Preventive Veterinary Medicine 253 (2026) 106879

Contents lists available at ScienceDirect

Preventive Veterinary Medicine

journal homepage: www.elsevier.com/locate/prevetmed

The evaluation of surveillance systems in veterinary public health: A scoping review on the attributes and assessment frameworks most commonly used

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ARTICLE INFO

Keywords:
Surveillance system
Surveillance evaluation
Attributes

ABSTRACT

Regular evaluation of disease surveillance programs is essential to ensure they provide reliable and useful information in an efficient manner. Surveillance systems' performance can be assessed using measurable characteristics, defined as attributes. This scoping review provides a global overview of the attributes and methodological frameworks used to assess veterinary public health surveillance systems over the past 15 years. A literature search was conducted on Pubmed and Scopus for studies published between 2010 and 2025, identifying 125 eligible studies, with 116 describing the evaluation of 157 surveillance systems, and nine describing an evaluation framework. The studies spanned all continents, with Europe, Africa, North America, and Asia being the most represented, and typically targeted multiple diseases or zoonoses such as avian influenza, bovine tuberculosis, and rabies. A total of 67 evaluation attributes were identified and analysed, highlighting both commonly used and underutilized measures of system performance. The evaluation frameworks represent useful available tools aiming to facilitate the evaluation of surveillance systems. However, their actual use is limited especially in the animal health domain, pointing to opportunities to strengthen evaluation practices. The evaluation of surveillance systems proved to be a relevant topic worldwide, encompassing human, animal health and One Health domains. The findings of this work provide valuable perspectives to guide the selection of attributes and assessment methods, and design future evaluations.

1. Introduction

In veterinary public health, surveillance can be defined as the systematic, continuous or repeated, measurement, collection, collation, analysis, interpretation, and timely dissemination of animal-health and -welfare data from defined populations. Its primary purpose is to describe the occurrence of health hazards and to support the planning, implementation and evaluation of risk-mitigation measures. Ultimately, surveillance serves to protect animal health, facilitate trade and protect public health (Hoinville et al., 2013). The evaluation of disease surveillance programs, defined as the systematic assessment of their relevance, adequacy, progress, efficiency, effectiveness and impact is an essential component of this process (Roberts, 1998). Regular evaluation ensures that surveillance systems continue to deliver reliable and useful information efficiently, thereby maintaining their value for decision-making and resource allocation (Drewe et al., 2012).

Surveillance system attributes refer to measurable characteristics whose evaluation is critical for accurately assessing system performance (Calba et al., 2015b; Drewe et al., 2015). The criteria to evaluate surveillance and their definitions were examined in a workshop held prior to the International Symposium of Veterinary Epidemiology and Economics (ISVEE) in 2009 (Hoinville et al., 2009). Building on this, a workshop with key experts in animal health surveillance annexed to the International Conference of Animal Health Surveillance (ICAHS) in 2011 represented a milestone with regards to the evaluation of surveillance strategies, since it set the basis for the identification of the most relevant attributes and contributed resolving inconsistencies in the terminology employed. This process culminated in a report that provided

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https://doi.org/10.1016/j.prevetmed.2026.106879
Received 31 October 2025; Received in revised form 12 March 2026; Accepted 3 April 2026
Available online 6 April 2026

detailed descriptions of the individual attributes and the specific aspects of surveillance systems they assess (Hoinville et al., 2013).

The attributes and methods for surveillance evaluation were examined in at least two key reviews published in 2012 and 2015. Drewe et al. (2012) conducted a systematic review assessing surveillance system attributes as well as the methods and frameworks used for evaluating surveillance in both animal and public health domains. The authors identified 23 distinct attributes with *sensitivity, timeliness* and *data quality* being the most frequently addressed. Their findings also highlighted the lack of standardized definitions and a scarcity of economic evaluations, which they considered as an essential component of a comprehensive surveillance system assessment. In 2015, Calba et al. (2015b) reviewed the various approaches developed to evaluate surveillance systems in public and animal health, in order to identify existing gaps. Across all the reviewed approaches the most commonly assessed attributes were *sensitivity, timeliness* and *representativeness*. This study also emphasized the importance of including economic and sociological attributes, such as *acceptability,* by taking into account stakeholders' needs and perceptions. Moreover, it highlighted the need to develop a framework to guide the assessment of surveillance attributes. More recently, Graziosi et al. (2026) conducted a scoping review focusing on attributes and evaluation approaches used to assess surveillance systems specifically in the context of avian diseases. The authors identified 26 attributes, with *sensitivity* being the most frequently evaluated. Their findings revealed a lack of harmonization in the way attributes are defined, measured and reported, and underscored the need for investment in training and capacity-building to enhance the adoption of evaluation tools in animal health surveillance.

The recommendations made by Drewe et al. (2012) and Calba et al. (2015b) to develop evaluation frameworks were later fulfilled and a range of evaluation frameworks developed within the domains of public and animal health are now available, offering structured guidance on the selection of appropriate attributes and the methodologies for their assessment (Drewe et al., 2015; Muellner et al., 2018; Peyre et al., 2019).

To our knowledge, since 2015, there have been no further attempt to describe the state of the art related to the attributes and the methodological frameworks in place to assess surveillance systems in veterinary public health at a global level. This review aims to fill this gap. This update is particularly important considering also the enormous technological advancements and computational capacity witnessed in this last decade, including the use of Artificial Intelligence.

This study examines the evaluation of surveillance systems in veterinary public health in the last 15 years at a global level, including animal infectious diseases as well as zoonotic diseases. While it assesses the most common methodological approaches for the evaluation of surveillance, including the diseases and species most frequently targeted, the emphasis is placed on the evaluation attributes and the ways they are assessed, identifying similarities and differences with prior related studies. This work also aims to describe existing frameworks for the evaluation of surveillance systems and investigate their application in real-world settings.

2. Materials and methods

2.1. Research question and protocol

The research question addressed in this study is: what attributes and evaluation frameworks have been used to assess the quality of surveillance activities targeting animal infectious diseases and zoonotic diseases?

This scoping review followed the updated methodological guidance for the conduct of scoping reviews of the Joanna Briggs Institute and the PRISMA extension for Scoping Reviews (PRISMA-ScR) (Peters et al., 2020; Tricco et al., 2018). The research question was formulated using the PCC (Population, Concept, Context) framework (Pollock et al., 2023), where animals and humans constituted the "Population", evaluation attributes and frameworks represented the "Concept", and surveillance system targeting animal infectious and zoonotic diseases at the global level defined the "Context". No protocol was preregistered for this scoping review.

