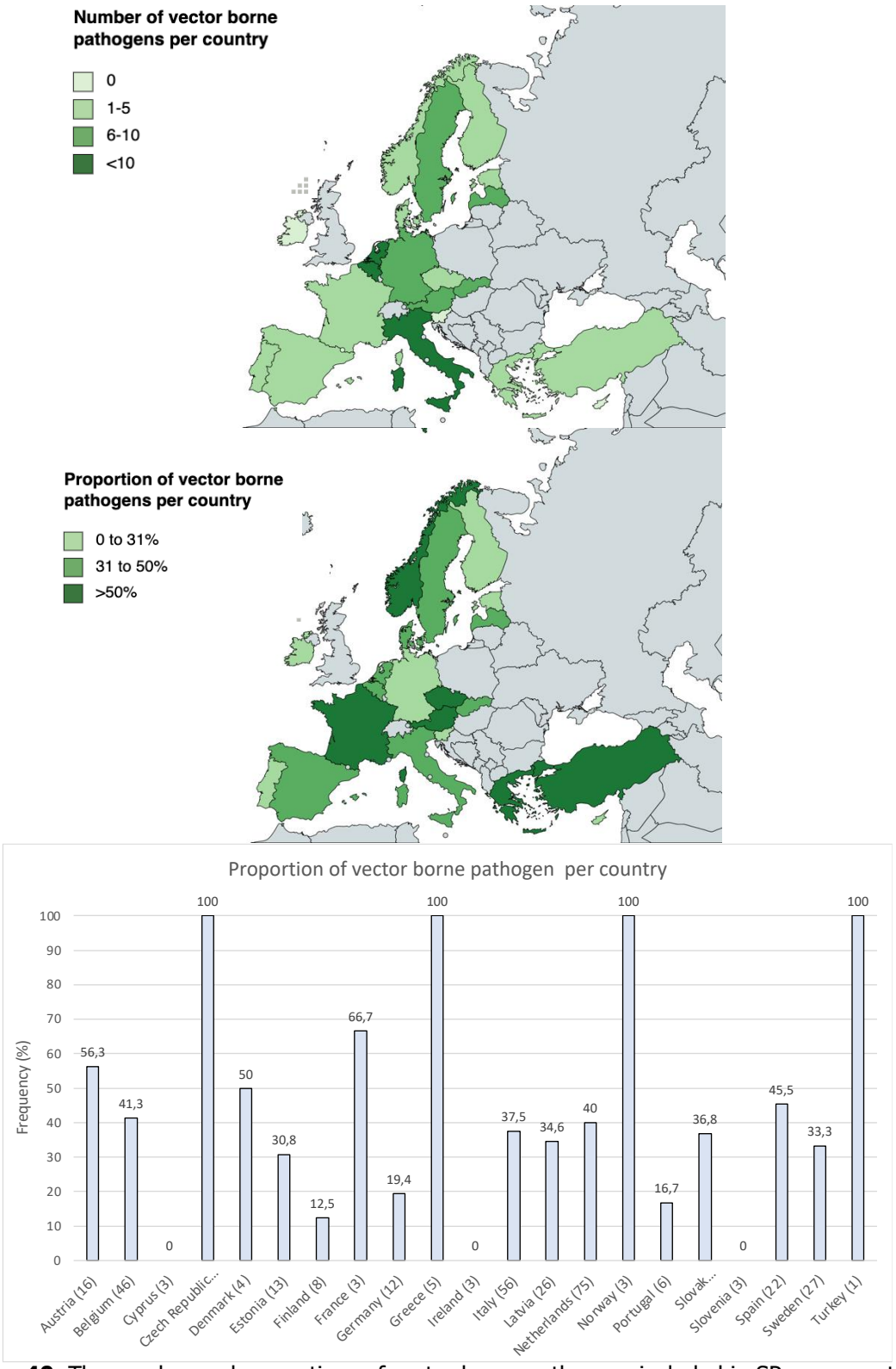


Figure 40. The number and proportions of vector borne pathogens included in SPs per country.

The proportion of vector-borne pathogens included in SPs (Figure 41) was higher for the environmental sector as well as in SPs where the three sectors, human, animal, and environmental heath, were jointly in charge.

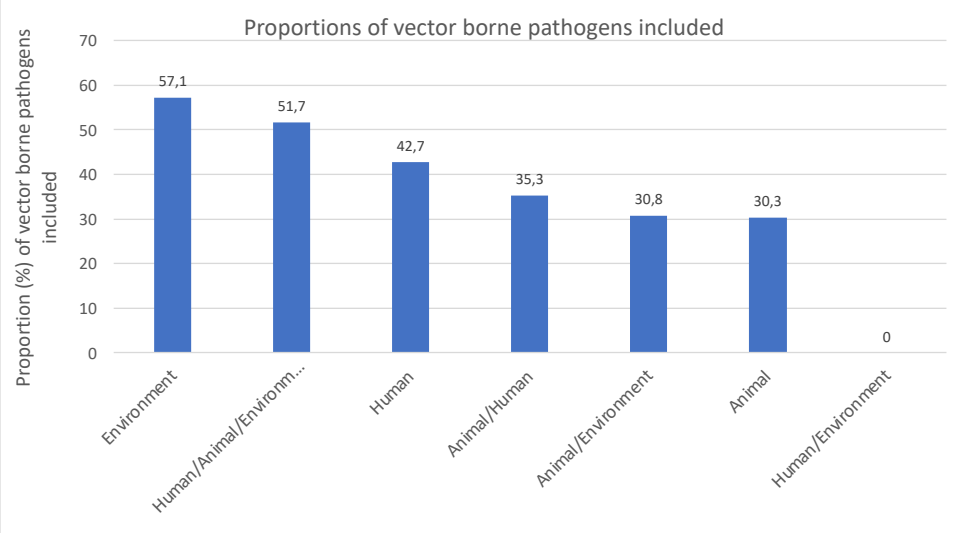


Figure 41. The proportion of vector borne pathogens included in SPs according to the sectors in charge.

The proportion of pathogen taxa included in SPs per country is showed in the Figure 42 (total frequency and relative cumulated bars), evidencing that in most countries the number of virus as higher than the number of bacteria included.

Table 5 shows the main characteristics of relevance for the purposes of describing and mapping the official zoonosis surveillance frameworks in Europe in this report. More details are provided in an Annex 2 [6].

[6] https://doi.org/10.5281/zenodo.7446484

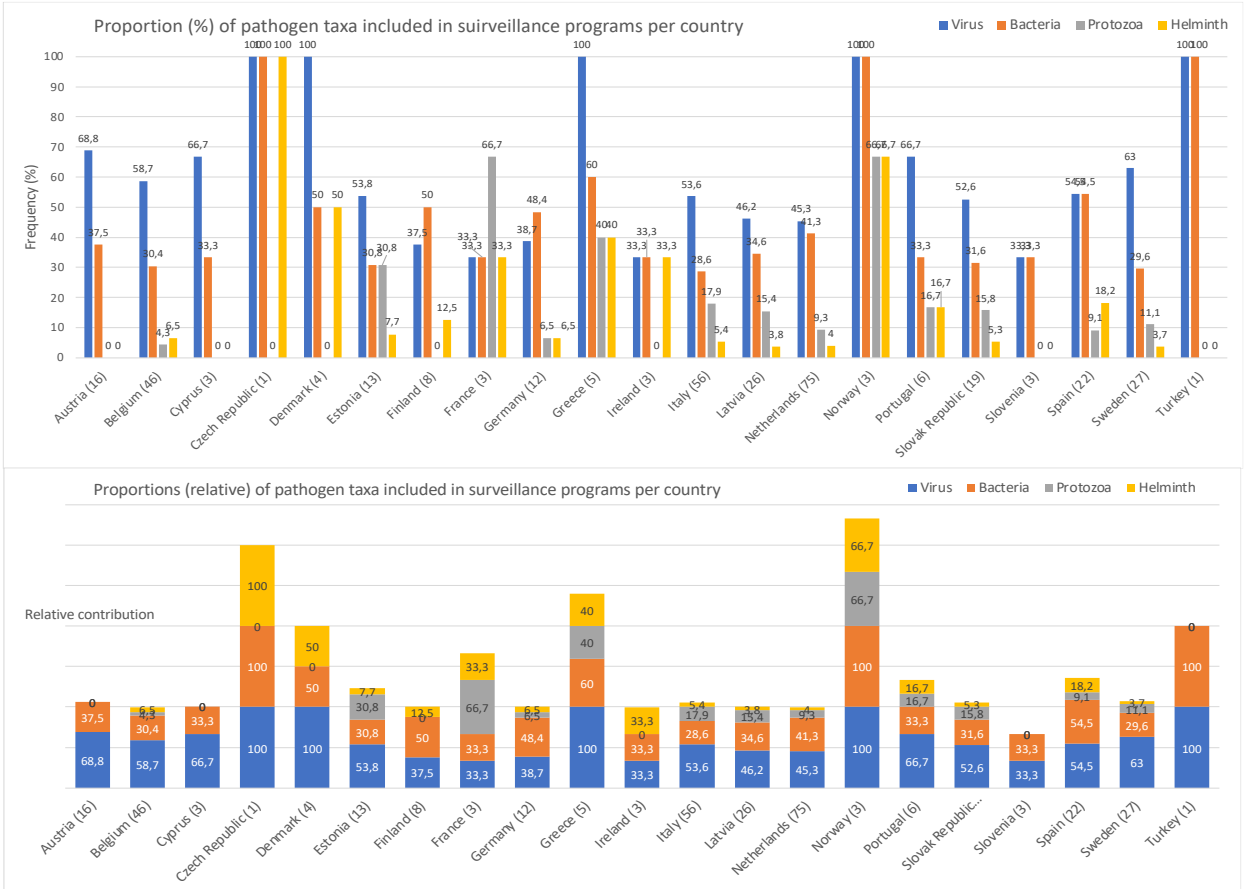


Figure 42. Proportions of pathogen taxa included in SPs per country (total frequency and relative cumulated bars). The number of SPs per country are indicated in brackets.

Table 5. Presence of the selected pathogens in SPs (frequency, N=360) as a function of the sectors in charge. Green colours (darker the higher) indicate the sector categories where the pathogens are more represented in SPs (see also Figure 43).

Sectors in charge of coordination	Avian Influenza	*Bacillus anthracis*	*Borrelia burgdorferi*	*Brucella (B. abortus, melitensis, suis)*	*Burkholderia mallei*	Chikungunya virus	*Coxiella burnetii*	Crimean-Congo haemorrhagic fever virus	*Cryptosporidium spp.*
Animal (n=122)	14	8	1	17	7	0	7	0	2
Human (n=124)	6	6	8	5	2	5	7	7	3
Environment (n=7)	0	0	1	1	0	0	0	0	0
Animal/Human (n=51)	2	3	2	7	1	0	5	1	4
Animal/Environment (n=13)	4	0	0	4	0	0	2	0	1
Human/Animal/Environment (n=29)	7	4	2	4	0	2	4	1	1
Human/Environment (n=5)	0	0	0	0	0	0	0	0	0
Total	33	21	14	38	10	8	25	10	12

Sectors in charge of coordination	Eastern equine encephalitis virus	Ebola virus disease virus	*Echinococcus spp. (E. granulosus, E. multilocularis)*	*Erysipelothrix rhusiopathiae*	*Francisella tularensis*	*Giardia spp.*	Hantavirus	Hendra virus	Hepatitis E virus	Influenza A virus (Avian)
Animal (n=122)	5	2	9	0	7	3	0	0	1	14
Human (n=124)	1	7	8	1	10	6	11	0	5	6
Environment (n=7)	0	0	1	0	0	1	0	0	0	0
Animal/Human (n=51)	2	1	2	1	6	1	2	0	5	2
Animal/Environment (n=13)	0	0	3	1	2	1	0	0	2	4
Human/Animal/Environment (n=29)	0	1	5	0	3	1	0	0	1	7
Human/Environment (n=5)	0	0	0	0	0	0	0	0	0	0
Total	8	12	28	3	28	13	13	0	14	33

Sectors in charge of co-ordination	Japanese encephalitis virus	Lassa virus	Leishmania spp.	Leptospira spp.	Lymphocytic choriomeningitis virus	Marburg virus	MERS-Corona-virus	Monkeypox virus	Nipah virus	Omsk haemorrhagic fever virus
Animal (n=122)	2	0	4	8	0	1	0	4	1	0
Human (n=124)	4	7	3	6	1	7	7	5	4	3
Environment (n=7)	0	0	0	0	0	0	0	0	0	0
Animal/Human (n=51)	2	1	0	4	1	1	1	3	2	0
Animal/Environment (n=13)	0	0	1	1	0	0	0	0	0	0
Human/Animal/Environment (n=29)	0	1	3	1	0	1	1	1	0	0
Human/Environment (n=5)	0	0	0	0	0	0	0	2	0	0
Total	8	10	11	20	2	10	9	16	7	3

Sectors in charge of co-ordination	*Orientia tsutsugamushi*	Possawan virus infection	Rabies virus	*Rickettsia conorii*	*Rickettsia helvetica*	Rickettsia typhi	Rift Valley fever virus	SARS	SARS-Corona-virus type 1	SARS-Corona-virus type 2
Animal (n=122)	0	0	11	0	0	0	3	0	0	7
Human (n=124)	1	1	7	4	2	4	5	2	6	8
Environment (n=7)	0	0	0	0	0	0	0	0	0	0
Animal/Human (n=51)	0	0	4	1	1	2	1	0	1	2
Animal/Environment (n=13)	0	0	4	0	1	0	0	0	0	3
Human/Animal/Environment (n=29)	0	0	5	2	1	1	1	0	1	4
Human/Environment (n=5)	0	0	0	0	0	0	0	0	0	4

Total	1	1	31	7	5	7	10	2	8	28

Sectors in charge of coordination	Sindbis virus	St. Louis encephalitis virus	Tick-borne encephalitis virus	*Toxoplasma gondii*	Usutu virus	Venezuelan equine encephalitis virus	West Nile virus	Western equine encephalitis virus	N
Animal (n=122)	0	0	2	5	3	5	8	5	122
Human (n=124)	1	2	7	7	6	0	8	0	124
Environment (n=7)	0	0	1	0	1	0	1	0	7
Animal/Human (n=51)	0	1	4	1	2	2	2	2	51
Animal/Environment (n=13)	0	0	1	3	2	0	1	0	13
Human/Animal/Environment (n=29)	0	0	1	1	1	0	8	0	29
Human/Environment (n=5)	0	0	0	0	0	0	0	0	5
Total	1	3	17	18	15	7	28	7	360

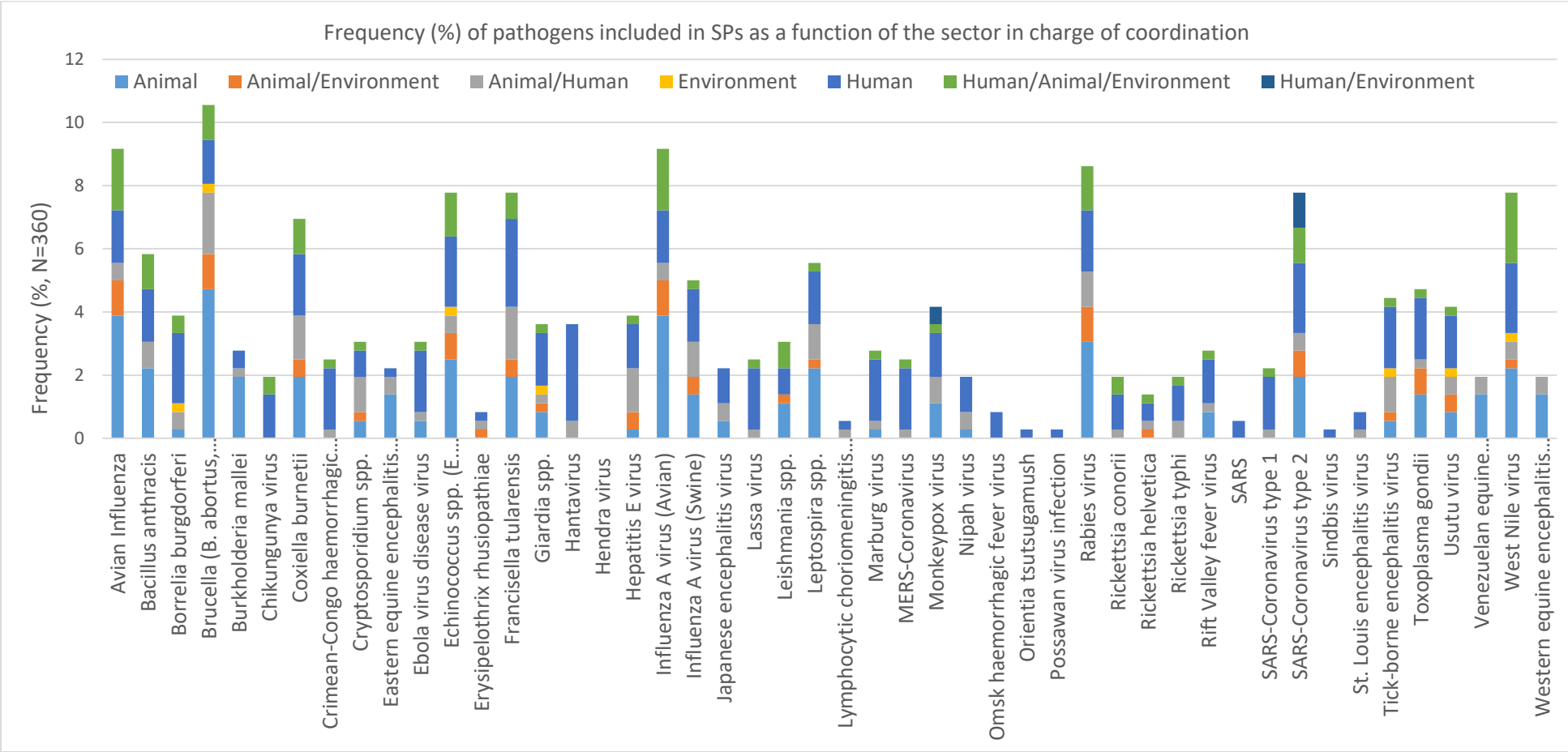


Figure 43. Presence (frequency, %) of the selected pathogens in SPs (frequency, N=360) as a function of the sectors in charge.

The Figure 44 represents the average number of institutions involved in SPs and the number of pathogens (of the list) included (a), indicating a positive relationship (b).