2.2. Search strategy

The literature search was conducted on PubMed (https://pubmed.ncbi.nlm.nih.gov/) and Scopus (https://www.elsevier.com/products/scopus) databases, using advanced search builders. The search strategy shown in Table 1 was adapted from Drewe et al. (2012) and Graziosi et al. (2026) and

limited on papers published in the last 15 years (2010–2025), as the previous review by Drewe et al. (2012) covered literature up to 2010. In addition, filter on language (English) was applied. Additional papers were identified by manually screening the reference lists of the studies included after full-text reading. The search was conducted on January 09, 2025.

Regarding gray literature, searches were conducted on Science.gov (https://www.science.gov/) and AGRIS (https://agris.fao.org/) databases to search for unpublished or institutional reports, using the query "surveillance system evaluation".

2.3. Inclusion and exclusion criteria

Eligibility of studies was assessed using predefined inclusion and exclusion criteria. Regarding publication type, peer-reviewed journal articles, conference papers, supplement articles, short communications and deliverables were considered eligible, while book chapters and reviews were excluded. There was no exclusion criteria related to the geographic location of the evaluated surveillance systems.

With respect to scope and context, studies were eligible if they assessed the quality of a surveillance system or its activities through the use of evaluation attributes, or if they presented a framework for surveillance systems evaluation incorporating such attributes. In the latter case, studies were included even when no practical evaluation was conducted.

Evaluations were included only if the surveillance targeted animal

Table 1
Search queries adapted from Drewe et al. (2012) and Graziosi et al. (2026), used for the literature search in the Pubmed and Scopus databases to identify papers on surveillance system evaluation and evaluation frameworks, published between January 2010 and January 2025.

Database	Search query
PubMed	((((((Surveillance[Title]) AND (evaluat*[Title] OR analy*[Title] OR perform*[Title] OR assess*[Title] OR monitor*[Title])) AND (surveillance[Title/Abstract])) AND (evaluat*[Title/Abstract] OR analy*[Title/Abstract] OR perform*[Title/Abstract] OR assess*[Title/Abstract] OR monitor*[Title/Abstract])) AND (chicken*[Title/Abstract] OR turkey*[Title/Abstract] OR poultry[Title/Abstract] OR animal [Title/Abstract] OR cattle[Title/Abstract] OR bovi*[Title/Abstract] OR pig[Title/Abstract] OR swine[Title/Abstract] OR livestock[Title/Abstract] OR zoono*[Title/Abstract] OR veter*[Title/Abstract] OR one health[Title/Abstract] OR infectious disease[Title/Abstract] OR communicable disease[Title/Abstract] OR transmi* disease[Title/Abstract])) AND (tool[Title/Abstract] OR framework[Title/Abstract] OR method[Title/Abstract] OR guidelines[Title/Abstract] OR indicator*[Title/Abstract])) NOT (clinical[Title/Abstract] OR trial[Title/Abstract] OR surg*[Title/Abstract])
Scopus	(TITLE (surveillance) AND TITLE (evaluat* OR analy* OR perform* OR assess* OR monitor*) AND TITLE-ABS-KEY (surveillance) AND TITLE-ABS-KEY (evaluat* OR analy* OR perform* OR assess* OR monitor*) AND TITLE-ABS-KEY (chicken* OR turkey* OR poultry OR animal OR cattle OR bovi* OR pig OR swine OR livestock OR zoono* OR veter* OR one AND health OR infectious AND disease OR communicable AND disease OR transmi* AND disease) AND TITLE-ABS-KEY (tool OR framework OR method OR guidelines OR indicator*) AND NOT TITLE-ABS-KEY (clinical OR trial OR surg*))

infectious diseases or zoonotic diseases. When surveillance systems were general – i.e. addressing multiple diseases (both zoonotic and not zoonotic) or based on symptoms or syndromes-base detection – studies were considered eligible only if at least one animal infectious disease or zoonotic disease was explicitly reported as a surveillance target. Surveillance systems related to aquaculture, entomological surveillance (without any component involving animals or humans), studies describing pathogen circulation exclusively in the environment or antimicrobial resistance were excluded as they fell outside the scope of this review which focuses on infectious diseases (including zoonoses) of terrestrial animals.

2.4. Selection of evidence, data extraction and data analysis

The papers identified through the search queries were imported into Rayyan software (https://www.rayyan.ai/) to check for duplicates. Duplicates were manually reviewed and removed. Abstracts were screened by two independent authors (L.M., M.D.N.) to determine the suitability of studies for full-text review. Eligibility of the included studies was assessed by L.M., while quality assurance was conducted by M.D.N. monitoring the methodological rigor, transparency, consistency, and reproducibility, in line with the review protocol. Key information, such as reference, publication year, geographic region, target species, diseases under surveillance, evaluated attributes (including definitions and assessment methods), and analytical frameworks applied, was extracted into Microsoft Excel for Microsoft 365. When specific details were missing from a paper, the notation NS (*not specified*) was used. If a study evaluated more than one surveillance system, data were collected separately for each system. In cases where multiple studies appeared to assess the same surveillance system, but confirmation was not possible due to insufficient information, they were treated as distinct systems. Regarding attribute extraction, when a paper described an evaluation consistent with a known attribute definition, but did not explicitly use the corresponding term, the attribute was included and labeled as an 'assumed attribute'. For example, Rossi et al. (2015) analysed the cumulative fraction of epidemics detected monthly by current versus alternative surveillance strategies, and the mean time to detection, concepts aligning with the attributes *sensitivity* and *timeliness* (German et al., 2001). Consequently, these were included in this work as "assumed attributes".

Microsoft Excel, R software and RStudio (R Core Team, 2024) were used for descriptive statistics and data visualization.

3. Results

3.1. Literature search

As shown in Fig. 1, 554 records were retrieved from the PubMed and Scopus databases. No gray literature was identified through searches in the AGRIS or Science.gov databases. After removal of duplicates, 452 abstracts were screened, of which 118 articles were selected for full-text assessment. Following full-text review, 49 articles were excluded, resulting in 69 eligible studies. Reference lists of the included articles were then screened manually, leading to the identification of 56 additional relevant publications. Overall, this scoping review included 125 papers, of which 116 reported an evaluation of a surveillance activity, while nine described only the methodology of a framework or tool for surveillance evaluation.

3.2. Studies characteristics

Regarding the 116 studies which included actual evaluations, 157 surveillance systems were identified. In the following sections are described the main characteristics of the papers retrieved, such as geographic location, species and diseases targeted by the surveillance systems, attributes and frameworks used for the evaluations.

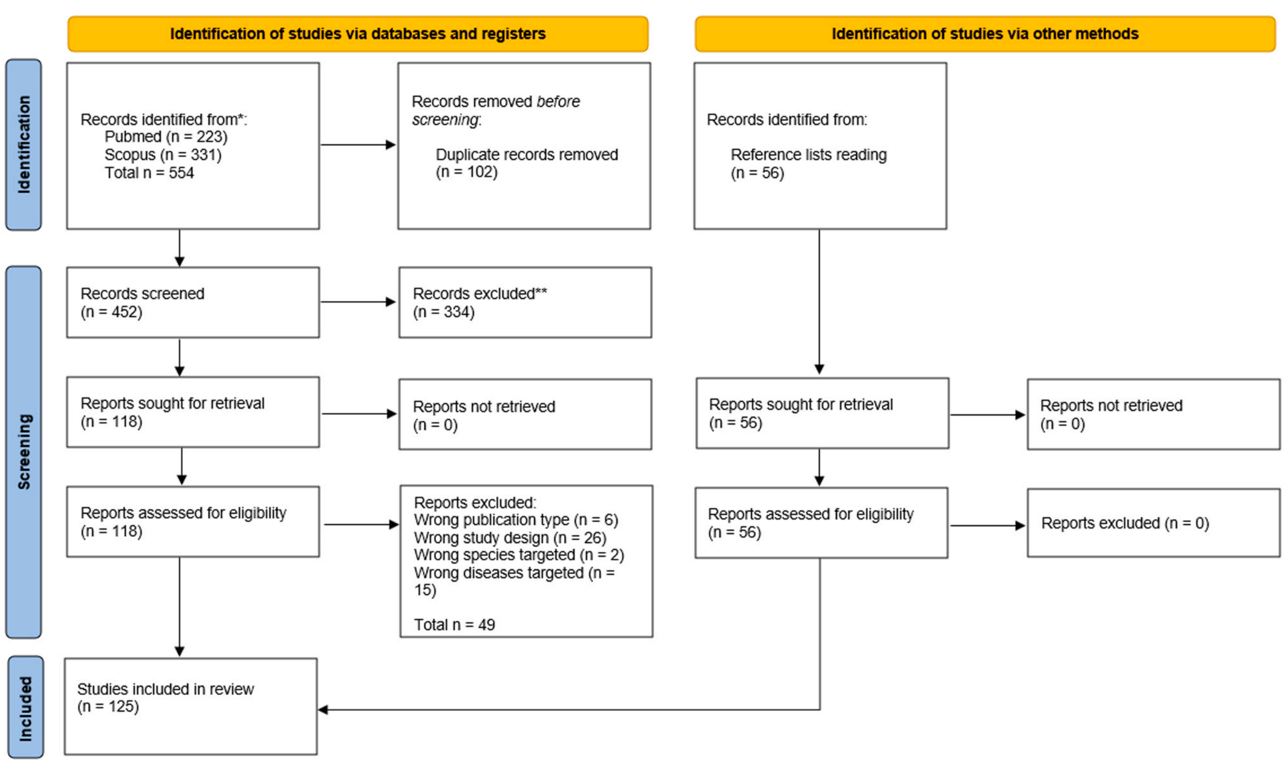

Fig. 1. Adapted PRISMA 2020 flow diagram for systematic reviews, illustrating the identification and selection of studies on surveillance systems evaluation and evaluation frameworks, published between 2010 and 2025. Studies were retrieved from the Pubmed and Scopus databases and through reference lists reading.

3.3. Geographic and temporal distribution of surveillance systems' evaluations

Table 2 and Fig. 2 show respectively the number of surveillance systems evaluated in each continent and the temporal distribution of the evaluations. The surveillance systems identified in this study were implemented worldwide. In some cases surveillance activities were simulations, therefore the geographic territory was not defined. Regarding the temporal distribution, the number of surveillance systems evaluations published per year ranged from four to 23, with a median of 10 evaluations conducted annually. The temporal trend fluctuated until 2021, followed by a negative downward trend thereafter.

Table 2
Regional distribution of 157 surveillance systems evaluated in 116 studies, published between January 2010 and January 2025, and corresponding references.

Region, n. of surveillance systems (%)	References
Europe 64 (40.8%)	(Alba et al., 2010; Amat et al., 2015; Babo Martins et al., 2017; Barboza et al., 2014, 2013; Bellini et al., 2014; Breed et al., 2012; Calba et al., 2016; Calba et al., 2015a; Calvo-Artavia et al., 2013; Chaintoutis et al., 2014; Colón-González et al., 2018; Comin et al., 2012; Drewe et al., 2017; Ely et al., 2012; Faverjon et al., 2019, 2017, 2016; Foddai et al., 2021, 2020; Fonseca et al., 2018; Garcia-Vozmediano et al., 2022; Gervasi et al., 2020; Guétin-Poirier et al., 2022; Guo et al., 2014; Häsler et al., 2012a, 2012b, 2012c; Hénaux and Calavas, 2017; Jamin and Rivière, 2020; Knight-Jones et al., 2010; Litzroth et al., 2015; Mercier et al., 2020; Nathues et al., 2015; Norström et al., 2014; Peyre et al., 2015; Poirier et al., 2019; Porcu et al., 2023; Pozo et al., 2021; Reber et al., 2012; Reijn et al., 2011; Rivers et al., 2023; Rivière et al., 2017, 2015; Rossi et al., 2015; Rüegg et al., 2018b; Rutten et al., 2012; Schulz et al., 2017; Schulz et al., 2016; Veldhuis et al., 2017; Vial et al., 2016; Vredenberg et al., 2024, 2022; Welby et al., 2013, 2012)
Africa 30 (19.1%)	(Adokiya et al., 2015; Alemu et al., 2019; Ario et al., 2022; Awekeya et al., 2021; Ba et al., 2024; Cameron et al., 2020; Chenais et al., 2015; El-Khatib et al., 2018; Hunduma and Leulseged, 2021; Kuye et al., 2024; Lopes et al., 2016; Mala et al., 2021; Maponga et al., 2014; Mremi et al., 2023; Mtema et al., 2016; Ng'etich et al., 2021; Olu et al., 2020; Peyre et al., 2015; Randriamiarana et al., 2018; Ratnayake et al., 2016; Rumunu et al., 2022; Stolka et al., 2018; Tom-Aba et al., 2018; Umeozuru et al., 2022; Waziri et al., 2014)
North America 24 (15.3%)	(Arruda et al., 2017; Barboza et al., 2014, 2013; Bonney et al., 2019; Christensen et al., 2011; El Allaki et al., 2016; Gerardo-Giorda et al., 2013; Mor et al., 2014; Sickbert-Bennett et al., 2011; Stewart et al., 2019; Thomas et al., 2018; Undurraga et al., 2017; Weaver et al., 2016)
Asia 22 (14%)	(Babaie et al., 2015; Barboza et al., 2014, 2013; Collineau et al., 2013; Craighead et al., 2015; Debnath and Ponnaiah, 2018; Delabouglise et al., 2016; Garcell et al., 2014; Grosbois et al., 2015; Liu et al., 2021; Mala et al., 2021; Ohashi et al., 2010; Pham et al., 2021; Prajapati et al., 2023; Qurat ul Ain et al., 2019; Sparrow et al., 2016; Van Boetzelaer et al., 2020)
Oceania 6 (3.8%)	(Grills et al., 2010; Hernández-Jover et al., 2011; Lokuge et al., 2022; Martin et al., 2015; Sergeant et al., 2017; Stephenson et al., 2016)
South America 4 (2.5%)	(Calero and Monti, 2022; Coelho et al., 2024; Ferrer-Miranda et al., 2022, 2020)
More than one continent 2 (1.3%)	(Attema et al., 2019; Schwind et al., 2014)
Not specified 5 (3.2%)	(Cameron et al., 2020; Grosbois et al., 2015)
Total 157 (100%)	