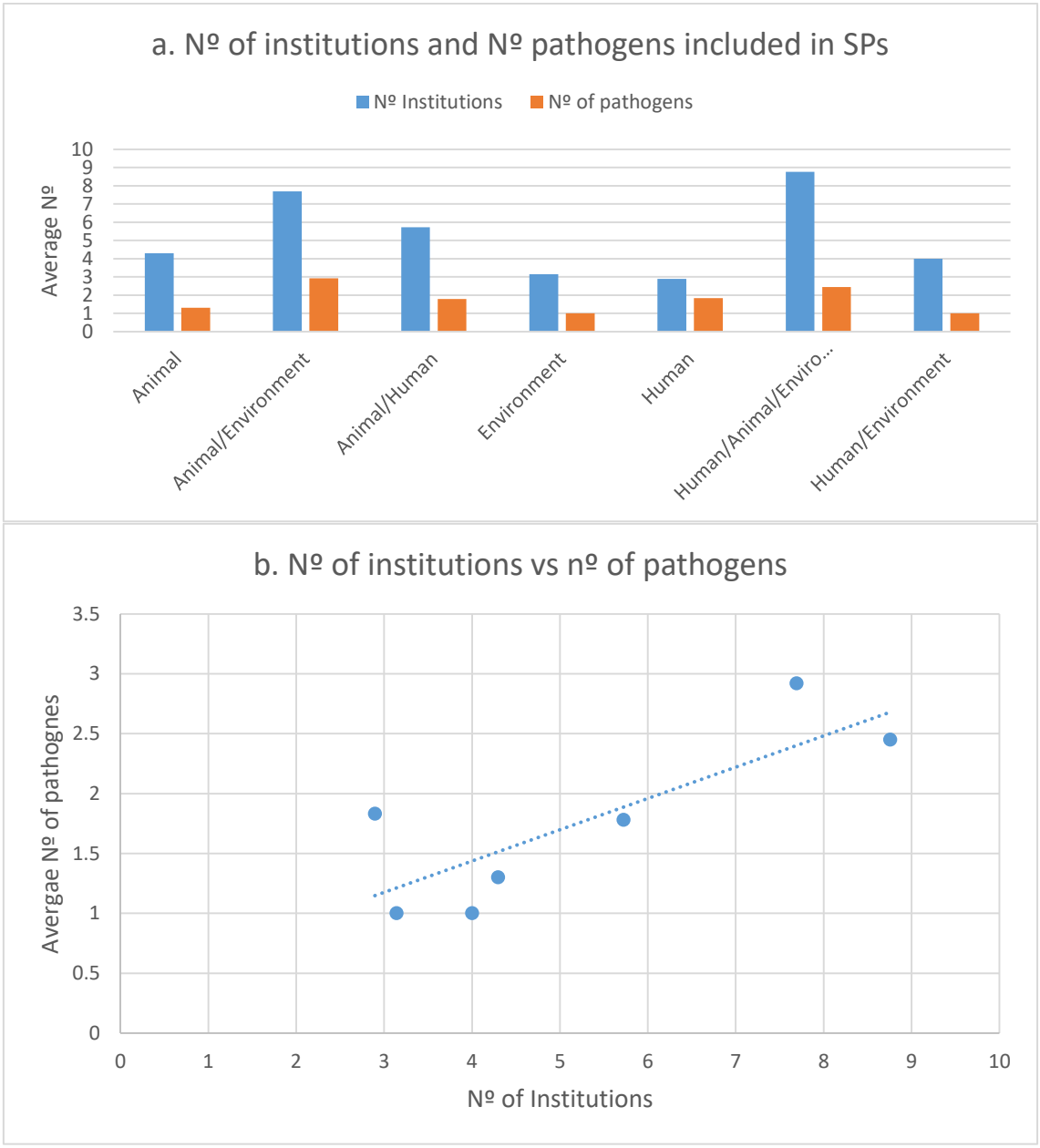
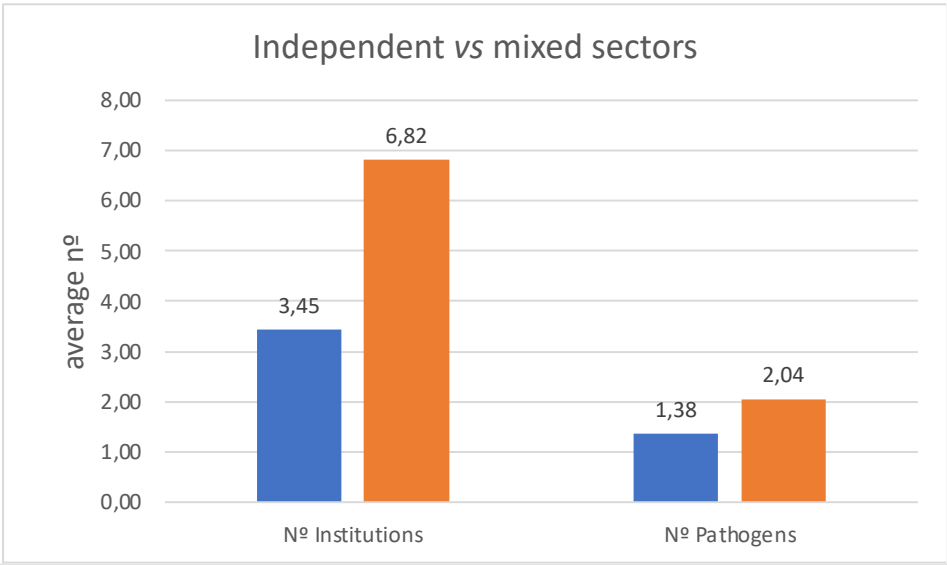


Figure 44. Average number of institutions involved in SPs and the number of pathogens (of the list) included (a), and their relationship (b).

The number of pathogens under study increased when several sectors joined to coordinate the SPs (Figure 45, top right). It is also observed that the number of Institutions involved (see previous sections) increased when mixed coordination of the SPs was developed (Figure 45, top left). There were marked differences in the number of institutions and pathogens per countries, so as in their relationship.



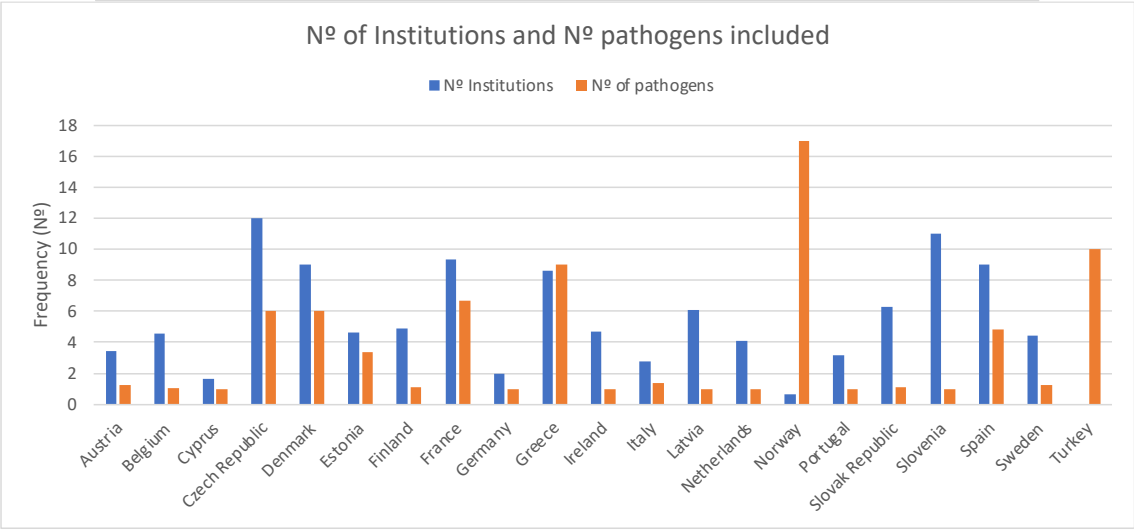
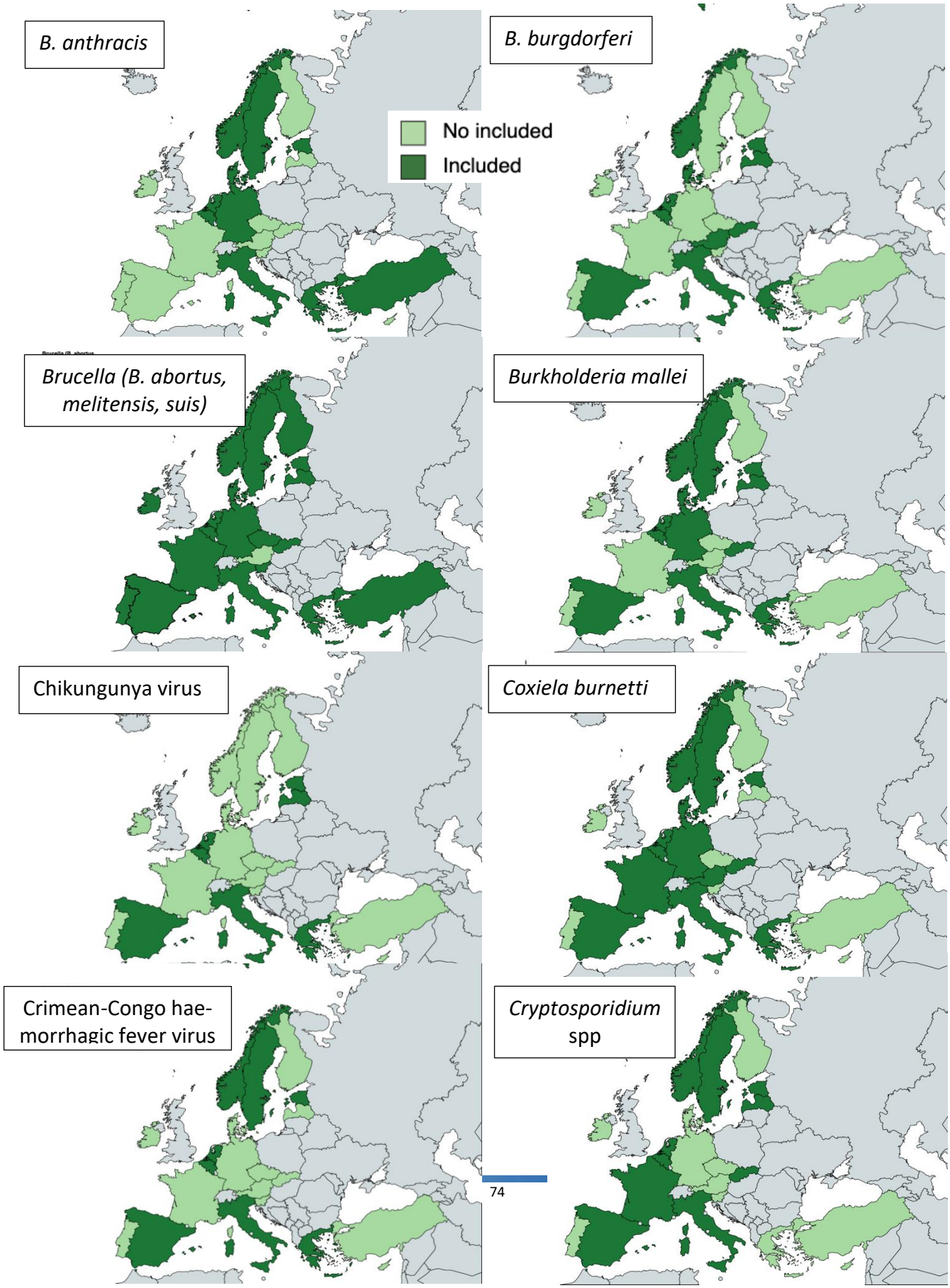
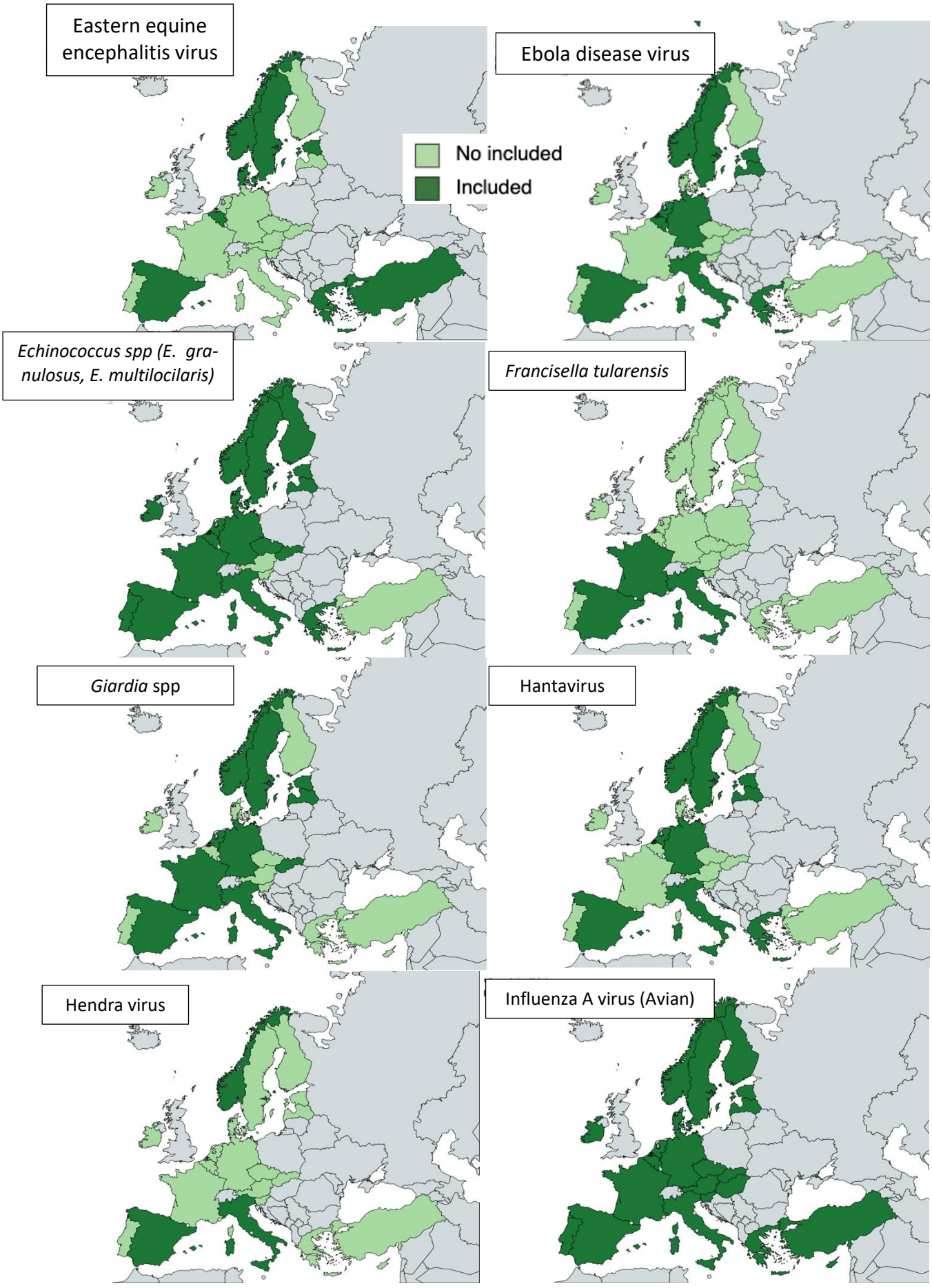


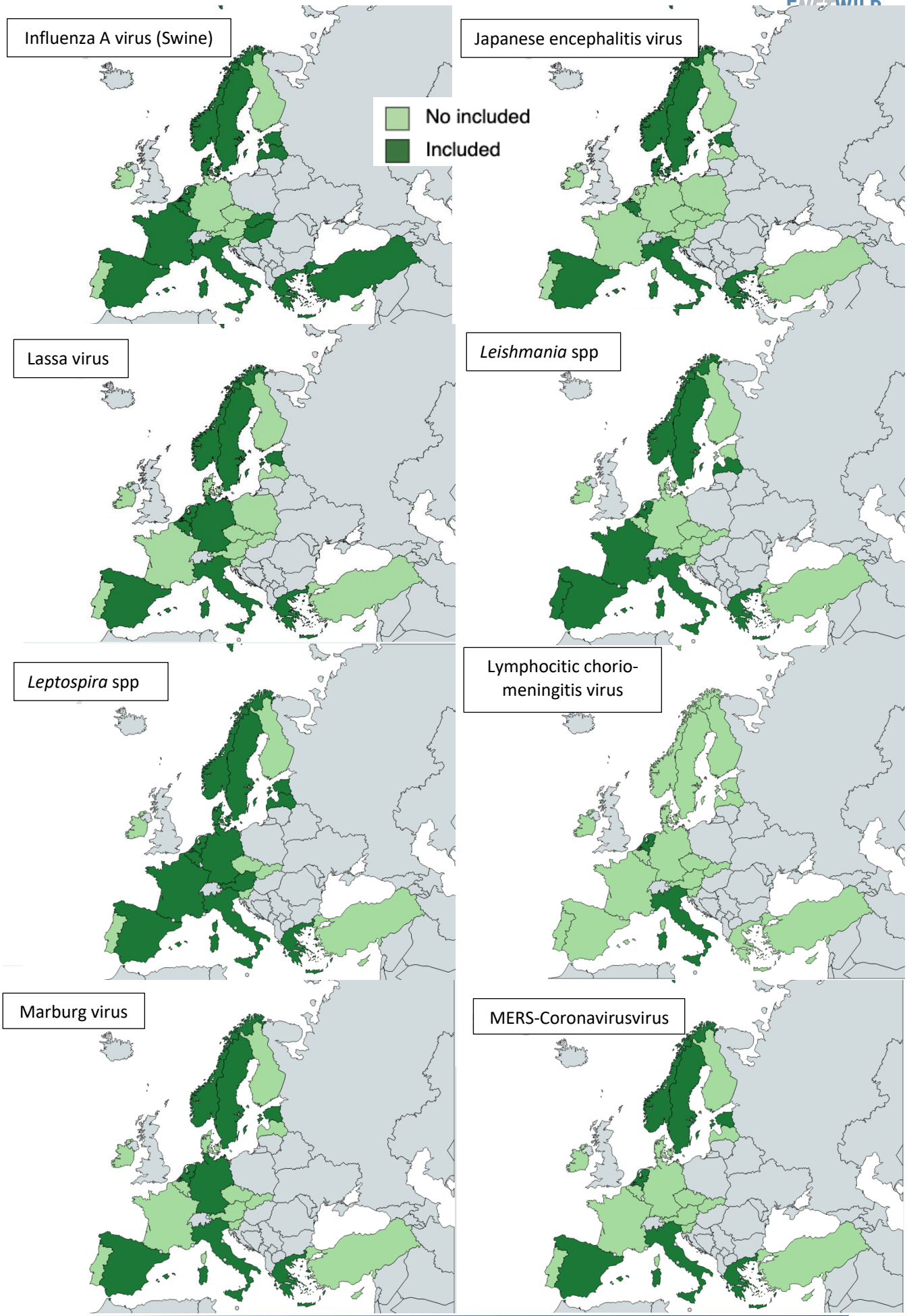
Figure 45. The number of pathogens and Institutions under study when single or several sectors coordinate the SPs (top). It is also show by Country (bottom).