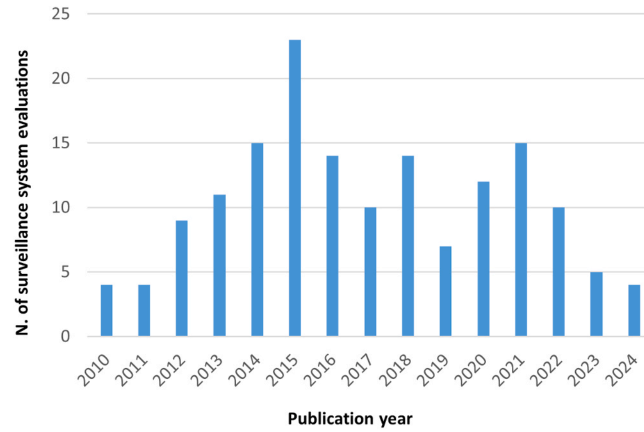

Fig. 2. Temporal distribution of the 157 surveillance systems evaluations identified across 116 studies published between January 2010 and January 2025.

3.4. Species targeted by the surveillance systems

The surveillance systems included in this review often (26.1%) targeted multiple species simultaneously. Table 3 shows the species monitored by each system. When two species were targeted, both are listed; systems covering three or more species are grouped under the category *multiple species*. This grouping includes surveillance activities focused on various ungulate species, such as ruminants and pigs (Calvo-Artavia et al., 2013; Coelho et al., 2024; Ferrer-Miranda et al., 2022, 2020), as well as wildlife (Calba et al., 2016; Jamin and Rivière, 2020; Rivière et al., 2017, 2015), and animals or livestock in general (Martin et al., 2015; Mercier et al., 2020; Mremi et al., 2023). Among individual targets, humans, cattle and poultry were the most frequently reported.

Table 4 presents the geographic distribution of surveillance systems targeting human health, and those within the veterinary public health domain, targeting animals, or both animals and humans. The articles related to surveillance systems targeting humans, published between 2010 and 2025, mainly refer to systems implemented in Africa, followed by Asia, North America, Europe, Oceania and South America. Only two systems covered multiple continents. In contrast, articles related to surveillance systems within the veterinary public health domain primarily addressed systems implemented in Europe, followed by North America, Africa, Asia, and both Oceania and South America.

3.5. Diseases targeted by the surveillance systems

Regarding the diseases targeted by the evaluated surveillance systems, the most common scenario involved systems addressing multiple diseases simultaneously. Avian influenza (AI) was the most frequently targeted individual disease. Other diseases, listed in descending order of frequency, included bovine tuberculosis (bTB), rabies, zoonotic influenza, African swine fever (ASF), Covid-19, foot-and-mouth disease (FMD), bluetongue (BT), cholera, classical swine fever (CSF), and West Nile fever (WNF) or West Nile neuroinvasive disease (WNND) (Fig. 3). A small proportion of surveillance systems were not disease-specific (*'NS'*). These included studies focused primarily on methodological aspects of attributes measurements (Ely et al., 2012), presented illustrative examples of hypothetical surveillance systems (Grosbois et al., 2015), or evaluated surveillance systems without specifying the targeted disease (Mremi et al., 2023).

The complete list of diseases and their corresponding frequencies, along with the target population (human or animal), is provided in Supplementary Material 1.

Table 3
Distribution of species included in 157 surveillance systems evaluated in 116 studies published between January 2010 and January 2025, and corresponding references.

Species, n. of surveillance systems (%)*	References
Human 54 (34.4%)	(Adokiya et al., 2015; Alemu et al., 2019; Ario et al., 2022; Attema et al., 2019; Awekeya et al., 2021; Ba et al., 2024; Babaie et al., 2015; Calero and Monti, 2022; Colón-González et al., 2018; Debnath and Ponnaiah, 2018; El-Khatib et al., 2018; Garcell et al., 2014; Grills et al., 2010; Hunduma and Leulseged, 2021; Litzroth et al., 2015; Liu et al., 2021; Lokuge et al., 2022; Mala et al., 2021; Maponga et al., 2014; Mor et al., 2014; Mremi et al., 2023; Mtema et al., 2016; Ng'etich et al., 2021; Olu et al., 2020; Porcu et al., 2023; Prajapati et al., 2023; Qurat ul Ain et al., 2019; Randriamiarana et al., 2018; Ratnayake et al., 2016; Reijn et al., 2011; Rumunu et al., 2022; Schwind et al., 2014; Sickbert-Bennett et al., 2011; Sparrow et al., 2016; Stephenson et al., 2016; Stolka et al., 2018; Thomas et al., 2018; Tom-Aba et al., 2018; Umeozuru et al., 2022; Van Boetzelaer et al., 2020)
Cattle 27 (17.2%)	(Calba et al., 2016; Cameron et al., 2020; Drewe et al., 2017; El Allaki et al., 2016; Faverjon et al., 2019; Foddai et al., 2021, 2020; Grosbois et al., 2015; Guétin-Poirier et al., 2020; Häsler et al., 2012c; Hénaux and Calavas, 2017; Lopes et al., 2016; Norström et al., 2014; Ohashi et al., 2010; Peyre et al., 2015; Poirier et al., 2019; Pozo et al., 2021; Reber et al., 2012; Rossi et al., 2015; Sergeant et al., 2017; Veldhuis et al., 2017; Vial et al., 2016; Vredenberg et al., 2024; Welby et al., 2012)
Humans & animals 19 (12.1%)	(Babo Martins et al., 2017; Barboza et al., 2014, 2013; Bellini et al., 2014; Fonseca et al., 2018; Garcia-Vozmediano et al., 2022)
Multiple species 12 (7.6%)	(Calba et al., 2016; Calvo-Artavia et al., 2013; Coelho et al., 2024; Ferrer-Miranda et al., 2022, 2020; Häsler et al., 2012a; Jamin and Rivière, 2020; Martin et al., 2015; Mercier et al., 2020; Mremi et al., 2023; Rivière et al., 2017, 2015)
Poultry 11 (7%)	(Bonney et al., 2019; Cameron et al., 2020; Christensen et al., 2011; Collineau et al., 2013; Comin et al., 2012; Delabouglise et al., 2016; Grosbois et al., 2015; Peyre et al., 2015; Rutten et al., 2012; Waziri et al., 2014)
Pig 9(5.7%)	(Amat et al., 2015; Arruda et al., 2017; Cameron et al., 2020; Chenais et al., 2015; Ely et al., 2012; Faverjon et al., 2017; Guo et al., 2014; Hernández-Jover et al., 2011; Nathues et al., 2015; Stewart et al., 2019)
Horse 4 (2.5%)	(Amat et al., 2015; Faverjon et al., 2017)
Wild boar 4 (2.5%)	(Gervasi et al., 2020; Peyre et al., 2015; Schulz et al., 2017; Schulz et al., 2016)
Human & dog 3 (1.9%)	(Kuye et al., 2024; Pham et al., 2021; Undurraga et al., 2017)
Cattle & sheep 2 (1.3%)	(Rüegg et al., 2018b; Welby et al., 2013)
Poultry & wild birds 2 (1.3%)	(Alba et al., 2010; Häsler et al., 2012b)
Wild birds 2 (1.3%)	(Breed et al., 2012; Knight-Jones et al., 2010)
Cattle & pig 1 (0.6%)	(Vredenberg et al., 2022)
Dog 1 (0.6%)	(Craighead et al., 2015)
Domestic pigeon 1 (0.6%)	(Chaintoutis et al., 2014)
Fox 1 (0.6%)	(Rivers et al., 2023)
Horses & wild birds 1 (0.6%)	(Faverjon et al., 2016)
Pig & wild boar 1 (0.6%)	(Calba et al., 2015a)
Racoon 1 (0.6%)	(Gerardo-Giorda et al., 2013)
Turkey 1 (0.6%)	(Weaver et al., 2016)
Total 157 (100%)	

3.6. *Attributes and methods most commonly applied to evaluate surveillance systems*

Overall, 67 distinct attributes used in the evaluation of surveillance systems were identified and categorized into five main attribute classes, following the classification proposed by Graziosi et al. (2026), in order to clearly delineate the domains under evaluation:

1) Organization: attributes assessing how the surveillance system is structured and managed;
2) Implementation: attributes evaluating the operational activities and functions of the system;
3) Performance: attributes related to the system's performance, efficacy and effectiveness;
4) Impact: attributes examining the costs, benefits, and overall usefulness of the surveillance system under evaluation;
5) One Health approach: attributes assessing the extent to which One Health principles are integrated into the surveillance strategy.

Table 5 summarizes the 10 most frequently assessed attributes, detailing their distribution across geographical regions, health domains (human vs. animal/veterinary public health), and the diseases most commonly evaluated. The complete list of attributes, grouped according to their respective classes and accompanied by references, general definitions, and the most commonly used assessment methods for each, is provided in Supplementary material 2. Fig. 4 presents the attributes ranked by frequency of use, rather than by class grouping. Less frequently used attributes are presented in Supplementary material 3.

The number of attributes per evaluation ranged from one to 24. Of the 157 evaluations, 48 (30.6%) used a single attribute, 34 (21.7%) used two, 31 (19.7%) used three to five, 38 (24.2%) used six to 10, and 6 (3.8%) used more than 10.

Sensitivity was the most frequently assessed attribute. Surveillance system *sensitivity* is variably defined as: the proportion of individuals with the health condition of interest that the surveillance system can detect; the probability of identifying a significant increase in disease occurrence or the appearance of new cases in a previously disease-free population; or the probability of detecting at least one case when the disease is present at a specified design prevalence (Martin et al., 2007; Peyre et al., 2019). This attribute was predominantly applied in the evaluation of animal health surveillance systems and less frequently in the human health domain. *Sensitivity* was applied across various contexts, including evaluations of operational surveillance systems (Alba et al., 2010; Amat et al., 2015; Ario et al., 2022; Awekeya et al., 2021; Calero and Monti, 2022; Craighead et al., 2015; Grills et al., 2010; Qurat ul Ain et al., 2019; Sergeant et al., 2017), systems developed and tested through simulation modeling (Arruda et al., 2017; Bonney et al., 2019; Faverjon et al., 2019, 2017, 2016; Foddai et al., 2021; Rossi et al., 2015; Weaver et al., 2016), and epidemic intelligence frameworks (Barboza et al., 2014, 2013). Furthermore, it was used for different purposes: to assess early detection capability (Cameron et al., 2020; Comin et al., 2012; Faverjon et al., 2017), to demonstrate freedom from infection (Calvo-Artavia et al., 2013; Norström et al., 2014; Peyre et al., 2015; Reber et al., 2012; Sergeant et al., 2017) and to evaluate cost-effectiveness when combined with the attribute *cost* (Poirier et al., 2019; Reber et al., 2012; Rüegg et al., 2018b).

Timeliness is defined as the speed between steps in a surveillance system (German et al., 2001). It most often measured time to detect outbreaks or cases (Arruda et al., 2017; Babaie et al., 2015;

Table 4
Distribution of 157 surveillance systems evaluated in 116 studies, published between January 2010 and January 2025, according to region and domain (human vs. animal/veterinary public health).