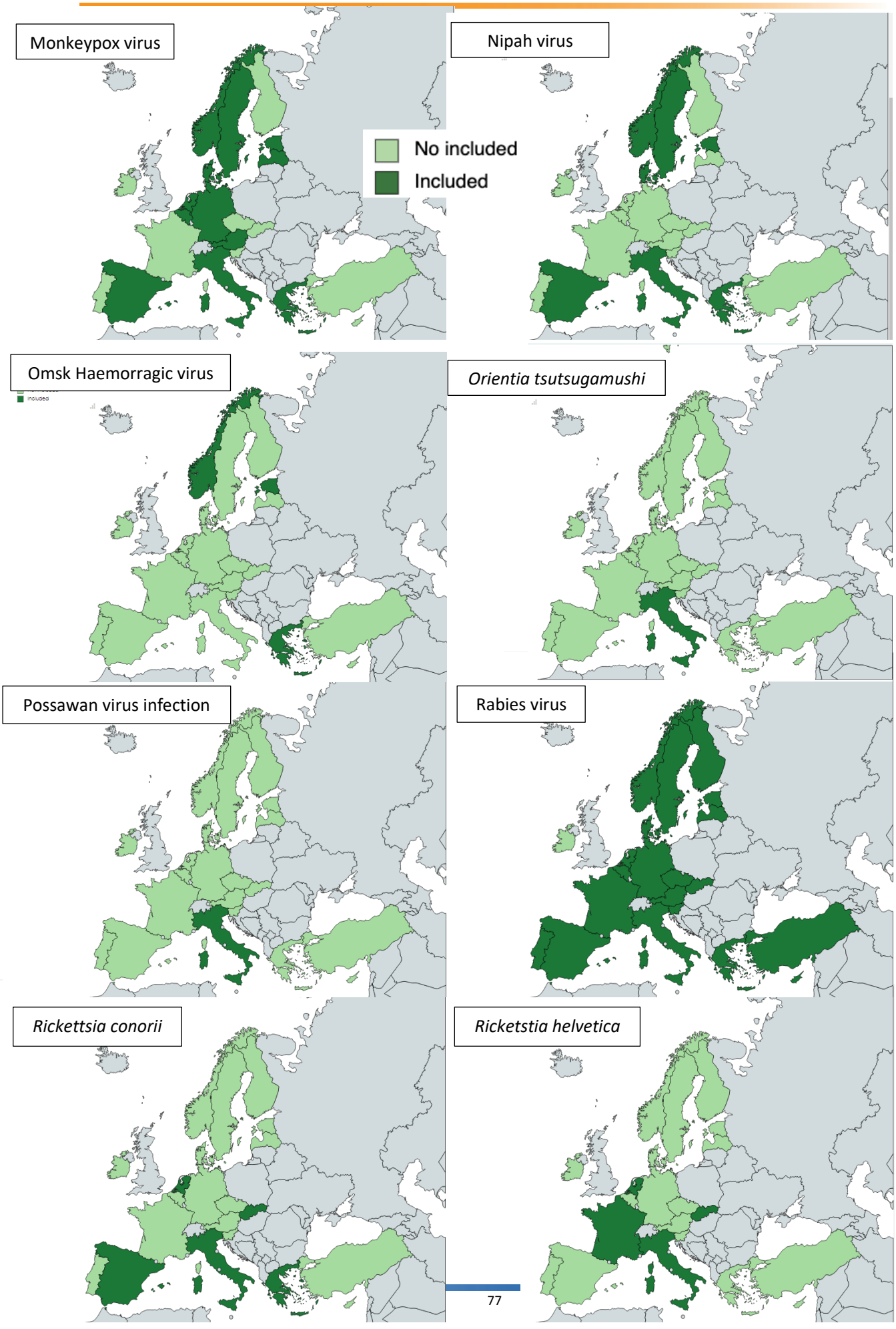
2.2.8.6. Spatial patterns of pathogens included in SPs

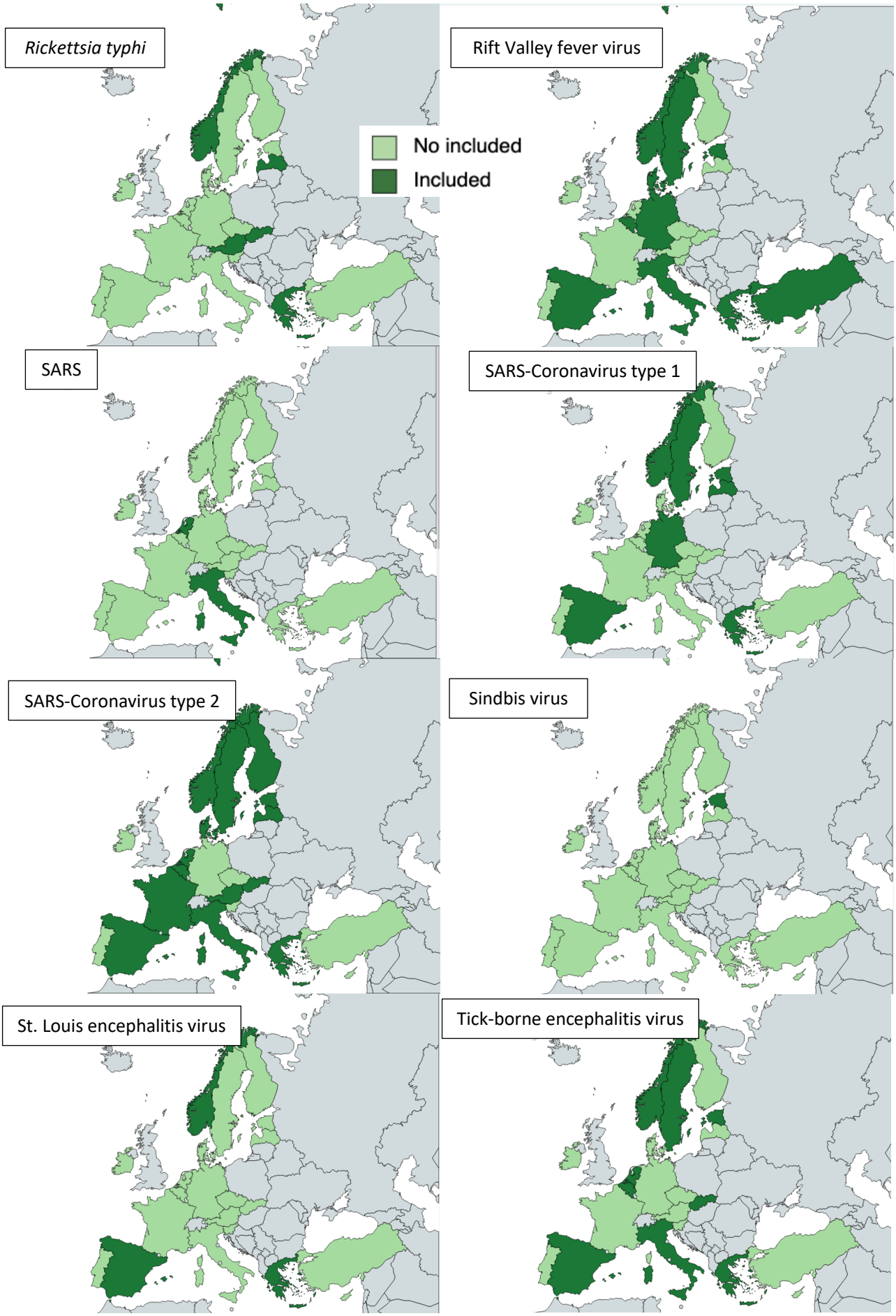
Below (Figure 46), the presence of pathogen in SPs over countries in a series of maps, separately for each pathogen is shown.











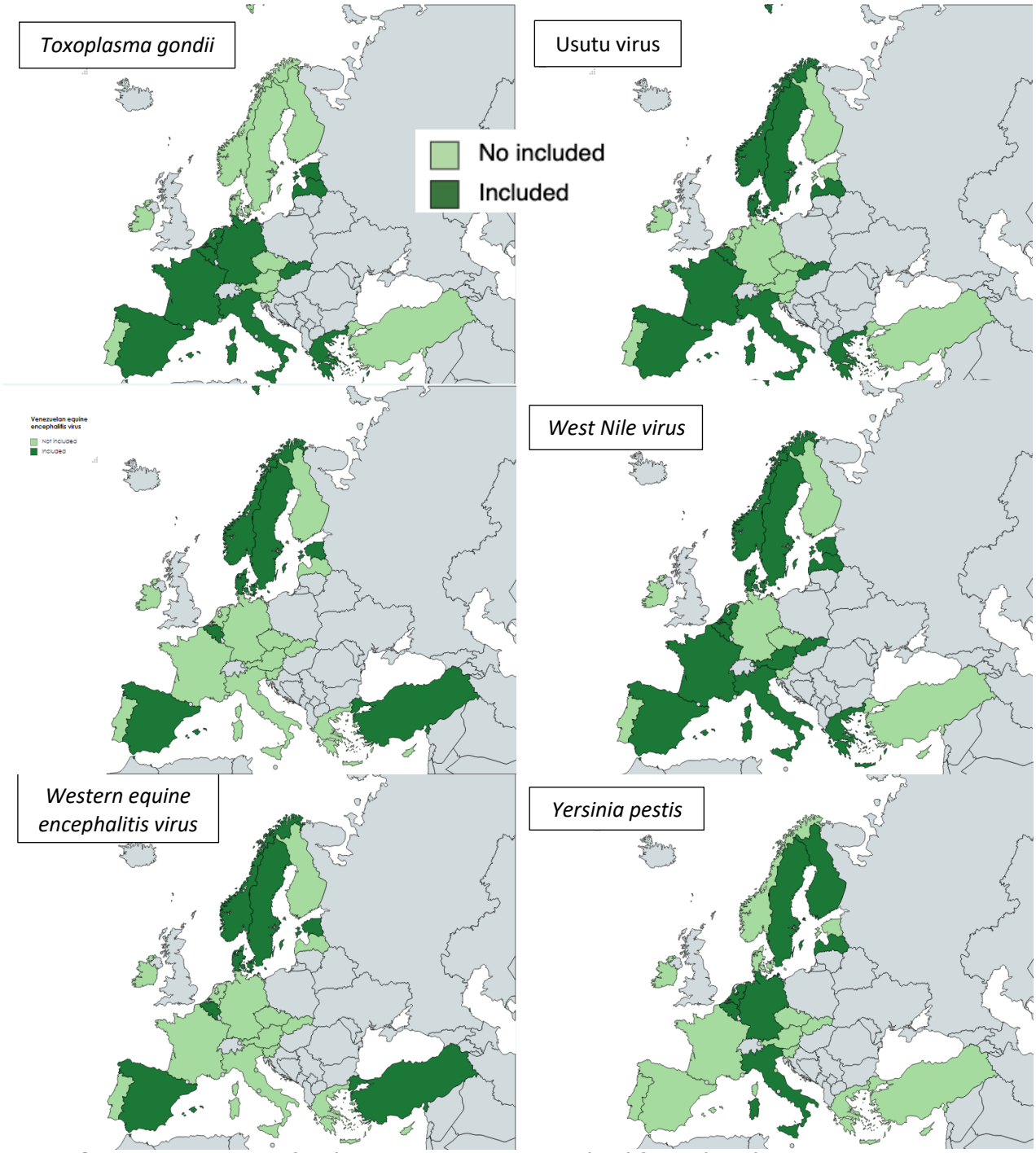


Figure 46. Presence of pathogen in SPs at Countries level for each pathogen.

The total number of pathogens of the selected list present SPs at Country level is displayed in Figure 47, indicating that the higher number of pathogens occurred in Mediterranean Countries, Belgium, The Netherlands, and Scandinavia,

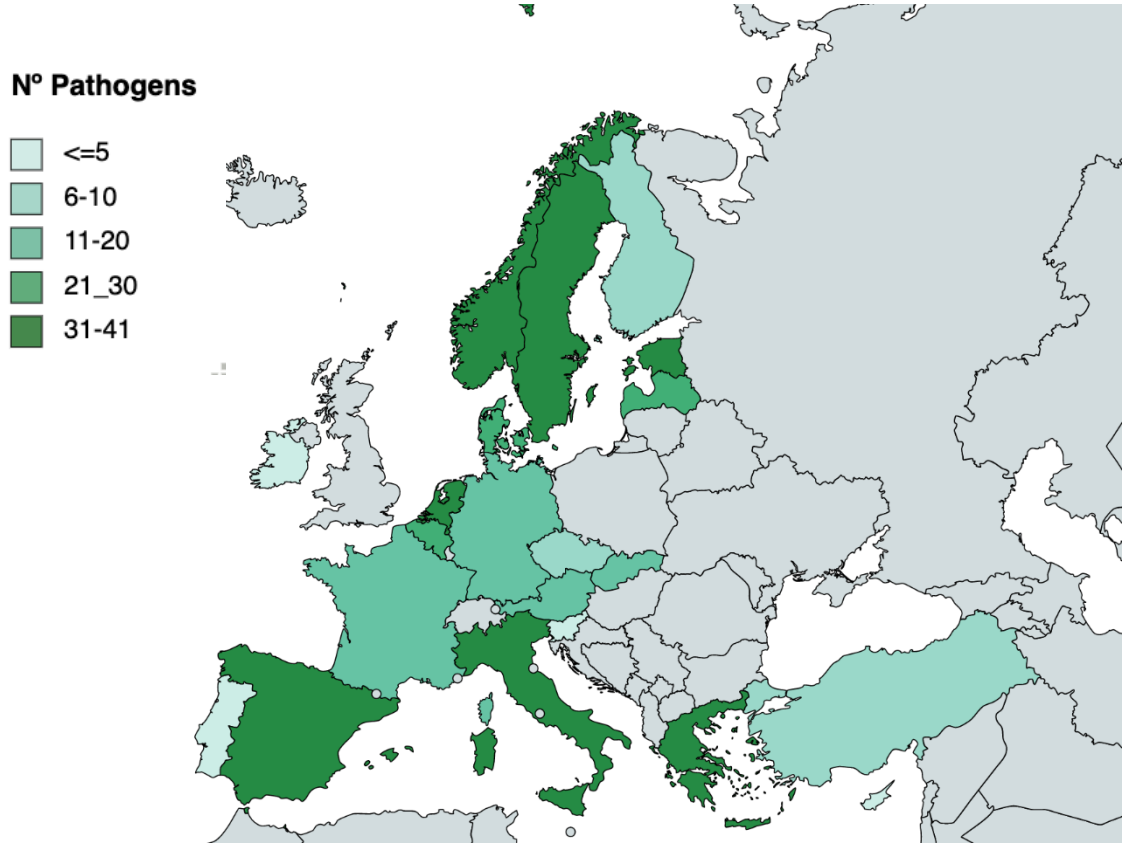


Figure 47. Number of pathogens of the selected list present SPs at Country level.

2.2.8.7. Spatial patterns of hosts included in SPs

Figure 48 displays maps representing the number of pathogens included in SP per country as a function of the specific groups of hosts that are the main reservoirs (one group per map: bats, wild rodents, wild mammals, wild birds, domestic animals, and the environment). The visualized patterns were very spatially heterogenous, and no clear spatial patterns where detected.

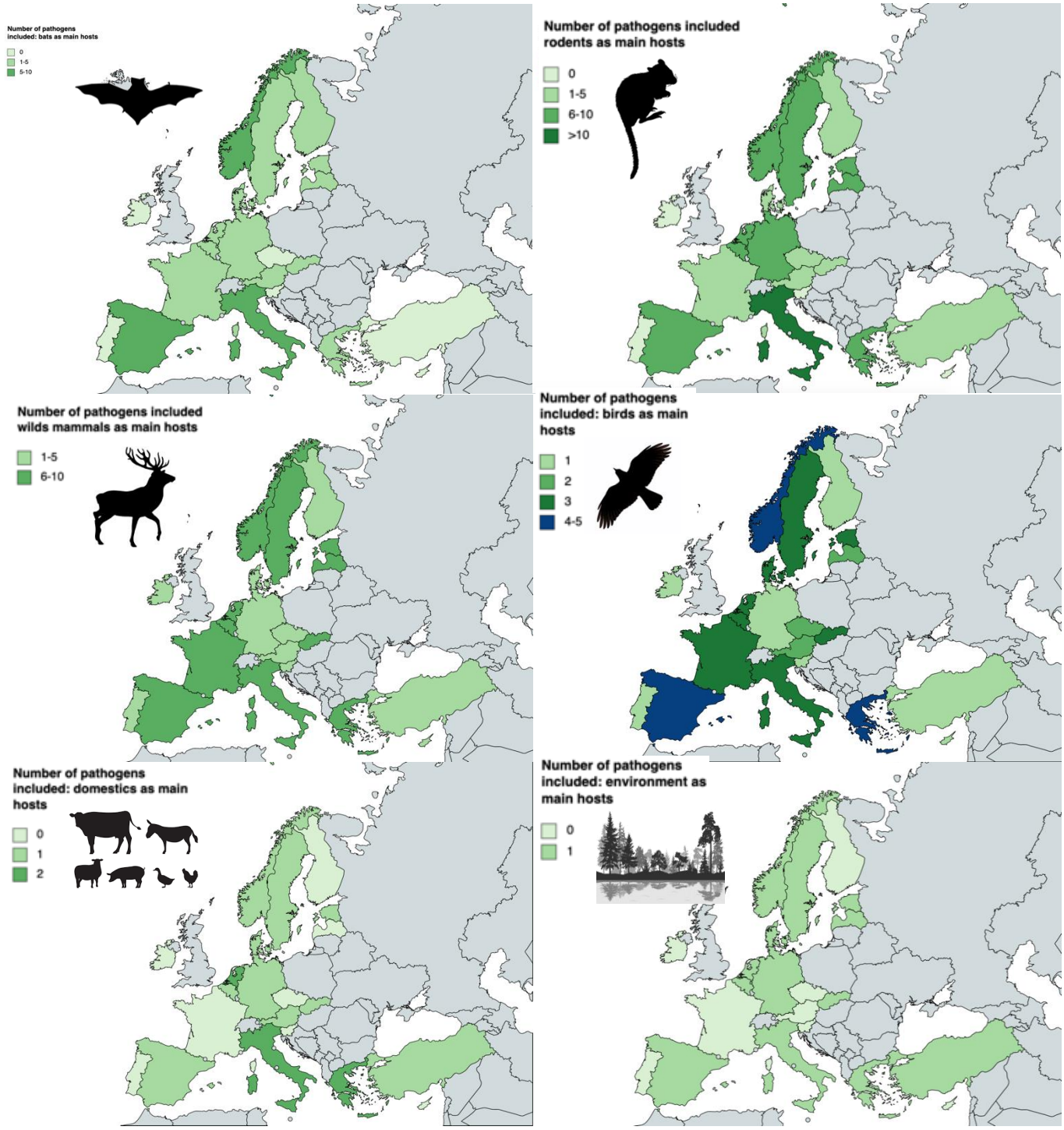


Figure 48. These maps represent the number of pathogens included in SP per country as a function of the specific groups of hosts that are the main reservoirs (one group per map: bats, wild rodents, wild mammals, wild birds, domestic animals, and the environment).

Discussion

To contextualize the information here presented, we remark that results refer to SPs from a number of countries which returned the questionnaire (n=21, mostly from the UE), which is considered a good sample rather than a complete census of SPs over Europe. We also note that we focused on a list of zoonotic diseases pre-selected for the prioritisation exercise by the OH working group of EFSA. The mapping here presented, therefore, refers to a large representation of European SPs, including different health sectors (public, animal, and environmental) including at least one of the listed zoonotic pathogens.

The fact that Human-only or Animal sectors-only clearly predominate over SPs where both sectors participated in coordination (relationship 3.2:1) indicates that **integration between sectors** is not still generalized, which is a necessary step to develop OH surveillance for such multi-host zoonotic pathogens. Programmes are mainly applied and funded at the national level, however OH approach requires an international approach as pathogens, risks and determining factors do not "care" about borders, and therefore surveillance must be planned and internationally coordinated accordingly. The integration among sectors was the exception and mainly applied to the last phase: dissemination of results. Different sectors work mainly independently and came together mainly to disseminate results of surveillance. This probably occurred because join reporting is obligatory or requested by national or international institutions. It is particularly worrying that the phase of sampling was the one with least integration among sectors (and only slightly increased for planning and analysis). This is consistent with the fact that among the dishomogeneities occurring in SPs, the one more frequently mentioned was that the number of samples differs. Sampling, planning, and analysis are essential steps to the foundations of real integrated OH surveillance. A relevant leant lesson was that integration among sectors was more frequent when different sectors oversee the coordination. This indicates that involving animal, public and environment health sectors is a necessary condition (or beneficial) for their integration over the different phases of surveillance.