Region, n. of surveillance systems (%) targeting humans (H), or humans and animals (A&H)	References
Africa	
H 21/54 (39%)	(Adokiya et al., 2015; Alemu et al., 2019; Ario et al., 2022; Awekeya et al., 2021; Ba et al., 2024; El-Khatib et al., 2018; Hunduma and Leulseged, 2021; Mala et al., 2021; Maponga et al., 2014; Mremi et al., 2023; Mtema et al., 2016; Ng'etich et al., 2021; Olu et al., 2020; Randriamiarana et al., 2018; Ratnayake et al., 2016; Rumunu et al., 2022; Stolka et al., 2018; Tom-Aba et al., 2018; Umeozuru et al., 2022)
A&H 9/103 (8.7%)	(Cameron et al., 2020; Chenais et al., 2015; Kuye et al., 2024; Lopes et al., 2016; Mremi et al., 2023; Peyre et al., 2015; Waziri et al., 2014)
Asia	
H 14/54 (26%)	(Babaie et al., 2015; Debnath and Ponnaiah, 2018; Garcell et al., 2014; Liu et al., 2021; Mala et al., 2021; Prajapati et al., 2023; Qurat ul Ain et al., 2019; Sparrow et al., 2016; Van Boetzelaer et al., 2020)
A&H 8/103 (7.8%)	(Barboza et al., 2014, 2013; Collineau et al., 2013; Craighead et al., 2015; Delabouglise et al., 2016; Grosbois et al., 2015; Ohashi et al., 2010; Pham et al., 2021)
Europe	
H 4/54 (7%)	(Colón-González et al., 2018; Litzroth et al., 2015; Porcu et al., 2023; Reijn et al., 2011)
A&H 60/103 (58.3%)	(Alba et al., 2010; Amat et al., 2015; Babo Martins et al., 2016; Barboza et al., 2014, 2013; Bellini et al., 2014; Breed et al., 2012; Calba et al., 2016; Calba et al., 2015a; Calvo-Artavia et al., 2013; Chaintoutis et al., 2014; Comin et al., 2012; Drewe et al., 2017; Ely et al., 2012; Faverjon et al., 2019, 2017, 2016; Foddai et al., 2021, 2020; Fonseca et al., 2018; Garcia-Vozmediano et al., 2022; Gervasi et al., 2020; Guétin-Poirier et al., 2022; Guo et al., 2014; Häsler et al., 2012a, 2012b, 2012c; Hénaux and Calavas, 2017; Jamin and Rivière, 2020; Knight-Jones et al., 2010; Mercier et al., 2020; Nathues et al., 2015; Norström et al., 2014; Peyre et al., 2015; Poirier et al., 2019; Pozo et al., 2021; Reber et al., 2012; Rivers et al., 2023; Rivière et al., 2017, 2015; Rossi et al., 2015; Rüegg et al., 2018b; Rutten et al., 2012; Schulz et al., 2017; Schulz et al., 2016; Veldhuis et al., 2017; Vial et al., 2016; Vredenberg et al., 2024, 2022; Welby et al., 2013, 2012)
North America	
H 9/54 (17%)	(Mor et al., 2014; Sickbert-Bennett et al., 2011; Stewart et al., 2019; Thomas et al., 2018)
A&H 15/103 (14.6%)	(Arruda et al., 2017; Barboza et al., 2014, 2013; Bonney et al., 2019; Christensen et al., 2011; El Allaki et al., 2016; Gerardo-Giorda et al., 2013; Undurraga et al., 2017; Weaver et al., 2016)
Oceania	
H 3/54 (6%)	(Grills et al., 2010; Lokuge et al., 2022; Stephenson et al., 2016)
A&H 3/103 (2.9%)	(Hernández-Jover et al., 2011; Martin et al., 2015; Sergeant et al., 2017)
South America	
H 1/54 (2%)	(Calero and Monti, 2022)
A&H 3/103 (2.9%)	(Coelho et al., 2024; Ferrer-Miranda et al., 2022, 2020)
More than 1 continent	
H 2/54 (4%)	(Attema et al., 2019; Schwind et al., 2014)
A&H 0	
Not specified	
H 0	
A&H 5/103 (4.9%)	(Cameron et al., 2020; Grosbois et al., 2015)
Total	
H 54 (100%)	
A&H 103 (100%)	

Colón-González et al., 2018; Faverjon et al., 2019, 2017; Porcu et al., 2023; Rossi et al., 2015; J. Schulz et al., 2017; Schwind et al., 2014), or the ability to identify health events within preset time limits (Attema et al., 2019), or delays from detection to notification to competent authorities (Debnath and Ponnaiah, 2018; Ferrer-Miranda et al., 2022, 2020; Lokuge et al., 2022; Olu et al., 2020; Reijn et al., 2011; Sparrow et al., 2016), or delays from detection to specimen submission (Debnath and Ponnaiah, 2018; Vredenberg et al., 2024), or on time receipt of surveillance reports (El-Khatib et al., 2018; Hunduma and Leulseged, 2021; Mala et al., 2021), or the interval from exposure to the start of interventions (Awekeya et al., 2021; Coelho et al., 2024). Its use was far more common in human health than in animal health.

Simplicity was mostly used in human health systems rather than animal health. It concerns system structure and ease of operations (Babaie et al., 2015; German et al., 2001), including data requirements (i.e., case definition), organizations involved in receiving case reports, integration with other systems, staff training, maintenance time, data collection forms, data collection processes and data management/analysis/dissemination methods.

Usefulness reflects a system's contribution to preventing and controlling adverse health events and meeting its objectives; it can be influenced by all other attributes (German et al., 2001; World Health Organization Regional Office for the Eastern Mediterranean, 2018). Like *simplicity*, it was used mainly in human health rather than animal health, or joint animals and human systems.

Flexibility was mostly assessed in human health and less in animal/veterinary public health. It captures the system's capacity to adapt to new information needs, regulatory changes or operating conditions with minimal added time, personnel, or funds (German et al., 2001), including repurposing for other diseases – an aspect examined in multi-disease surveillance (Alemu et al., 2019; Maponga et al., 2014), AI (Waziri et al., 2014), bTB (Lopes et al., 2016), and Crimean-Congo hemorrhagic fever (CCHF) (Qurat ul Ain et al., 2019).

Acceptability evaluates the willingness of people and organizations to participate in the surveillance system and the extent of their involvement (Hoinville et al., 2013). As with *flexibility*, it was more common in human health than in animal-focused or joint systems.

Representativeness was examined more in human health studies than in animals or joint animal-human studies. It is defined as the system's ability to describe the occurrence of a health event over time and its distribution by place and person (German et al., 2001) without bias.

Data quality assesses the completeness and validity of recorded data (German et al., 2001). It was assessed more in human health than animal health.

Cost or cost-effectiveness was used predominantly in animal or joint animals - humans surveillance. Most analyses estimated direct and indirect surveillance costs (Awekeya et al., 2021; Babo Martins et al., 2017; Bellini et al., 2014; Delabouglise et al., 2016; Drewe et al., 2017; El-Khatib et al., 2018; Guo et al., 2014; Maponga et al., 2014; Mtema et al., 2016; Nathues et al., 2015; Rutten et al., 2012; Veldhuis et al., 2017). Cost-effectiveness analyses – comparing program cost to sensitivity – was reported only in animal health, for brucellosis (Hénaux and Calavas, 2017), AI (Häsler et al., 2012b; Knight-Jones et al., 2010), bTB (Guétin-Poirier et al., 2020; Rivière et al., 2017), BT (Rüegg et al., 2018b), and CSF (Peyre et al., 2015; Schulz et al., 2017). In public

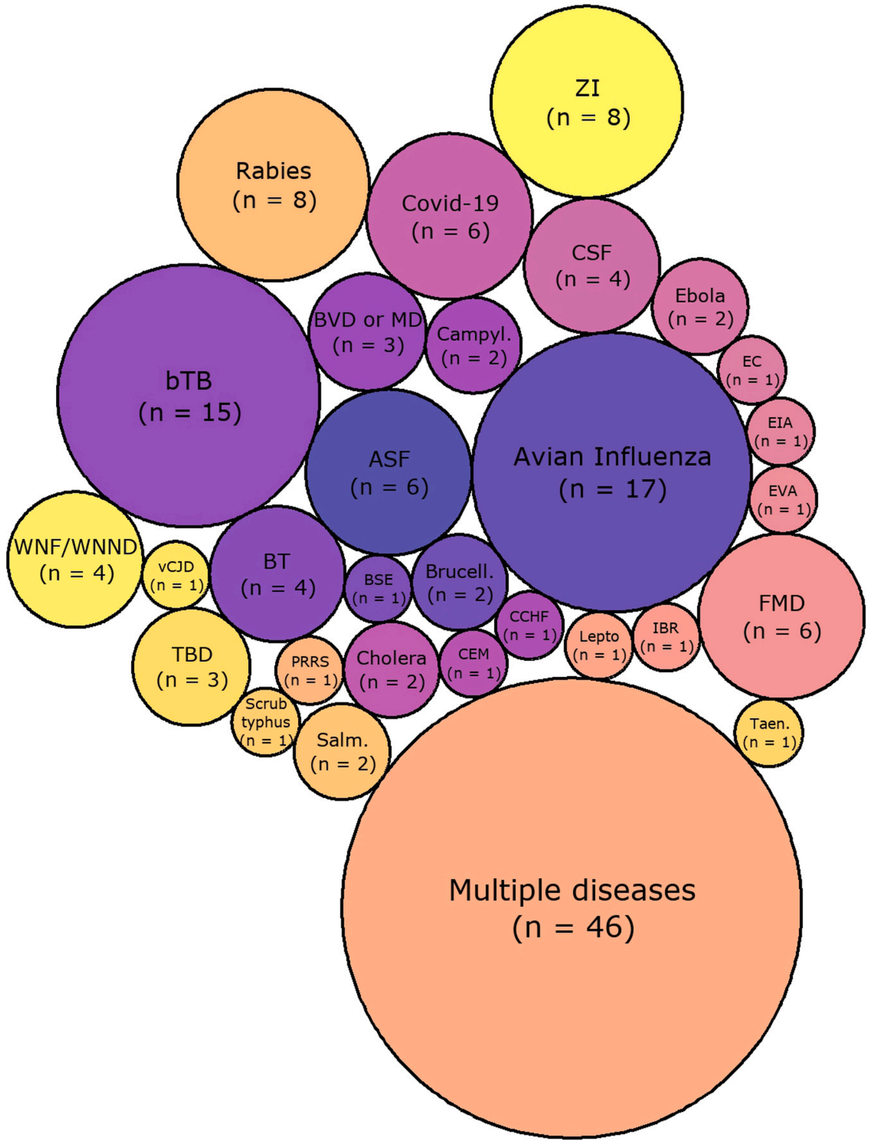

Fig. 3. Packed bubble plot of diseases targeted by the 157 surveillance systems evaluated in 116 studies published between January 2010 and January 2025, and corresponding frequencies. Abbreviations: ASF = african swine fever; Brucell. = brucellosis; BSE = bovine spongiform encephalophathy; BT = bluetongue; bTB = bovine tuberculosis; BVD = bovine viral diarrhea; Campyl. = campylobacteriosis; CCHF = crimean congo hemorrhagic fever; CEM = contagious equine metritis; CSF = classical swine fever; EIA = equine infectious anemia; EC = echinococcosis; EVA = equine viral arteritis; FMD = foot and mouth disease; IBR = infectious bovine rhinotracheitis; Lepto. = leptospirosis; MD = mucosal disease; PRRS = porcine reproductive and respiratory syndrome; Salm. = salmonellosis; Taen. = taeniasis or cysticercosis; TBD = tick-borne diseases; vCJD = variant Creutzfeld-Jacob disease; WNF = West Nile fever; WNND = West Nile neuroinvasive disease; ZI = zoonotic influenza.

health, one rabies study estimated average cost per human death averted and per life year gained (Undurraga et al., 2017).

Completeness examines the "exhaustivity" of information collected (often the proportion of intended reports/data actually submitted relative to the expected number) (Alemu et al., 2019; Barboza et al., 2013; Drewe et al., 2017). It was used more in evaluations targeting human health surveillance.

A wide range of qualitative and quantitative methods were used to assess the attributes. Qualitative methods primarily assessed implementation attributes such as *acceptability, flexibility, simplicity, stability,* and the impact attribute *usefulness* (Amat et al., 2015; Alemu et al., 2019; Ario et al., 2022; Babaie et al., 2015). Common approaches included stakeholders/key informants surveys or interviews, often paired with reviews of reports, documents or surveillance data. In animal health participatory approaches were used for *acceptability* (Calba et al., 2016; Peyre et al., 2015; Schulz et al., 2017).

Quantitative methods chiefly focused on performance and impact attributes. For performance attributes, Scenario Tree Modeling (Martin et al., 2007) was used to estimate *sensitivity*, *positive predictive value (PPV), negative predictive value (NPV), type I error,* and *type II error* (Calvo-Artavia et al., 2013; Jamin and Rivière, 2020; Knight-Jones et al., 2010).

Sensitivity was also derived via specific formulas (Barboza et al., 2013; Waziri et al., 2014), simulation models (Bonney et al., 2019; Foddai et al., 2021, 2020), stochastic agent-based models (Arruda et al., 2017), stochastic susceptible-exposed-infectious-recovered or removed (SEIR) model (Comin et al., 2012), Receiver Operating Characteristic (ROC) curve analysis (Faverjon et al., 2017, 2016) and semi-quantitative methods (Amat et al., 2015; Drewe et al., 2017). *Timeliness* was measured by time intervals between surveillance steps (Garcell et al., 2014), the share of on-time reports (Lopes et al., 2016), Kaplan-Meier survival analysis (Arruda et al., 2017), capture-recapture (Peyre et al.,

Table 5
Distribution of the most frequently applied surveillance evaluation attributes by health domain, geographic region, and disease focus (2010–2025).*.