Two main **factors** were **referred to as favouring (or barrier** when not implemented): the first one, "existence of appropriate Legislation", can be considered objective and a liability if implemented, whereas the second, "Interest to collaborate" maybe influenced by subjective perceptions from different health sectors and/or their awareness and knowledge about OH surveillance approach. Therefore, there is still a need to increase the interest on collaboration among sectors. No legislation will success if there is no interest to integrate other sectors, and no interest will be fruitful without the appropriate legislative framework to develop real OH surveillance. These appreciations were especially remarked as relevant by SPs where the coordination was mixed between sectors, an opinion that is particularly relevant given their experience in coordination among sectors.

Within sectors, animal health presented the higher average **number of involved institutions**, whereas the public health sector was the one involving the smaller number of institutions per SP. This may indicate that animal health, given the higher diversity of hazards (pathogens), host and environments, is more used (or requires) to involve different institutions in surveillance, for example domestic animals and wildlife institutions. We speculate that this can contribute to explain animal health as more receptive to integrate OH surveillance than other sectors.

The two most frequently **reported objectives** of the SPs were related to disease reporting, early or at the end of outbreaks: "detecting new pathogen/diseases or unusual epidemiological events", and "the demonstration of freedom from a particular pathogen/infection". Both objectives were specially remarked by SPs coordinated by different sectors. This evidences that the difficult task of determining pathogen emergence requires multi-actor coordinated SPs to be more effective. It is also worth mentioning that the objective "evaluate control or eradication strategies" was more prevalent in SPs coordinated by different sectors (except the human/animal). Given that most reported SPs only involved one single sector, we can conclude that animal and public health seldom work together to control and eradicate zoonosis in spite of their potential to do so. When the environmental sector participated in coordination, this objective was highly reported,

indicating that public health-animal health collaboration may be triggered when environment is relevant to pathogens of animal and medical interest (epidemiology, surveillance, control).

The low rates reported for presence of **evaluation processes** in SPs (approximately 50%, the external evaluation was only performed in 11 % of SPs) indicates that this activity must be promoted, and it must be done in a standardized comparable way, but flexible. The attributes to evaluate, for instance, would include the ability of a system to detect an emergent event (sensitivity) while keeping the simplest or timeliness as possible, but also acceptability, predictive value positive and representativeness. We are aware that SPs vary widely in methodology, scope, and objectives, and characteristics that are important to one system may be less important to another. The purpose of the evaluation of epidemiologic surveillance systems is to promote the best use of public/animal/environment health resources through the development of effective and efficient systems. We remind that Epidemiologic surveillance is the ongoing and systematic collection, analysis, and interpretation of health data. This information is used for planning, implementing, and evaluating health interventions and programmes (to assess the effectiveness of programs). Therefore, implementing evaluation of SPs is not minor, and is needed to promote the best use of health resources by ensuring that only important problems are under surveillance and that surveillance systems operate efficiently. While it was not the scope of this report to analyse the evaluation of surveillance systems including recommendations for their quality and efficiency must be addressed, and more importantly, what the SP requirements, which determines the characteristics to be assessed. The fact that animal health presented the higher rates of results of evaluation being used (in contrast to public health-only coordinated programmes) may indicate that the evaluation of SPs present different levels of implementation, however the general lower rates detected for this practice makes evident that an important effort is needed in all sectors to develop effective evaluation processes.

Regarding the main **characteristics of surveillance**, passive and active systems have advantages and disadvantages. The overall purpose of passive SPs is to assess trends in diseases and risk factors for disease prevention and control. Passive systems may underreport, present limited accuracy of reporting and show selection bias depending on the sources of reports or samples. However, passive systems can often be effective in an acceptable timeframe. Some of the data sources mentioned are collections for purposes other than disease surveillance and this make the integration of different sectors (e.g., environment) relevant to OH approach by contributing to passive surveillance. Active surveillance can produce early, timely and complete information, but methodology must be carefully developed, and data interpreted. No single surveillance tool is perfect, and usually combinations of approaches work best. However, according to our questionnaire, most SPs applied only passive surveillance (60%) or in combination with active surveillance (31.1%), i.e., 91% applied passive surveillance (alone nor combined with active). 8.9% of the SPs were exclusively based on active surveillance. Therefore, less than one third of SPs combined active and passive surveillance. Each SPs require its own evaluation in terms of the required passive and/or active surveillance approach (here we reported a total of 360, and this is not within the scope of this report). However, considering the specificities of each pathogen group, hosts (reservoirs), potential source, access, and types of samples, and finally, the costs (normally lower for passive surveillance), a general framework could be developed to design best strategies shared among sectors. For instance, we found that active surveillance predominated for environment-coordinated programmes (74%). Interestingly, we evidenced that combined SPs (sectors) tended to use both passive and active in relatively equilibrated proportions, probably as an integral strategy arising from the collaborative approach and complementary specialization of sectors. As indicative, combined public-animal-environmental programmes used both (passive and active) in a large proportion (76%).

Sampling design: The sampling design predominantly includes risk based (72.6% of SPs), followed by random (45.8%) and stratified sampling (29%). Random and risk-based sampling predominated in programmes were multiple sectors (animal, public health, and environment) where co-ordinately in charge, whereas stratified sampling was most frequently reported in SPs jointly coordinated by human and animal health sectors. Since risk-based design requires relevant understanding of the epidemiological context and prior information, we must consider if current

risk-based sampling, which is highly prevalent, is sound. The collaboration of sectors based on their respective expertise would help to this aim.

About **hosts/reservoirs sampled** in SPs, domestic species apart, the questionnaire evidenced the relevance of wild mammals (both game and nongame species), and to a less extent, wild birds, and the environment. Particularly, wildlife was predominant in SPs co-coordinated by animal health and environmental sectors, and the environmental sector alone. However, an important fragmentation of SPs occurs in terms of the number of different groups hosts sampled: the average number of different groups of hosts sampled per SP was about 2, even tending to lower values for the animal health and environmental sectors. This is illustrative of the large level of fragmentation of SPs occurring in Europe and the challenge is to integrate different SPs to really integrate OH surveillance. OH focused surveillance integrates different health sectors (including environment), but also needs to consider multi-pathogen multi-hosts and environment systems as a whole, and this maybe constrained by fragmented surveillance, especially if different SPs are not coordinated.

Beyond the fact that the number of pathogens included in surveillance system per country according to the taxa was variable, we remark that the average number of **pathogens** (of the list, separately for each taxon) included per SP was less than one. This is because the number of pathogens included per single SP is normally low, and often multiple pathogen taxa are not represented. This is similarly indicative of the degree of fragmentation of SPs. Multiple host SPs may benefit at all steps of the process (planning, sampling, analysis, dissemination), both, in terms of logistics and costs, being able to integrate multi-pathogen multi-hosts and environment systems as a whole.

A relevant exercise to evaluate and improve future European SPs will be to compare the actual sampled hosts/reservoirs species and the **primary hosts/reservoirs for the selected pathogens.** For instance, domestic animals are among those more frequently sampled by SPs, but not preferential main hosts for most pathogens of the list, and the opposite occurred for wild birds. Wild mammals predominated as the main potential reservoirs for the selected list of pathogens. Some of them, such as wild ungulates, are widely distributed all over the continent and are involved in similar conflicts, including sharing diseases. This situation requires a common transboundary approach over Europe. A relevant proportion included birds as main hosts (about 30%), many of which are migratory and may carry pathogens all over Europe. This reinforces the need of coordinated SPs in the continent as pathogen does not care about borders.

Approximately half of the pathogens here considered are **vector borne**, and the main vectors included, in this order of frequency, are mosquitoes and ticks (to a less extent fleas, sand flies and trombiculid mites). This adds a new dimension to the complex scenario of pathogens, hosts, and environment subject to surveillance. Activities developed on vector surveillance were not included in the scope of the present report. However, the main recommendations presented by this report should apply to vector surveillance (see discussion above and final section about recommendations), including the fact that an enormous fragmentation and heterogeneity of SPs occurs over Europe. The surveillance of vectors should be integrated together with pathogens and addressed in coordination by the different health sectors. As indicative, the proportion of vector borne pathogens included in surveillance systems was higher for the environmental sector so as for SPs where the three sectors, public, animal, and environmental heath, were coordinated in charge.

3. Literature review on the main existing structures and systematic activities for surveillance in the EU for zoonoses (transboundary, emerging and re-emerging) in domestic animals and wildlife

In order to assess a different source of data on disease surveillance (literature browsers and grey sources for non-indexed documents), this section presents the **literature review** on the main existing structures and systematic activities for surveillance in the EU for zoonoses (transboundary, emerging and re-emerging). A literature review on zoonotic disease surveillance targeting the environment is also presented in a separate report.

3.1. The literature review

Our approach aimed at searching for documents describing systematic and structured surveillance systems targeting zoonotic diseases in humans, domestic animals, and wildlife in Member states and neighboring countries. The list of target zoonotic pathogens has already been produced by EFSA. The target pathogens/diseases included were the following (as they were included in the search strings):

((Bacillus anthracis) OR Brucella OR Chikungunya OR (Crimean-Congo haemorrhagic fever) OR Cryptosporidium OR (Eastern equine encephalitis) OR (Ebola virus disease) OR Echinococcus OR (Erysipelothrix rhusiopathiae) OR Giardia OR (Burkholderia mallei) OR Hantavirus OR (Rickettsia Helvetica) OR (Hepatitis E) OR (avian influenza) OR (swine influenza) OR (Japanese encephalitis) OR Lassa OR Leishmania OR Leptospira OR (Borrelia burgdorferi) OR (Lymphocytic choriomeningitis) OR Marburg OR (Rickettsia conorii) OR MERS-Coronavirus OR Monkeypox OR (Rickettsia typhi) OR Nipah OR (Yersinia pestis) OR (Coxiella burnetiid) OR Rabies OR (Rift Valley fever) OR (Tick-borne encephalitis) OR (Toxoplasma gondii) OR (Francisella tularensis) OR Usutu OR (West Nile))

Scientific databases

Our approach aimed at searching academic, peer-reviewed articles/documents describing Transboundary and emerging zoonotic disease surveillance systems in the EU using:

- Biomedical databases (Embase)
- Science databases (ISI web of Science, Pubmed)

The search string used was:

(List of pathogens) AND (Surveillance OR Monitoring*) AND (List of countries) AND (Country OR State OR Nation-wide OR National)

Table 6 details the search terms and string used.

Table 6. Detailed search string used for indexed literature.

Concept to address	Target	Terms	String
Hazards (pathogens)	Topic (Title, Abstract, Keywords)	Bacillus anthracis OR Brucella OR Chikungunya OR Crimean-Congo haemorrhagic fever OR Cryptosporidium OR Eastern equine encephalitis OR Ebola virus OR Echinococcus OR Erysipelothrix rhusiopathiae OR Giardia OR Burkholderia mallei OR Hantavirus OR Rickettsia helvetica OR Hendra virus OR Hepatitis E OR Influenza avian OR Influenza swine OR Japanese encephalitis OR Lassa OR Leishmania OR Leptospira OR Borrelia burgdorferi OR Lymphocytic choriomeningitis OR Marburg virus OR Rickettsia conorii OR MERS-Coronavirus OR Monkeypox OR Rickettsia typhi OR Nipah virus OR Omsk haemorrhagic fever OR Yersinia pestis OR Possawan virus OR Coxiella burnetii OR Rabies OR Rift Valley fever OR Orientia tsutsugamush OR Shuni virus OR Sindbis virus OR St. Louis encephalitis OR Thogoto virus OR Tick-borne encephalitis OR Toxoplasma gondii OR Francisella tularensis OR Usutu virus OR Venezuelan equine encephalitis OR Wesselsbron virus OR West Nile OR Anthrax OR Brucellosis OR Cryptosporidiosis OR Echinococcosis OR Erysipelothricosis OR Giardiasis OR Glanders OR Leishmaniosis OR Leptospirosis OR Lyme borreliosis OR Mediterranean Spotted Fever OR MERS OR Murine thypus OR Plague OR Q-fever OR SARS OR Scrub typhus OR Toxoplasmosis OR Tularemia	Hazards [Topic] AND Surveillance activities [Title] AND Geography [Topic] AND Coverage [Topic]
Surveillance activities	Title	Surveillance OR monitor*	
Geography	Topic (Title, Abstract, Keywords)	Albania OR Latvia OR Andorra OR Liechtenstein OR Armenia OR Lithuania OR Austria OR Luxembourg OR Azerbaijan OR Malta OR Belarus OR Moldova OR Belgium OR Monaco OR "Bosnia and Herzegovina" OR Montenegro OR Bulgaria OR Netherlands OR Croatia OR Norway OR Cyprus OR Poland OR "Czech Republic" OR Portugal OR Denmark OR Romania OR Estonia OR Russia OR Finland OR "San Marino" OR Macedonia OR Serbia OR France OR Slovakia OR Georgia OR Slovenia OR Germany OR Spain OR Greece OR Sweden OR Hungary OR Iceland OR Switzerland OR Ireland OR Turkey OR Italy OR Ukraine OR Kosovo OR "United Kingdom" OR Algeria OR Egypt OR Libya OR Morocco OR Sudan OR Tunisia OR Sahara OR Bahrain OR Cyprus OR Egypt OR Iran OR Iraq OR Israel OR Jordan OR Kuwait OR Lebanon OR Oman OR Palestine OR Qatar OR "Saudi Arabia" OR Syria* OR "United Arab Emirates" OR Yemen OR Europe OR European Union OR EU	
Coverage	Topic (Title, Abstract, Keywords)	country OR state-wide OR nation-wide OR national	

We obtained a total of 575 references (Table 7) after the removal of duplicates. In addition to references retrieved directly from scientific browsers, we examined the literature cited to identify missing references.

Table 7. Outputs (number of references) rom Literature review on the main existing structures and systematic/academic initiatives academic activities for surveillance in the EU for zoonoses

(transboundary, emerging and re-emerging) in humans, domestic animals, and wildlife. The inclusion criteria are presented.

Outputs in ISI	Outputs in PubMed	Outputs in Embase	Total with duplicates removed	Inclusion Criteria
386	240	226	575	1. Does the Paper describe a Systematic and Structured Surveillance System? 2. Does the Surveillance System monitor a zoonotic emerging disease? 3. Is the Surveillance System applied in MSs or neighbouring countries?

Grey literature

In parallel to a "free-text search", a standardized strategy should be applied for each country:

1. **Translate** the following string into the language of the country:
   ((surveillance plan) OR (monitoring plan)) AND (list of diseases)
   When needed, translate the diseases and substitute to the English names.
   Boolean operators (AND/OR) shall remain the **same**.
2. **Split the search** in 4 or more parts. Google platform will only search for the first 32 words of your string, so divide the string into enough parts so that all pathogens will be searched. Each part shall begin with ((surveillance plan) OR (monitoring plan)) AND (part of the list of diseases). See example at the end.
3. **Run each search** in **google search bar**.

Example of search strings (for Italy):
Search string 1: *((piano di sorveglianza) OR (piano di monitoraggio)) AND ((Bacillus anthracis) OR Brucella OR Chikungunya OR (Febbre emorragica di Crimea-Congo) OR Cryptosporidium OR (Encefalite equina dell'Est) OR (Ebola virus) OR Echinococco OR Echinococcus OR (Erysipelothrix rhusiopathiae) OR Giardia OR (Burkholderia mallei) OR Hantavirus))*
Search string 2: *((piano di sorveglianza) OR (piano di monitoraggio)) AND ((Rickettsia Helvetica) OR (Epatite E) OR (Influenza aviare) OR (Influenza suina) OR (Encefalite giapponese) OR Lassa OR Leishmania OR Leptospira OR (Borrelia burgdorferi) OR (Coriomeningite linfocitica) OR Marburg OR (Rickettsia conorii) OR MERS-Coronavirus OR Monkeypox)*
Search string 4: *((piano di sorveglianza) OR (piano di monitoraggio)) AND ((vaiolo delle scimmie) OR (Rickettsia typhi) OR Nipah OR (Yersinia pestis) OR (Coxiella burnetiid) OR Rabbia OR (Febbre della Valle del Rift) OR (Encefalite trasmessa da zecche) OR (Toxoplasma gondii)*)
Search string 5: *((piano di sorveglianza) OR (piano di monitoraggio)) AND ((Francisella tularensis) OR Usutu OR (West Nile))*

The string was adjusted the way partners found it more suitable for their country(ies). The documents that refer to a national or subnational systematic surveillance system targeting the pathogens in the list and addressing any domain (human, environment, wildlife, and domestic animals) were retrieved. Documents shall include the description of the surveillance system. Documents should be official and therefore come from government agencies or official veterinary services (exclude documents produced by private laboratories if not part of an official surveillance plan or articles from newspapers/online newspapers). If documents come from a supernational surveillance plan (e.g., ECDC reports,…), were included as well. All surveillance systems currently ongoing or concluded within the last 10 years were reported.

Exclusion/inclusion criteria

This was done in a systematic way, and the procedure and steps performed to review the literature are summarized in Figure 49. The criteria for inclusion in the review were:

1. Does the Paper describe a Systematic and Structured Surveillance System?
2. Does the Surveillance System monitor a zoonotic emerging disease?
3. Is the Surveillance System applied in MSs or neighboring countries?

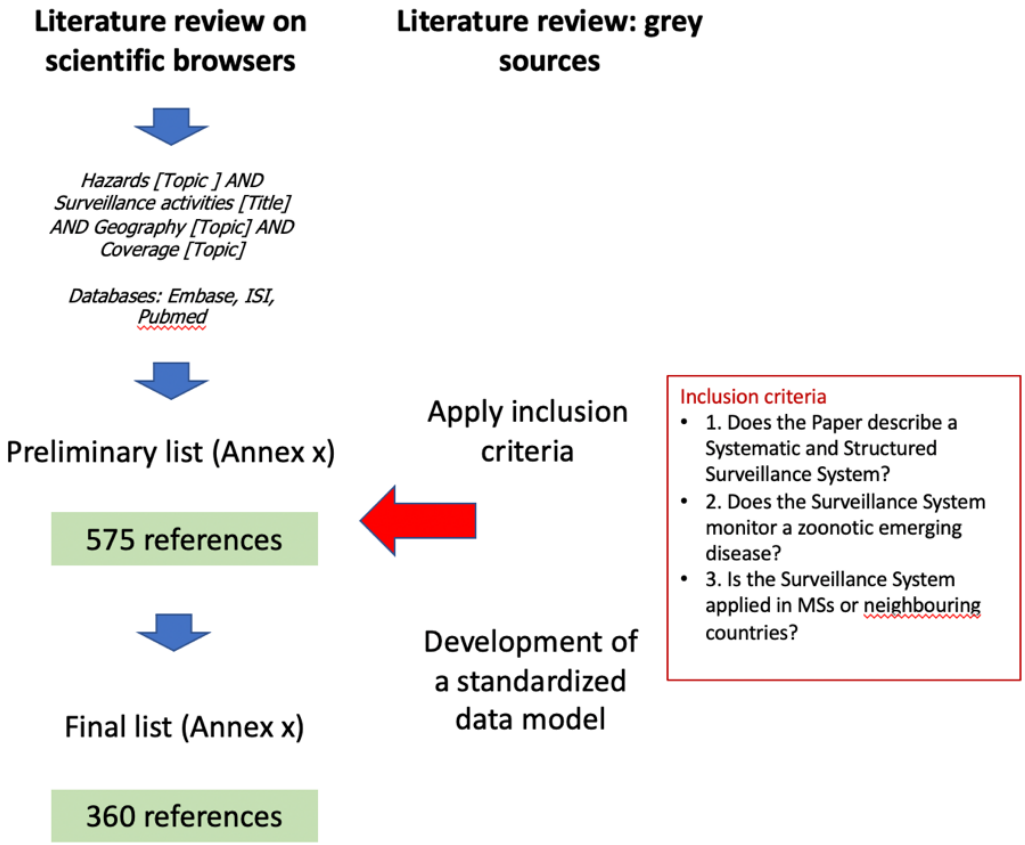


Figure 49. Procedure and steps performed to review the literature on the main existing structures and systematic/academic initiatives academic activities for surveillance in the EU for zoonoses in the present report.

The data model

A standardized data model (see Annex 4[7]) was used to extract key information to characterize the surveillance systems. Variables were categorized, for which an associated vocabulary with definitions was developed (references sheet). The data model was divided into two parts:

- PART 1 – Surveillance system (explores the general organization)
- PART 2 – Pathogens (identifies the target pathogen, species, and methods)

The Annex 4 details the data model used to gather information.

3.2. Data analysis

Data was collected at reference level, normally several of them per country, each coordinated by one or multiple institutions belonging to one of different health sectors (animal health, public health, environmental authorities, or in coordination), with variable objectives and focusing on different pathogen/s (of different nature and epidemiological characteristics). All this heterogeneity is considered to describe and map official SPs in EU at different levels:

First, we present general information on the references describing SPs over the countries. Thereafter, following the structure of the questionnaire, we organise the presentation of results like this:

- **Coordination** of the SP
- **Integration among sectors** (animal health, human health, environmental health) within the surveillance scheme
- Participating **Institutions**
- **Geographical** and **temporal** coverage
- **Objectives**
- **Pathogens** and target **hosts**
- **Characteristics of surveillance**, such as target hazards, sampling design, type of samples

3.3. Results

3.3.1. General

Our approach aimed at searching for documents describing systematic and structured surveillance systems targeting zoonotic diseases in Member states and neighboring countries in scientific databases and grey literature available in the web. Initially, 712 references were retrieved (after duplicates were removed).

These 712 studies were initially retrieved from literature browsers (n=575), and to a less extent, from grey literature sources (n=207). The application of exclusion and inclusion criteria resulted in a total of 380 surveillance systems (Annex 4). These pertain to 364 references, as some references described more than one surveillance system.

Regarding the **origin of funding**, the proportion and number of surveillance systems are summarized in Figure 50, being mainly national (58,68%). International refers to funding from outside EU, from more than one country or in the case where funding is from outside the country where surveillance is implemented.

[7] https://doi.org/10.5281/zenodo.7446484

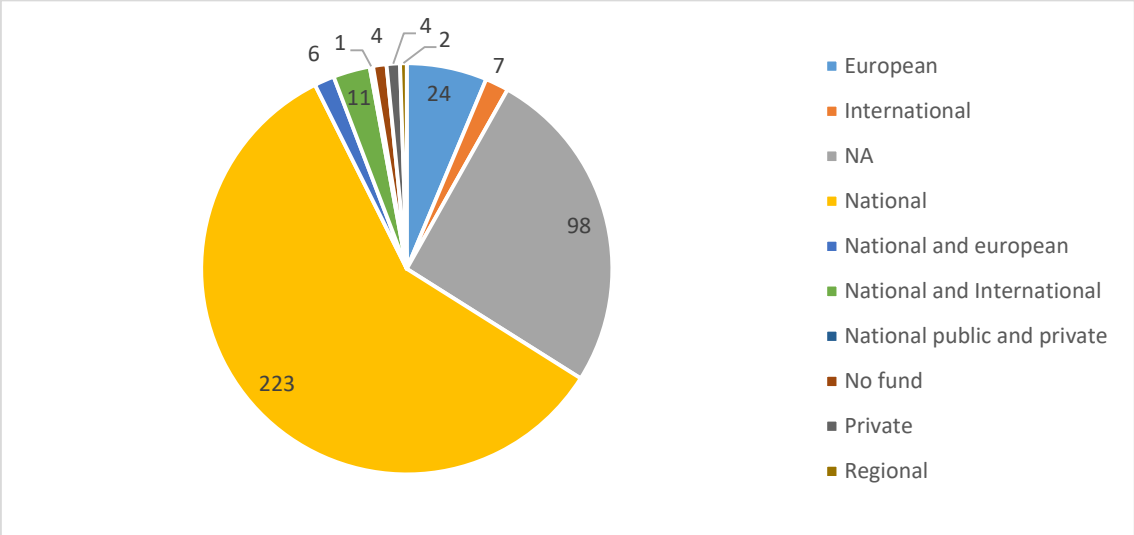


Figure 50. The origin of funding (the proportion and number) of SPss (n=380).

The sustainability of the funding (Figure 51) was not reported by most studies (n=316), but for those that did (n=64), the duration of funding is shown in Figure 51, where 46.9% have continuous funding. When looking at the surveillance systems with continuous funding they are mainly from national origin (Figure 52).

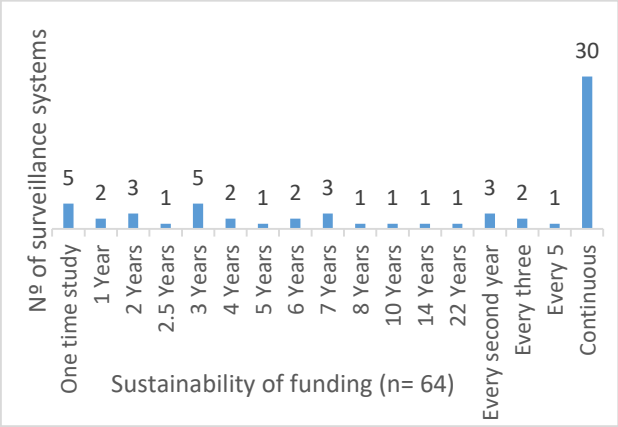


Figure 51. Sustainability of funding (n=64).

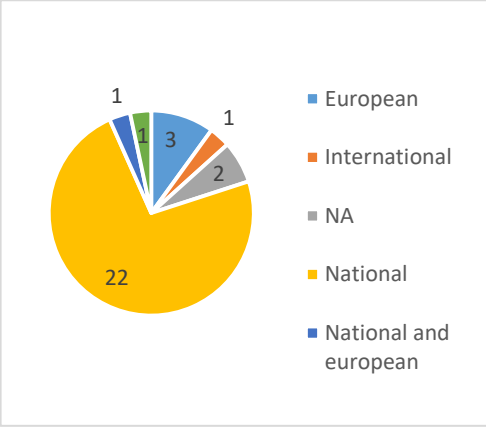


Figure 52. Origin of continuous funding (n=30).

Information on status of the surveillance system was also gathered (n=266), we looked into if they were an atonomous system or rather part of a bigger surveillance system, results are shown in Figure 53.

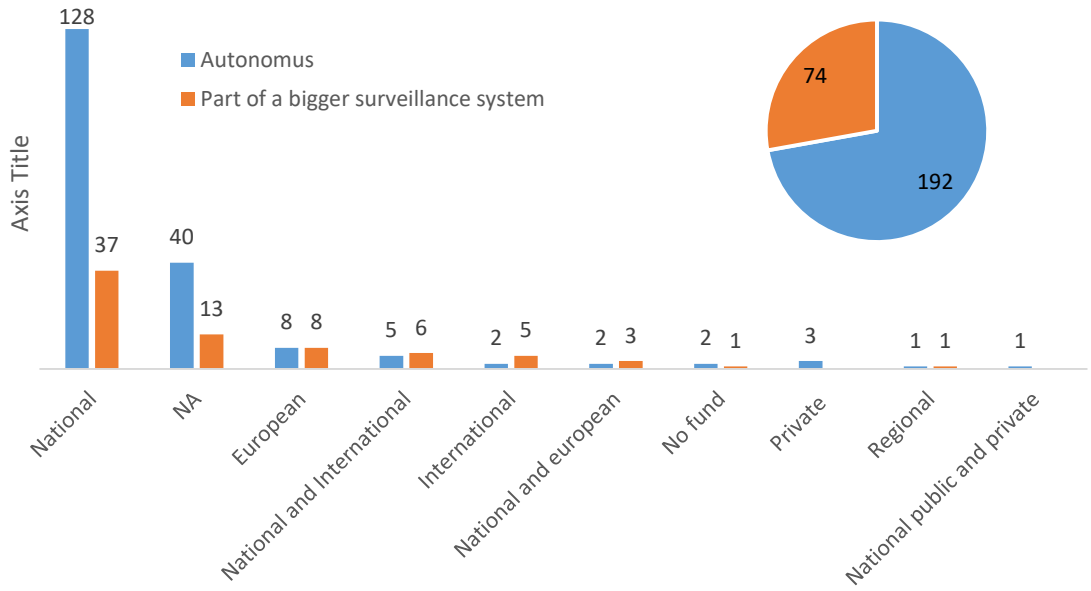


Figure 53. Number of surveillance systems by their status. Relative Frequency (n) and results present by origin of funding as well.

3.3.2. Coordination of the SPs

If we look into the coordination of the SP (Figure 54), in 60.75% of them the coordination was done by more than one institution (n=195), while the remaining 39.25% (n=126) was done by one single institution.

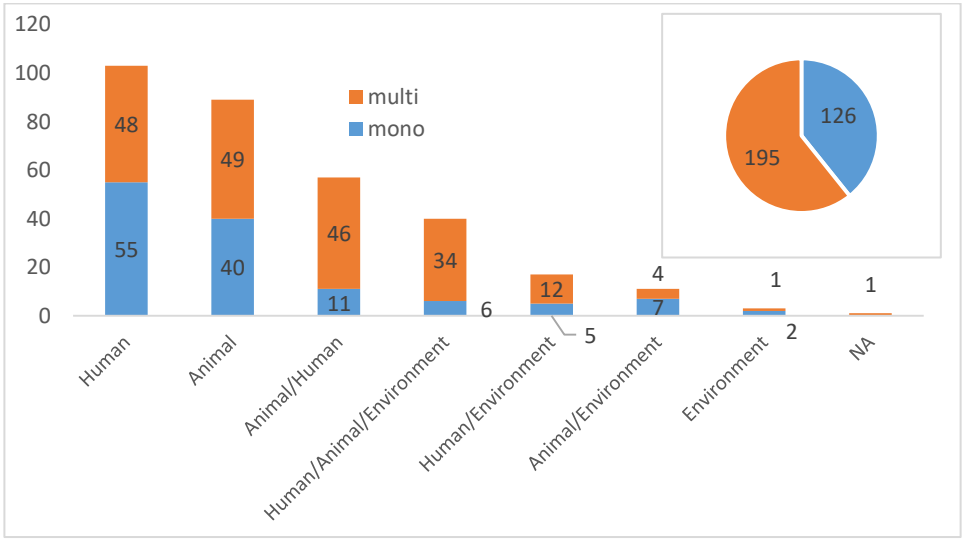
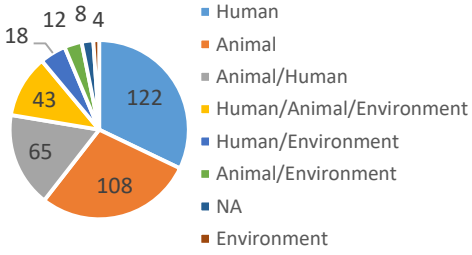


Figure 54. Coordination of the SPs (by one single institution or "mono" and by multiple institutions or "multi"). Relative frequency (n=321), and information is also shown by sector.

The analysis of the number of SPs by sector participating in coordination (type of health organization) indicates that separetly both human and animal sectors predominate (in total accounting for 60.5% of surveillance systems, Figure 55). These are followed by surveillance systems where both sectors (Animal/Human) were coordinately participating (n=65) and by surveillance systems where all sectors participate (Ani
extent, other combinations of sectors participitaded.



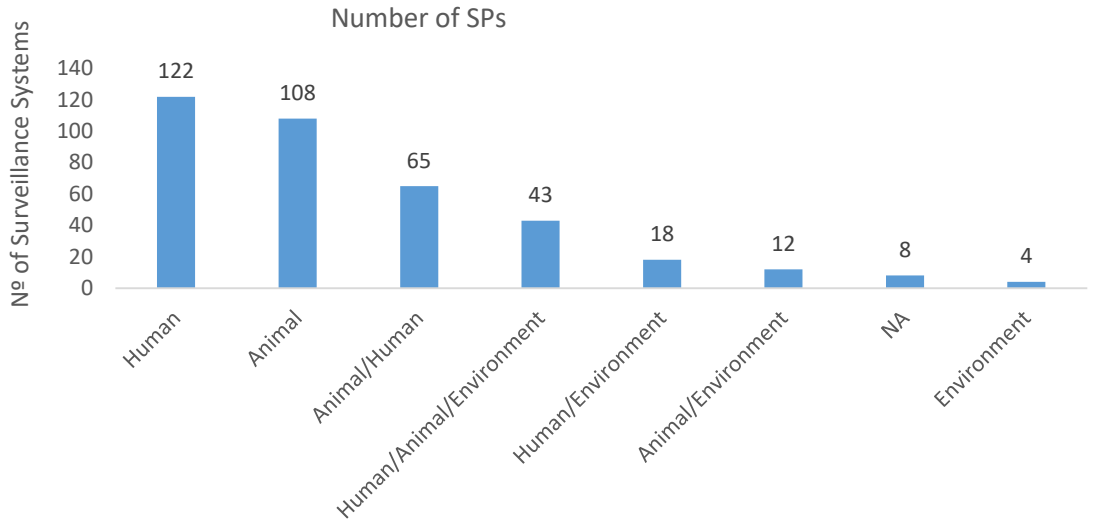


Figure 55. Number of SPs by sector (type of health organization in charge), n=380.

3.3.3. Integration

The integration/collaboration among Human, Animal, or Environmental agencies during the different phases of the surveillance system (planning, sampling, testing/analysis of data, and dissemination) are indicated in Figure 56, ranging about 30% of SPs. The highest collaboration occurs during planning, where from the 380 SPs, 129 collaborate in planning, followed by dissemination (n=122), sampling (n=117) and testing and analysis (n=102).

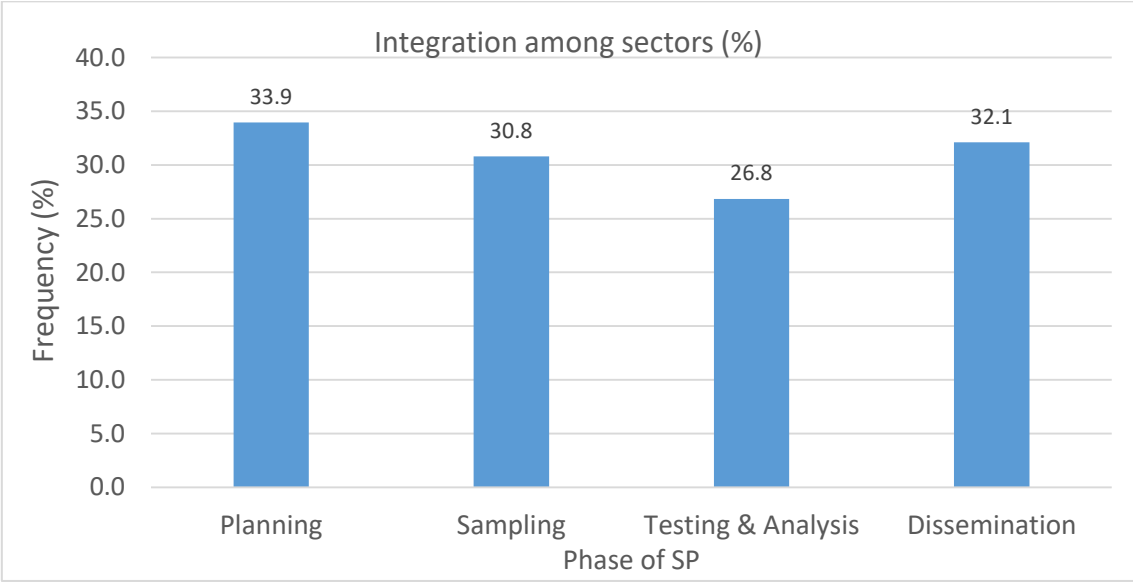


Figure 56. Number of surveillance systems that integrate/collaborate during each phase (from planning to dissemination) of the SP.

The frequency of surveillance systems (n=380) that do not collaborate in any phase (0 phases) amounts to 29.21% (n=111, Figure 57). It is followed by systems that collaborate in at least one phase 17.1% (n=65). Systems that collaborate in more than one phase (2–3 phases) equals to 17.6% of surveillance systems. And finally, 16.5% (n=59) collaborate in all 4 phases.

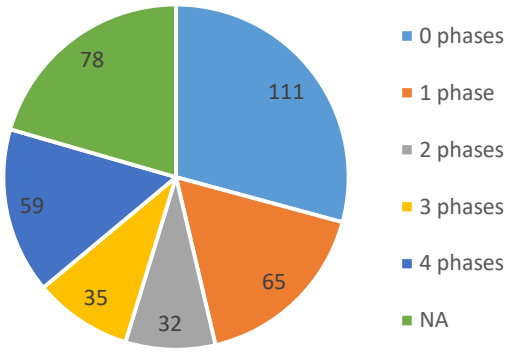


Figure 57. Frequency of surveillance systems by the number of phases where integration/collaboration occurs (n=380).

When assesing the favouring factors and barriers to collaboration (Figure 58), out of the 380 surveillance systems, "initiatives" were the most reported one (n=67) followed by "facilities and interests".

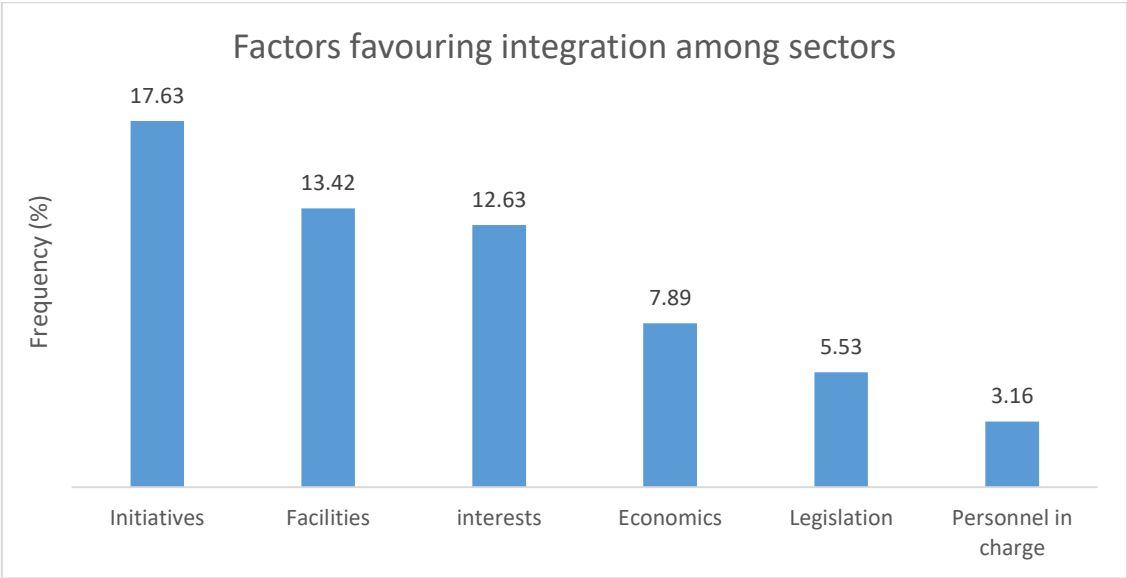


Figure 58. Factors favouring integration among sectors.

In relation to the identified barriers for collaboration (Figure 59), very few surveillance systems reported such information. The "Economical" barrier was the most reported, followed by "Facilities" and "Personnel in charge". Some reported other barriers, such has lack of/not enough data and lack of awareness/knowledge.

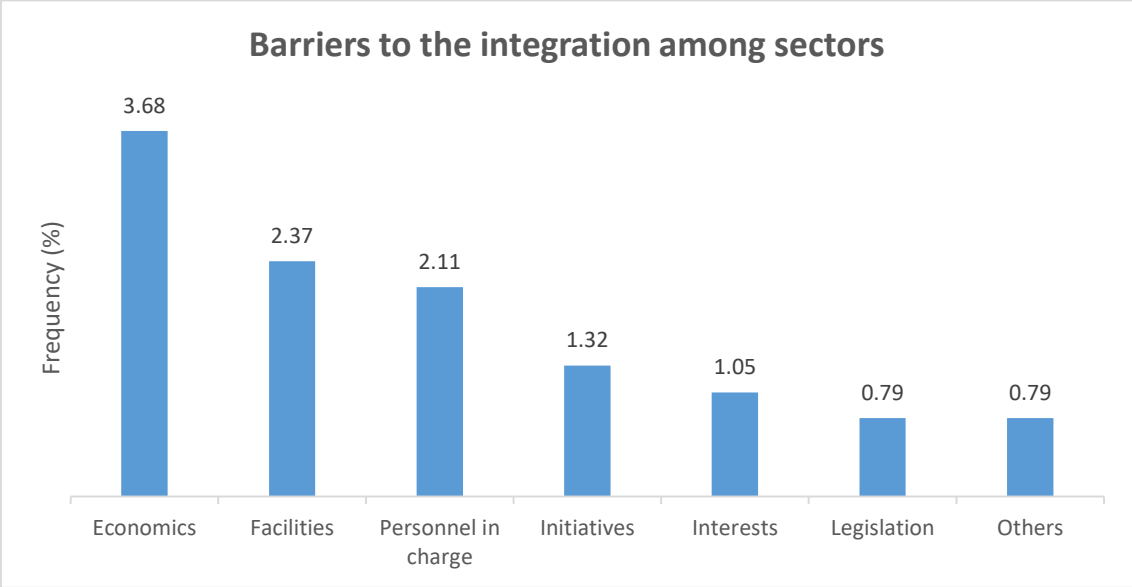


Figure 59. Barriers to the integration among sectors.

3.3.4. Participating Institutions

The institutions participating in the surveillance are diverse and represent different sectors, as displayed in Figure 60. The hunting sector was the institution most frequently involved, followed closely by official laboratories. Research Institutions were the third type of institution more frequently involved. Pharmaceutical companies ranked the lowest (involved in 2.63% of SPs). Other institutions mentioned by respondents included: dog kennels, women's health centers, wastewater treatment plants, Blood centers, and ornithologists. The number of Institutions participating in surveillance averaged 5.24, ranging up to 12 (Figure 61).

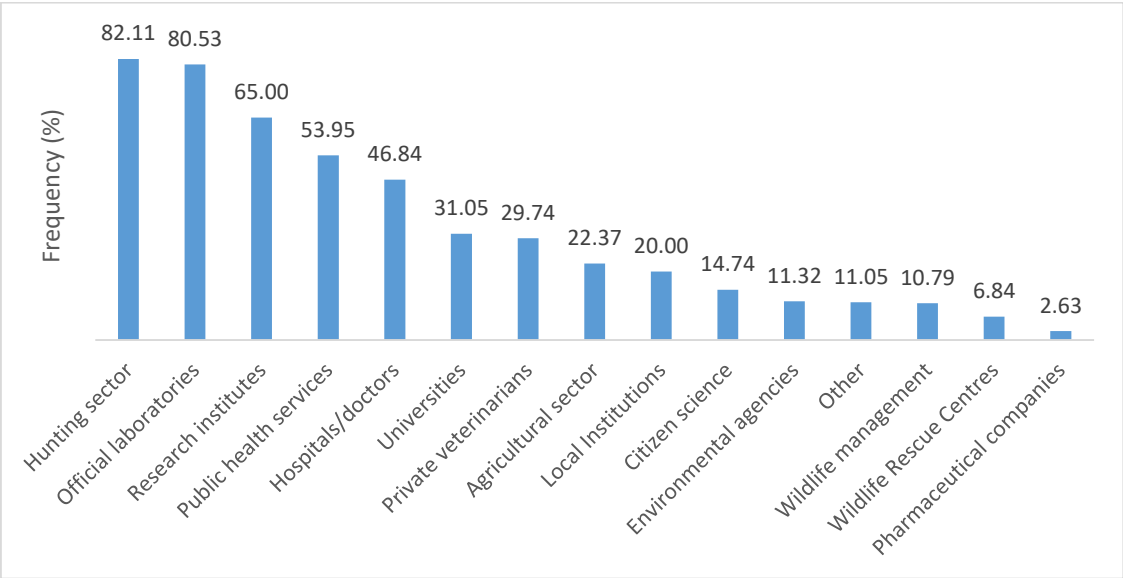


Figure 60. Contribution (frequency) to the SPs here analysed (n=380) of the different Institutions participating in surveillance.

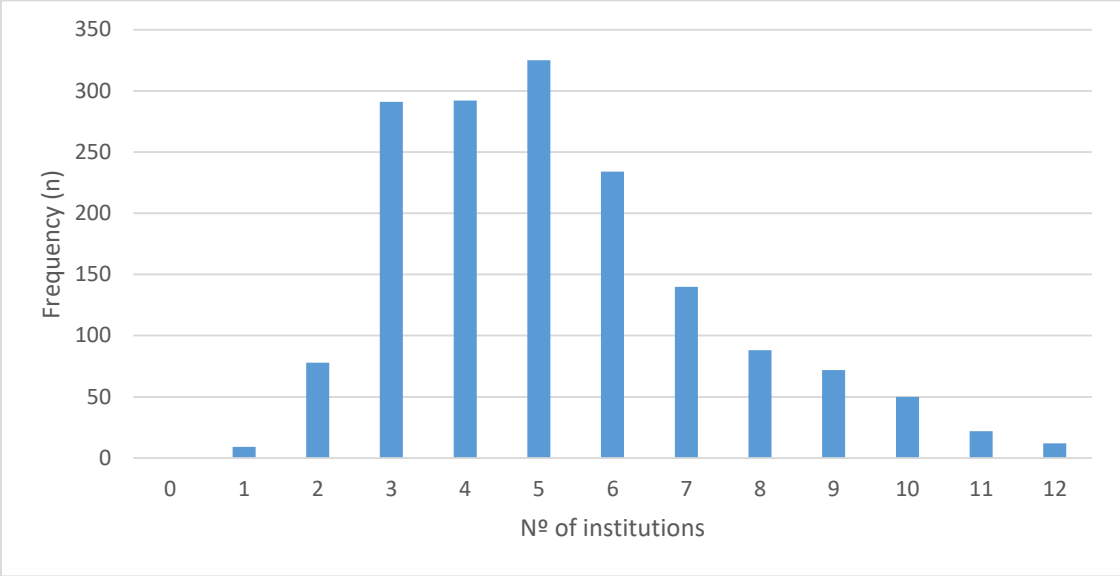


Figure 61. Number of institutions participating in the SP.

3.3.5. Geographical and temporal coverage

The sectoral graph (Figure 62) indicates that most SPs operated at the national level (73.16%), followed by subnational (13.42%). The remaining 11.06% operated at the supranational level. The frequency of establishment of SPs (number by year) is represented in the Figure 63.

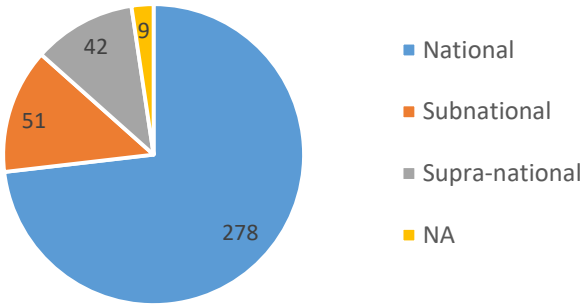


Figure 62. Geographical coverage of SPs (national, subnational, or supranational).

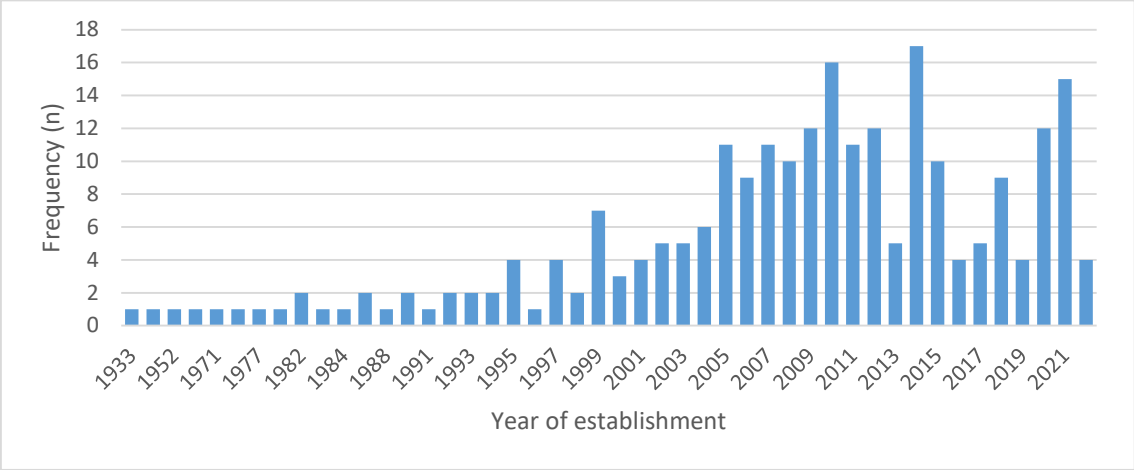


Figure 63. Timeline indicating the frequency of establishment of SPs (number by year).

3.3.6. Objectives

The objectives of the surveillance systems are summarized in Figure 64. The most frequently reported objective was to document the distribution and spread of a health event (32.37%) followed closely by trends monitoring to improve knowledge (30.79%).

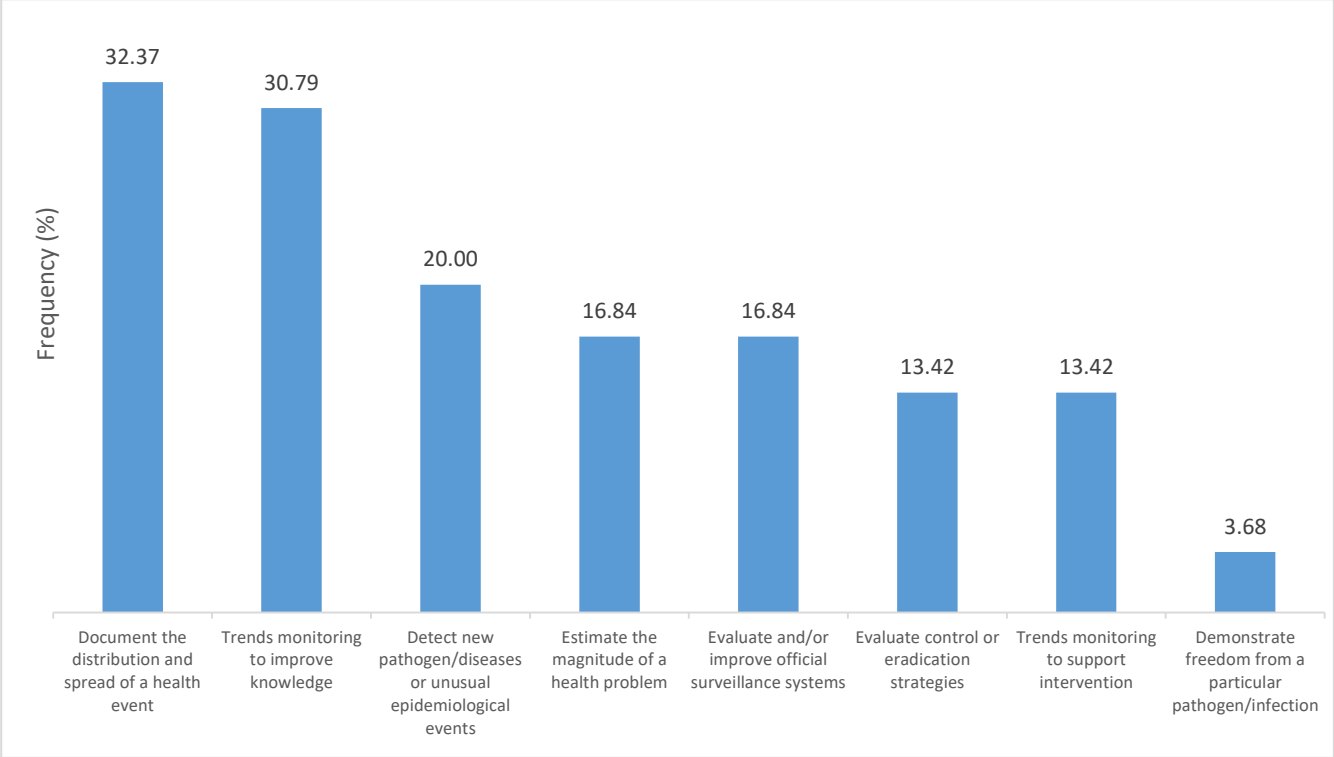


Figure 64. Frequency of different objectives (non-mutually exclusive) of the SPs (N=360).

3.3.7. Characteristics of surveillance

3.3.7.1. Active *vs* passive surveillance

Figure 65 displays the frequency of passive and active surveillance (or combined) applied by surveillance systems. Most surveillance systems applied either passive surveillance (26.9%) or combined active and passive surveillance 27.1%. Only 18.4% of the SPs were exclusively based on active surveillance.

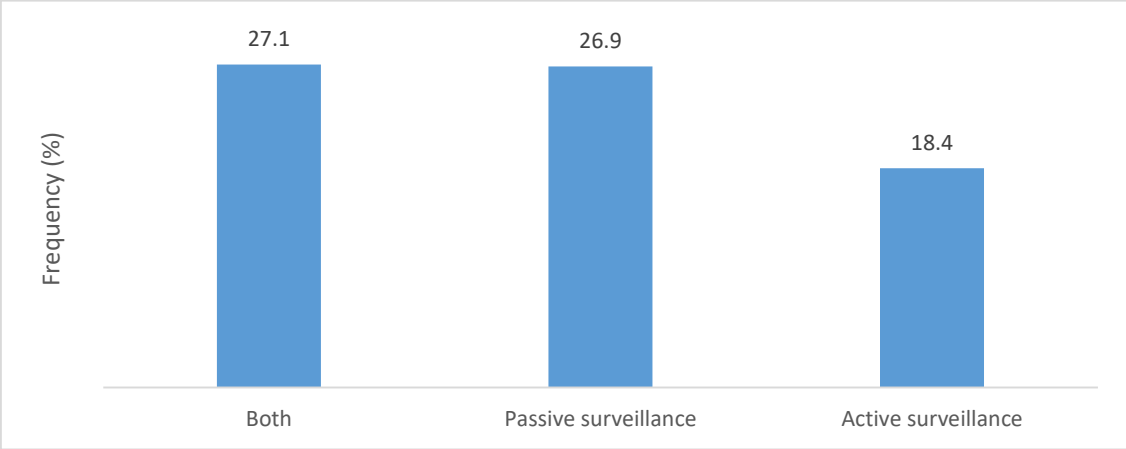


Figure 65. Frequency of passive and active surveillance (or combined) applied by SP

3.3.7.2. Sampling design

The sampling design (Figure 66) predominantly includes risk-based (50.4%), followed by random (46.3%) and stratified sampling (15%).

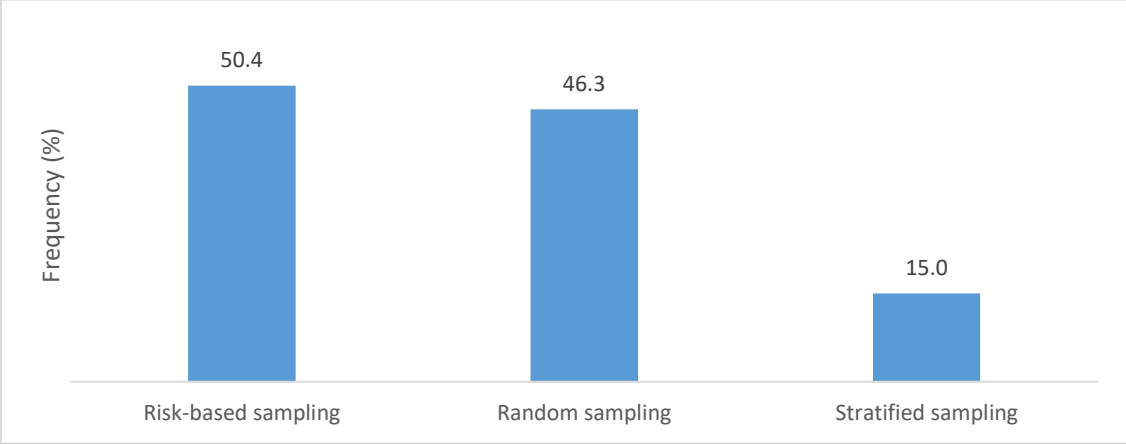


Figure 66. Frequency (%) of sampling design (non-mutually exclusive) of SPs.

As for the porprotion of surveillance system that store samples, only 11.4% (n=76) report to do so.

3.3.7.3. Hosts sampled

The sampled hosts are summarized in Figure 67. There is a marked predominance of human samples (44.8%) followed by livestock, wild birds, and vectors.

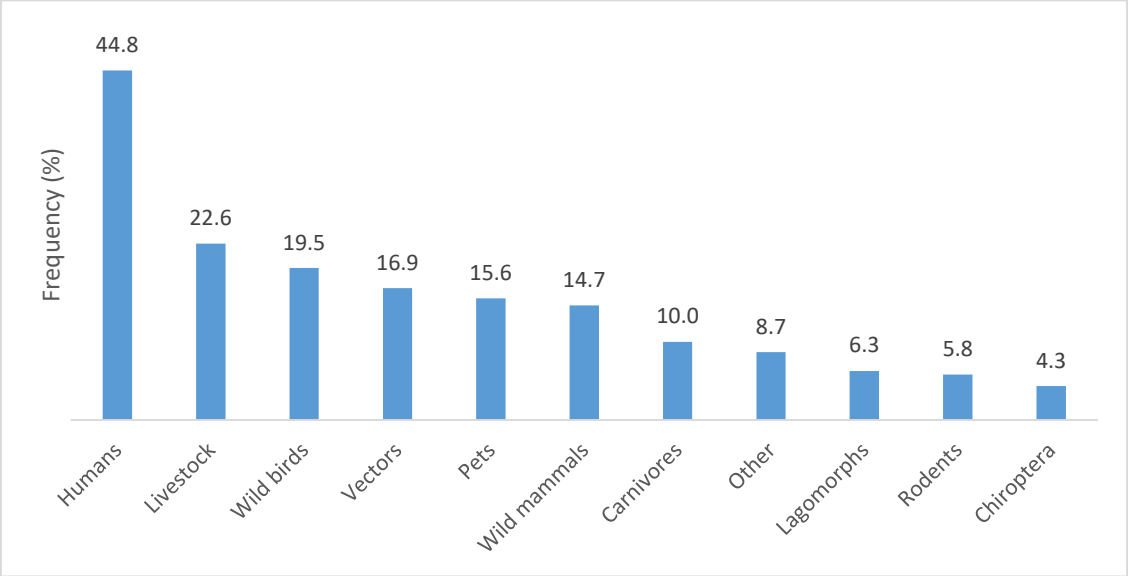


Figure 67. Frequency (%) of sampled hosts.

3.3.7.4. Target pathogens

Figure 68 details the list of pathogens (n=39). Viral agents predominate (n=367), followed by bacteria (n=200), protozoa (n=48, *Toxopama gondii, Leishmania, Giardia* and *Criptosporidium*), and helminths (n=1, *Echinococcus* spp). Others include surveillance systems that reported non-specific surveillance (either any pathogen/all pathogens), notifiable diseases or other diseases outside the EFSA's 50 pathogen list, such as: dengue, tuberculosis, *Trichinella spiralis* and zika virus. West Nile Virus was the most frequently included pathogen (13.5%), followed by *Brucella* spp (10.3%), Avian Influenza (9.3%) and Rabies (7.2%).

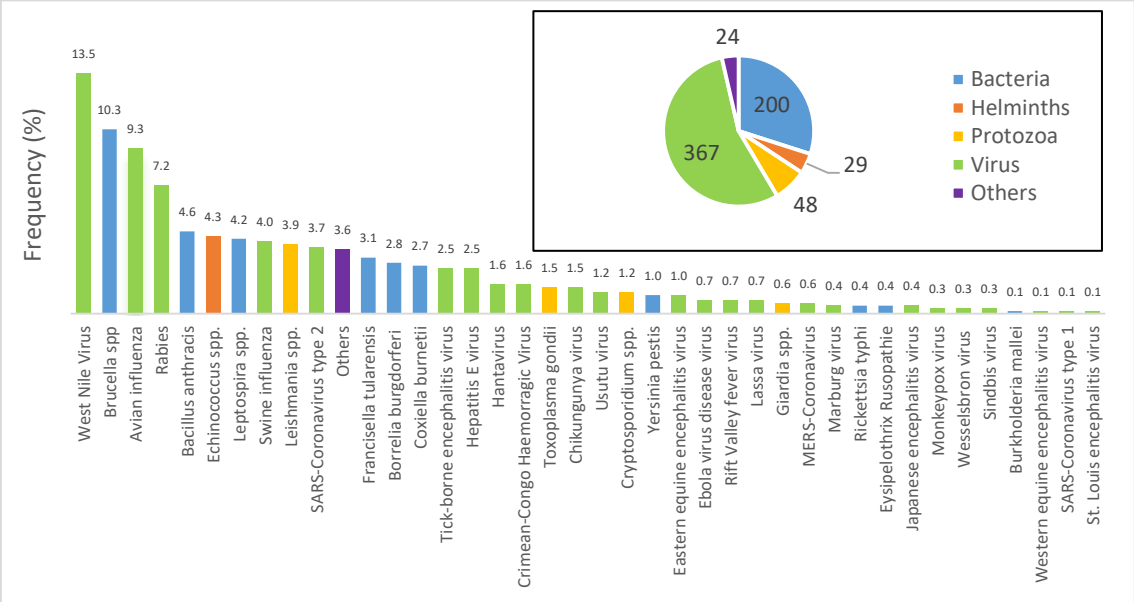


Figure 68. The pie chart represents the frequency (n) of type of pathogen that was included in a surveillance system. Frequency (%) for each specific pathogen is also present.

3.4. Discussion

The evaluation of zoonotic pathogen monitoring in Europe through a literature review (on domestic animals and wildlife in this case) provided interesting information, which complements

the questionnaire to national administrations aimed at official authorities and helps to understand current schemes of surveillance in Europe. Next, we will focus on the main differences and complementary results provided by the literature review versus the questionnaire.

We evidenced that the international component of funding, although not majority, is more relevant, and this is probably because the literature review approach evidenced some international SPs that were not reported through the questionnaires by national authorities. It is remarkable that the integration/collaboration among Human, Animal, or Environmental agencies during the different phases of the surveillance system is also low. Particularly, the collaboration for sampling is relatively less frequent in official surveillance (questionnaire) that in other contexts of zoonotic disease surveillance.

The institutions participating in the SPs are varied and represent different sectors, and also there were relevant differences in the relative frequency of participation by type of institution. A big difference is that the hunting sector was the institution most frequently involved when comparing versus the questionnaire (official laboratories, research Institutions and public health institutions were similarly high in the ranking). This indicates that the hunting sector is more involved in disease surveillance in programs not officially run by the national administrations, as indicated in the questionnaires (relatively low participation).

The most frequently reported objective was to document the distribution and spread of a health event, followed closely by trends monitoring to improve knowledge, which contrasts with the fact that detecting new pathogens and unusual epidemiological events were the most frequent objective for official SPs. It seems there is a higher motivation to evidence trends and improve knowledge compared to only official surveillance. No relevant differences were evidenced in the ranking of pathogens more frequently included in SPs (the top ten coincided, except for Leishmania, which was not present in the questionnaire results).

4. Literature review on surveillance activities carried out by the academia for surveillance in the EU for zoonoses in domestic animals, wildlife, and environment

4.1. The literature review

Our approach aimed at searching for documents on surveillance activities targeting zoonotic diseases in Member states and neighboring countries performed by the academia in wildlife, with the aim to explore the availability of information which compements oficial surveillance systems (see sections above).

The list of target zoonotic pathogens has already been produced by EFSA. The target pathogens/diseases to be included are the following (as they were included in the search strings):

((Bacillus anthracis) OR Brucella OR Chikungunya OR (Crimean-Congo haemorrhagic fever) OR Cryptosporidium OR (Eastern equine encephalitis) OR (Ebola virus disease) OR Echinococcus OR (Erysipelothrix rhusiopathiae) OR Giardia OR (Burkholderia mallei) OR Hantavirus OR (Rickettsia Helvetica) OR (Hepatitis E) OR (avian influenza) OR (swine influenza) OR (Japanese encephalitis) OR Lassa OR Leishmania OR Leptospira OR (Borrelia burgdorferi) OR (Lymphocytic choriomeningitis) OR Marburg OR (Rickettsia conorii) OR MERS-Coronavirus OR Monkeypox OR (Rickettsia typhi) OR Nipah OR (Yersinia pestis) OR (Coxiella burnetiid) OR Rabies OR (Rift Valley fever) OR (Tick-borne encephalitis) OR (Toxoplasma gondii) OR (Francisella tularensis) OR Usutu OR (West Nile))

Scientific databases

Our approach aimed at searching academic, peer-reviewed articles/documents describing Transboundary and emerging zoonotic disease surveillance performed by academia in the EU and neighbouring countries using the Web of Science core collection database-Topic.

The search string used was:

> **(List of countries) AND (List of pathogens) AND (surveillance OR sampling OR prevalence OR monitor* OR survey)**

Results were filtered from 2000 onwards. We obtained a total of **11948 references**. Since the objective was to explore the potential of the academia to provide complementary information to official surveillance systems, we selected 10% of these, which were further analysed, finally corresponding to **1200 references**.

Exclusion/inclusion criteria

This was done in a systematic way, and the procedure and steps performed to review the literature are summarized in Figure 69. The criteria for inclusion in the review were:

- It is a survey of presence or prevalence.
- It is not an official surveillance.
- It surveys a disease included in the 50 pathogens list.
- It is not a review.

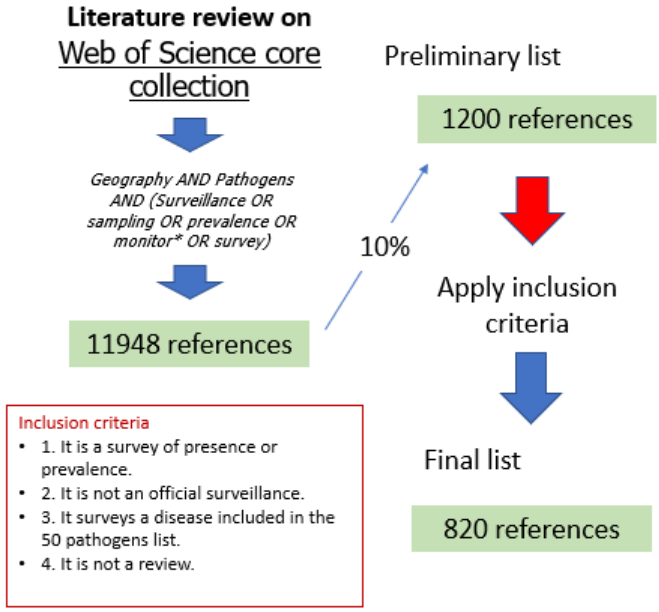


Figure 69. Procedure and steps performed to review the literature on academic activities for surveillance in the EU for zoonoses domestic animals, wildlife, and environment.

The data model

A standardized data model (see Annex 5[8]) was used to extract key information to characterize the surveillance systems. Variables were categorized, for which an associated vocabulary with definitions was developed (references sheet). The Annex 5 details the data model used to gather the information.

4.2. Results

Our approach aimed at searching for documents describing surveillance activities performed by academia domestic animals, wildlife, and environment in the EU. Initially, 11948 references were retrieved (Figure 69). From these 10% were randomly selected for further analyses, corresponding to 1200 references. The application of exclusion and inclusion criteria resulted in a total of 820 references (Annex 5).

4.2.1. Geographical and temporal coverage

The sectoral graph (Figure 70) indicates that most surveillance activities described operated by the academia in the selected list of papers occur at a regional level (54.8%). The remaining 33.1% occur at a national level and 11.3% at supranational level.

The frequency of establishment of surveillance efforts is represented in Figure 71.

[8] https://doi.org/10.5281/zenodo.7446484

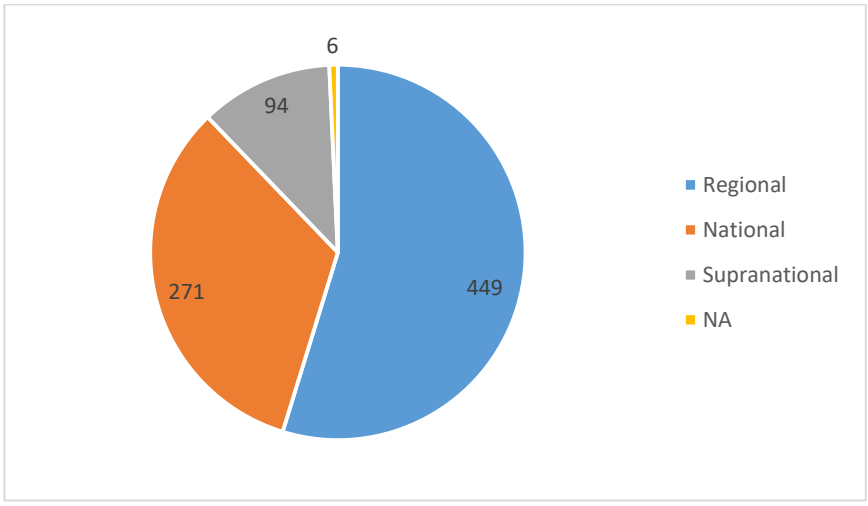


Figure 70. Geographical coverage of surveillance activities (national, subnational, or supranational, n=820).

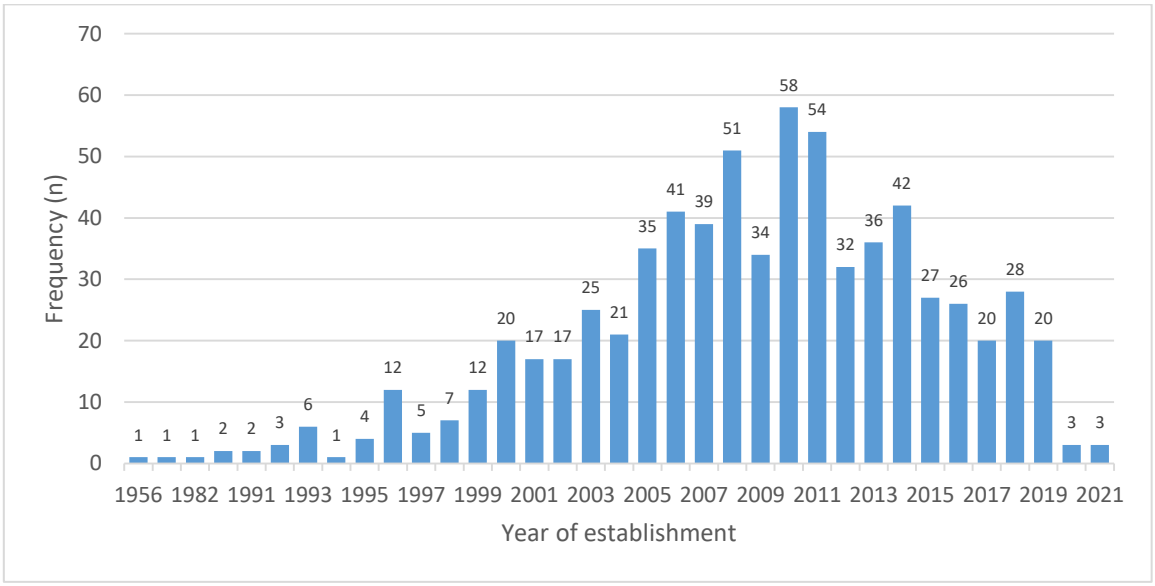


Figure 71. Timeline indicating the frequency of establishment of surveillance activities (number by year, n=706).

4.2.2. Objectives

The objectives of the surveillance activities are summarized in Figure 72. The most frequently reported objective was "Estimating the magnitude of a health problem" (41.95%) followed closely by "Trends monitoring to improve knowledge" (40.85%). The category "other" includes, for example, "Assessing diagnostic methods and genotypic characterization of new strains".

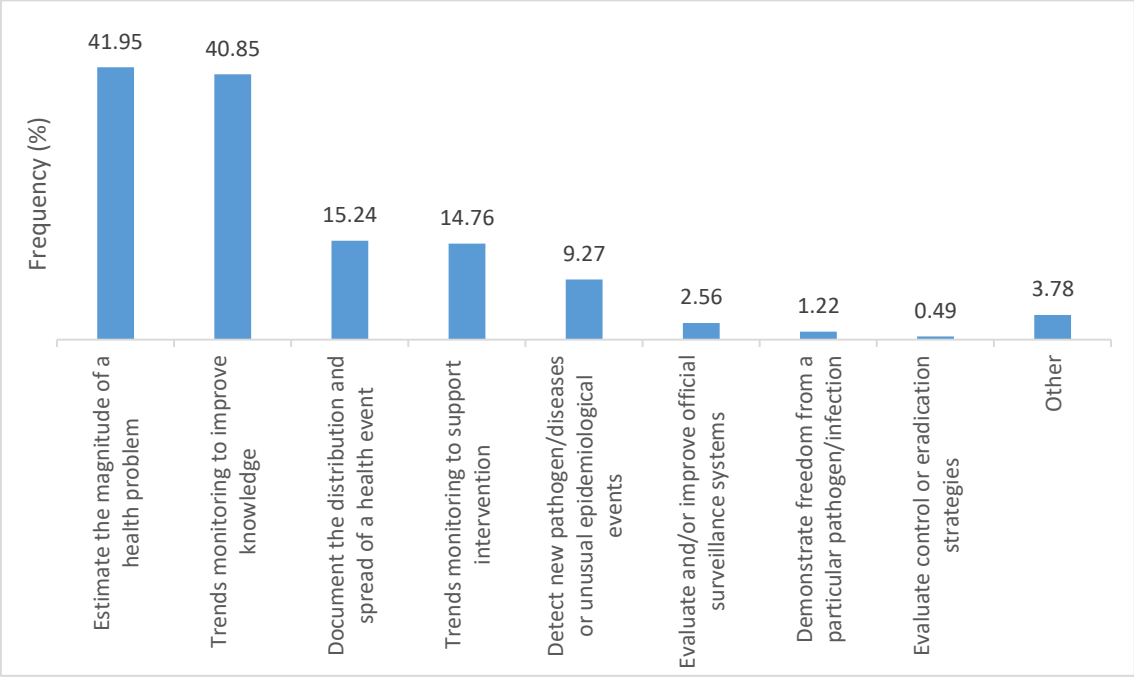


Figure 72. Frequency of different objectives (non-mutually exclusive) of the surveillance activities (N=786).

4.2.3. Characterization of surveillance

4.2.3.1. Active *vs* passive surveillance

Figure 73 displays the frequency of passive and active surveillance (or combined) applied by surveillance activities. Most surveillance systems applied an active surveillance (82.87%). Only 13.4% applied a passive surveillance and 4.04% applied a combination of both.

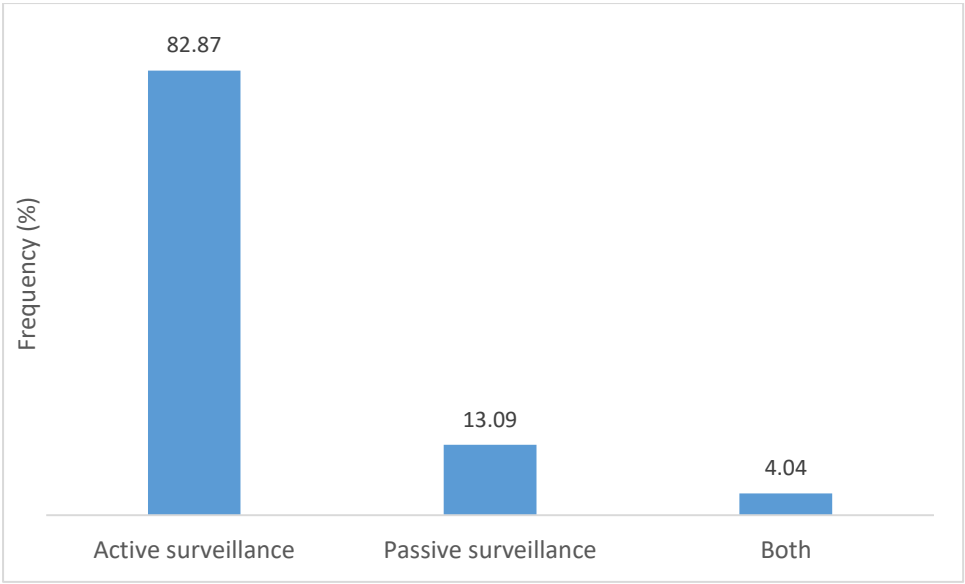


Figure 73. Frequency of passive and active surveillance (or combined) applied by surveillance activities (n=718).

4.2.3.2. Diagnosis method

As for the diagnosis method used (Figure 74), half of the surveillance activities reported the use of a direct method (50.7%). As for the rest, 36.8% used an indirect method, and only 12.5% reported the use of a combination of both direct and indirect methods for diagnosis.

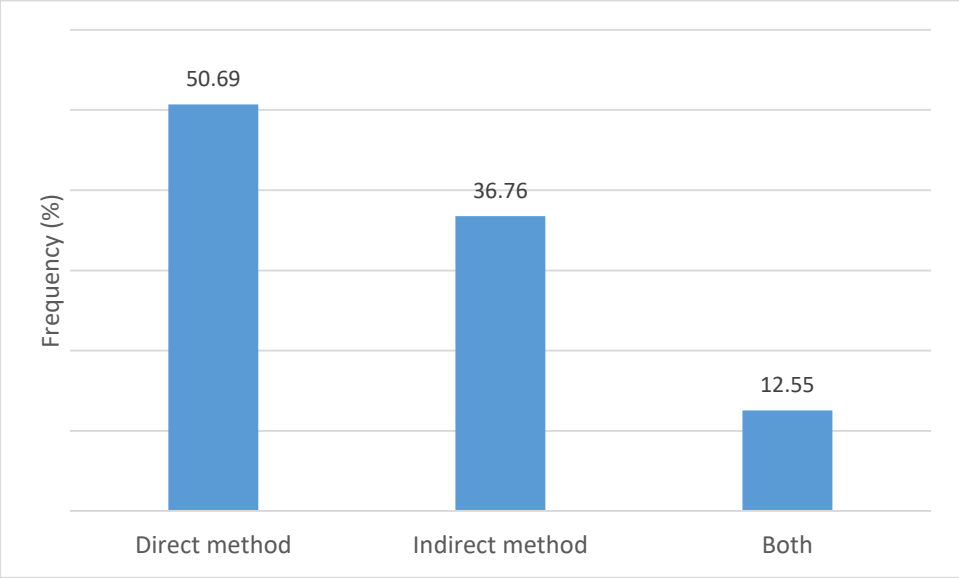


Figure 74. Frequency of diagnosis method (direct, indirect or both) applied by surveillance activities for diagnostic.

4.2.4. Hosts sampled

The domains/species sampled are summarized in Figure 75. There is a marked predominance of arthropod vectors (25.0 %) and humans (24.3%) followed by livestock (17.9%). While wildlife was less relevant when separately looking different taxa, overall, wildlife reached over 30% of frequency, and therefore topped the ranking. The category "others" included environmental samples such as water, air, environmental faeces, or food (fruit and shellfish).

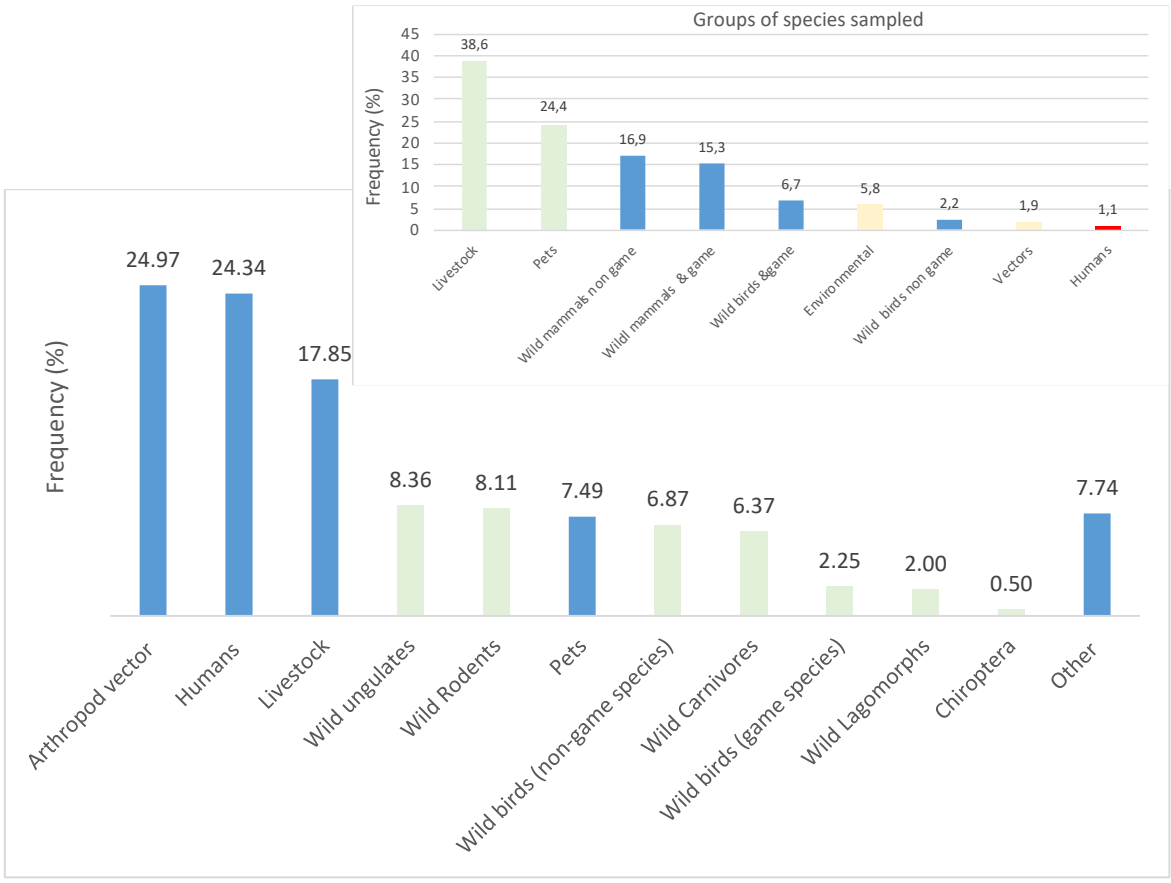


Figure 75. Frequency (%) of samples hosts (n=801). Wildlife is indicated in light green. For comparison, the results of the questionnaire are shown at the top right.

4.2.5. Target pathogens

Figure 76 details the pathogens targeted by the surveillance activities carried out by academia in our sub-sample from literature review. Viral agents predominate (n=383), followed by bacteria (354), protozoa (n=267), and helminths (n=24). The frequency (%) for each pathogen/disease is also represented.

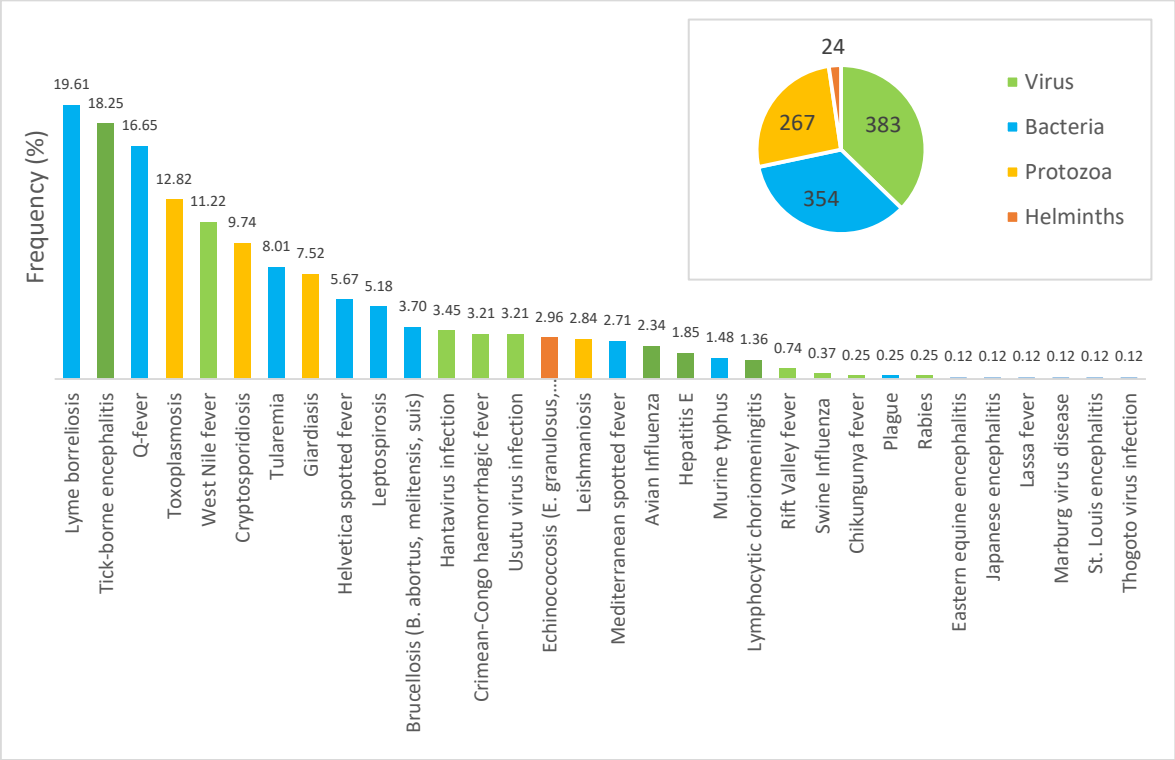


Figure 76. The pie chart represents the frequency (n) each pathogen was included in surveillance activities (some activities included more than one pathogen) by the academia. Frequency (%) for each specific pathogen/disease is also present (n=811 references).

4.3. Discussion

The evaluation of zoonotic pathogens monitored by academia in Europe gathered through a selection after of literature provided interesting information, which complements the previous literature review and the questionnaire. We evidenced that most of the activities carried out by academia are performed at a regional level. The evaluation of the timeline indicated that the frequency of establishment of activities increased in the ealy 2000s, in the same lines as the official surveillance, indicating that motivations were similar in response to outbreaks and health crisis.

The most frequently reported objective was "to estimate the magnitude of a health problem", followed closely by" trends monitoring to improve knowledge", aspects that are relevant to answer research and epidemiological questions. This contrasts with the previous literature review and the questionnaire, where the main objectives were "to document the distribution and spread of a health event" and "detect new pathogens and unusual epidemiological events", respectivelly. This reflects that there is higher motivation to estimate the magnitude of a health problem and improve knowledge in academia compared to official surveillance, which are more interested on detecting pathogen emergence, spread and/or fade out. Unlike official surveillance, in academic activities active surveillance alone seems to predominate over passive surveillance or combined surveillance, which is probably a neccesary approach to test hyphotheses and develop experimental and obsevational designs in the context of research.

About the sampled hosts, there is also a predominance of Arthropod vectors, which contrasts with the questionnaire on offical surveillance. As concerns the targeted pathogens, vector borne viruses and bacteria predominated (Lyme borreliosis as the most frequent disease caused by bacteria and Tick-borne encephalitis virus the most researched virus), followed by West Nile. All together, this indicates that interests and/or motivations of the academia are biased towards vector-borne pathogens and vectors, and this complements the scope of official surveillance. Therefore, it would be wise offclal surveillance to build on what the academia is doing in relation

to vector borne pathogens and vectors, and this include pathogen/vector detection/diagnosis methods.

5. Conclusions and Recommendations

- The results here presented on the questionnaire refer to SPs from a number of countries which returned the questionnaire (n=21, mostly from the UE), which is a **good sample rather than a complete census of SPs over Europe**, illustrating a large representation of European SPs, including different health sectors (public, animal, and environmental) with at least one of the listed zoonotic pathogens. However, it is advisable to increase the number of countries (questionnaires on official surveillance) to be analysed, although the present report is considered a good sample.
    - The **integration between sectors** was not predominant, and mainly applied to the last phase of SPs (dissemination of results). However, sampling, planning and analysis (lab and data) are essential steps to the foundations of OH surveillance. The integration among sectors was more frequent when different sectors oversee the coordination, which illustrates the way to progress on coordinated harmonized OH surveillance.
    - Two main factors referred to as **favouring** (**or barrier** when not implemented) were "existence of appropriate legislation" and "interest to collaborate", which evidences there still is relevant job to do to: defining an appropriate legislative framework and promoting the interest of collaboration between sectors.
    - The difficult **objective** of detecting new pathogen/diseases or unusual epidemiological events, and the demonstration of freedom require multi-actor coordinated SPs to be effectively addressed. Most reported SPs only involved one single health sector, illustrating that animal and public health seldom work together to control and eradicate zoonosis in spite of their potential to do so. Public health-animal health collaboration may be triggered when environment is relevant to pathogens of animal and medical interest.
    - The **evaluation of SPs** is not frequently implemented by SPs, therefore an important effort is needed by all health sectors to develop effective evaluation processes.
    - While no single surveillance tool, either **active or passive**, is perfect, usually combinations of approaches work best. However, less than one third of SPs combined active and passive surveillance. Each SPs, as well as future European surveillance schemes, requires its own evaluation in terms of the required passive and/or active surveillance approach.
    - The **sampling design** predominantly includes risk-based sampling, followed by random and stratified (random) sampling. Risk-based sampling is the one requiring more previous information and therefore current SPs and future European schemes must ensure this strategy is really yielding both higher sensitivity and higher positive predictive value than surveillance conducted randomly across the host populations. The collaboration of sectors based on their respective expertise would help to achieve this aim.
    - About hosts/reservoirs, domestic species apart, wild mammals and wild birds, were the most frequently sampled. However, an important **fragmentation of SPs occurs in terms of the nª of different groups hosts sampled**. This illustrates the need to integrate different SPs to achieve proper OH surveillance.
    - The **number of pathogens** included per SP is normally low, and often multiple pathogen taxa are not represented, indicating a high degree of fragmentation of SPs and need for future integration.
    - Many pathogens here considered are **vector borne**, adding complexity to integral OH surveillance.

- The literature reviews indicated the potential relevance of the hunting sector to be more involved in SPs, and the bias towards borne pathogens and vectors by the academia, which can be used by official surveillance to build OH surveillance upon existing experience.

The main **RECOMMENDATIONS** for further understanding and implementing surveillance are:

1. The **integration** between sectors (human, animal, and environment health) is a necessary step to develop OH surveillance. Moreover, efforts should be made to plan surveillance and coordinate and integrate approaches at an international level.
    a. We recommend that different sectors become involved in the coordination of SPs to facilitate their subsequent integration over the different phases of the surveillance. Since objectives maybe specific to SP and health sectors, surveillance must ensure these specific objectives are met when surveillance is planned as multi-sectorial. Integrated disease and population monitoring is essential to meet this diversity of objectives.
    b. No legislation will succeed if interest to integrate other sectors is not motivated, and no interest will be fruitful without the appropriate legislative framework to implement OH surveillance. Multi-sectoral national and international OH surveillance working groups involving the multiple disciplines are essential. They should regularly and frequently meet, and their activities should go beyond merely reporting. They should define policies and plan surveillance in an adaptive way, the objective of the surveillance is a central element for planning and decision-making.
    c. Surveillance planning must be addressed from the very beginning by different institutions/sectors. The plan should include:
        - Sampling design: risk-based, random, stratified; active vs passive
        - What, how, who, when
        - Documentation and data management
        - Synergies: technical (diagnosis), facilities, access to samples
        - Communication
    d. For effective detection of pathogen emergence multi-actor coordinated SPs are required. Public health-animal health collaboration can be triggered when the environment is relevant to pathogens of animal and public health interest.
2. Future OH European surveillance is an opportunity to implement critical evaluation of programmes. SP evaluation processes must be promoted, and they should be conducted in a standardized and comparable way. At the same time, flexibility on the planning, implementation, and evaluation of health interventions and programmes should be considered assessing their effectiveness within a common European OH framework. We recommend an analysis of the evaluation of surveillance systems, including recommendations on quality and efficiency, and most importantly, to define the SP requirements and objectives to be able to determine the characteristics to be assessed.
3. Considering the specificities of each pathogen group, hosts (reservoirs), potential source, access, types of samples and costs (normally lower for passive surveillance), a general framework need be developed to design best strategies (active and passive surveillance) shared among sectors.
4. The sampling design of the reviewed SPs predominantly included risk-based sampling (vs random and random stratified), which requires relevant prior knowledge.
    a. Therefore, a structured approach is needed to determine priorities for surveillance and the approach to be used in European surveillance schemes to achieve a higher benefit-cost ratio with existing or reduced resources.
    b. Transnational research and collaboration of sectors/countries based on their respective expertise would help to this aim (data and expertise sharing).

c. High quality (spatially precise) information for livestock at European level is needed to assess risks (such as the interface with wildlife) and subsequent risk-based sampling. However, this information is not available at European level at sufficient resolution and must be openly shared by countries.

d. Wildlife population monitoring (integrated surveillance) is also essential to develop risk-based surveillance.

5. A high fragmentation of SPs occurs in Europe and therefore the challenge to integrate OH surveillance is to integrate different SPs. OH focused surveillance must integrate different health sectors (including environment), but also needs to consider multi-pathogen multi-hosts and environment systems as a whole. Integration of SPs does not necessarily mean the complete convergence/fusion of SPs but planning them in coordination to making them comparable and synergic.

6. The low number of pathogens included per SP indicates a high fragmentation of SPs. We recommend progressing towards multiple-host SPs, which will be beneficial at all steps of the process in terms of logistics, costs, and elucidating determining factors. Integration of all sectors with international focus is required. The surveillance of a higher number of pathogens (which may well apply to vectors too) may need to involve larger and diverse number of institutions and again, requires different sectors to join for coordinating the SPs.

7. Comparison of the actual sampled hosts and the primary known reservoir species for the selected pathogens is needed to evaluate and improve future European SPs. Overall, a first exercise revealed that wildlife, the main reservoir host for most zoonotic pathogens, is underrepresented in current SPs. Wildlife under-represented in current surveillance schemes, particularly mammals, namely rodents and bats, and to a less extent, wild ungulates, and carnivores, should be included in SPs.

    a. There is need to involve more wildlife and environmental institutions to increase feasibility of surveillance. These institutions have the technical ability, knowledge, and expertise to develop active and passive surveillance and can also provide means and logistics, which, however, need improvement.

    b. Concerning passive surveillance, wildlife disease professionals can assess clinical signs and pathology, the preliminary clinico-pathological diagnosis guides the correct selection of samples/organs and of pathogens to be tested. Testing of animals found dead or with clinical sigs provides a higher chance of detecting pathogens. Passive surveillance is very important for the early detection of new diseases/pathogens.

    c. Regarding active surveillance, the hunting sector, as well as wildlife management and environmental agencies have access to samples from apparently healthy animals, which may carry subclinical/inapparent infections.

    d. For all the above, guidelines/protocols, means and reliable diagnostic tests are needed.

The recommendations above should apply also to vector surveillance, including the fact that an enormous fragmentation and heterogeneity of SPs for vectors may occur. The surveillance of vectors for specific pathogens should be integrated with surveillance of animals and humans, thus, should be designed and coordinated among the different health sectors.

References

See complete list of references reviewed in Annexes available at this link https://doi.org/10.5281/zenodo.7446484 .

Annexes

Annex 1. Questionnaire survey on official zoonotic disease surveillance activities in the EU and neighbouring countries.

- Sheet 1: PART 1 – Surveillance. This part explores the general organization of the SP
- Sheet 2: PART 2 – Pathogens. This part aims to identify target pathogen and species and methods for surveillance

Annex 2. Characteristic of SPs.

- Sheet "Pathogens", where not primary but also a wide range of hosts are summarized.
- Sheet "active/passive surveillance" by country
- Sheet "origin of funding" (the proportion and number) of SPs

Annex 3. More detailed distribution of active and passive SPs according to countries and pathogen is presented in this Annex.

Annex 4. Standardized data model (to extract key information to characterize the surveillance systems in the literature review on systematic surveillance. The data model was divided into two parts:

- Sheet 1: PART 1 – Surveillance system (explores the general organization)
- Sheet 2: PART 2 – Pathogens (identifies the target pathogen, species, and methods)

Annex 5. Standardized data model used during the literature review to extract key information to characterize the surveillance performed by the academia.

Index of Tables and Figures

Figure 76. The pie chart represents the frequency (n) each pathogen was included in surveillance activities (some activities included more than one pathogen) by the academia. Frequency (%) for each specific pathogen/disease is also present (n=811 references).	106