Attribute	Use in surveillance systems targeting animals, or both humans and animals (%) (A&H), or humans (%) (H)	Use by continental region	Most targeted diseases
Sensitivity	**A&H**: 67% (69/103) **H**: 24% (13/54)	Africa: 53% (16/30) Asia: 23% (5/22) Europe: 59% (38/64) North America: 58% (14/24) Oceania: 83% (5/6) South America: 25% (1/4) Not specified: 60% (3/5)	Multiple diseases, AI, bTB, zoonotic influenza
Timeliness	**A&H**: 28.2% (29/103) **H**: 83% (45/54)	Africa: 73% (22/30) Asia: 73% (16/22) Europe: 27% (17/64) North America: 46% (11/24) Oceania: 50% (3/6) South America: 75% (3/4) More than one: 100% (2/2)	Multiple diseases, zoonotic influenza, rabies, FMD
Simplicity	**A&H**: 15.5% (16/103) **H**: 63% (34/54)	Africa: 63% (19/30) Asia: 55% (12/22) Europe: 11% (7/64) North America: 46% (11/24) Oceania: 17% (1/6) South America: 0	Multiple diseases, zoonotic influenza, Covid-19
Usefulness	**A&H**: 13.6% (14/103) **H**: 39% (21/54)	Africa: 40% (12/30) Asia: 32% (7/22) Europe: 8% (5/64) North America: 42% (10/24) Oceania: 0 South America: 0 More than one: 50% (1/2)	Multiple diseases, zoonotic influenza, rabies
Flexibility	**A&H**: 14.6% (15/103) **H**: 37% (20/54)	Africa: 40% (12/30) Asia: 27% (6/22) Europe: 9% (6/64) North America: 42% (10/24) Oceania: 0 South America: 0 More than one: 50% (1/2)	Multiple diseases, zoonotic influenza
Acceptability	**A&H**: 14.6% (15/103) **H**: 37% (20/54)	Africa: 43% (13/30) Asia: 27% (6/22) Europe: 20% (13/64) North America: 4% (1/24) Oceania: 17% (1/6) South America: 0 More than one: 50% (1/2)	Multiple diseases, bTB, Covid-19, CSF, rabies
Representativeness	**A&H**: 13.6% (14/103) **H**: 35% (19/54)	Africa: 33% (10/30) Asia: 27% (6/22) Europe: 11% (7/64) North America: 42% (10/24) Oceania: 0 South America: 0	Multiple diseases, zoonotic influenza
Data quality	**A&H**: 3.9% (4/103) **H**: 48% (26/54)	Africa: 53% (16/30) Asia: 23% (5/22) Europe: 2% (1/64) North America: 29% (7/24) Oceania: 17% (1/6) South America: 0	Multiple diseases, rabies, Covid-19
Cost or cost-effectiveness	**A&H**: 24.3% (25/103) **H**: 9% (5/54)	Africa: 13% (4/30) Asia: 5% (1/22) Europe: 36% (23/64) North America: 4% (1/24) Oceania: 17% (1/6) South America: 0	AI, bTB, multiple diseases, CSF
Completeness	**A&H**: 8.7% (9/103) **H**: 33% (18/54)	Africa: 37% (11/30) Asia: 36% (8/22) Europe: 5% (3/64) North America: 17% (4/24) Oceania: 17% (1/6) South America: 0	Multiple diseases, zoonotic influenza

* To account for unequal numbers of evaluations across regions or domains, results are expressed as proportions within each region or domain. References to studies applying these attributes are provided in Supplementary Material 2.

2015), and other quantitative models. It was also evaluated qualitatively through stakeholder interviews/questionnaires (Awekeya et al., 2021) and with semi-quantitative methods (Amat et al., 2015; Drewe et al., 2017).

For impact attributes, Häsler et al. (2012a), (2012c) applied an economic model to estimate *cost*, *benefit*, *margin over intervention* and *net value of the program. Cost or cost-effectiveness* was further examined using cost analysis (Babo Martins et al., 2017), cost-effectiveness analysis (Poirier et al., 2019), cost minimization analysis (Bellini et al., 2014), scenario tree model (Hénaux and Calavas, 2017), and participatory interviews (Delabouglise et al., 2016). ***Benefit*** were identified as both direct and indirect (Drewe et al., 2017) and via participatory interviews (Calba et al., 2015a; Delabouglise et al., 2016).

Organizational attributes were assessed via qualitative literature review and stakeholder engagement (Rivers et al., 2023),

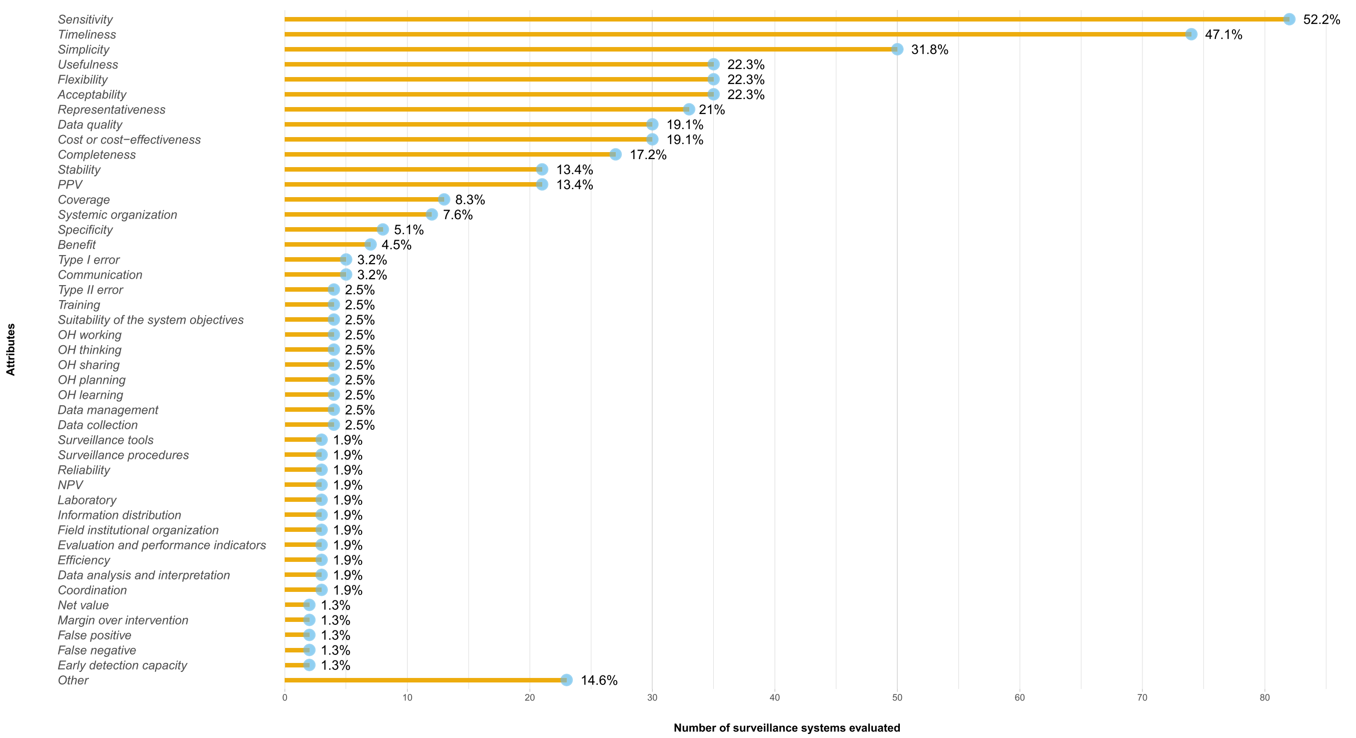

Fig. 4. Distribution of 67 attributes related to 157 surveillance systems evaluated in 116 studies, published between January 2010 and January 2025. The category "Other" covers attributes used only in one evaluation.

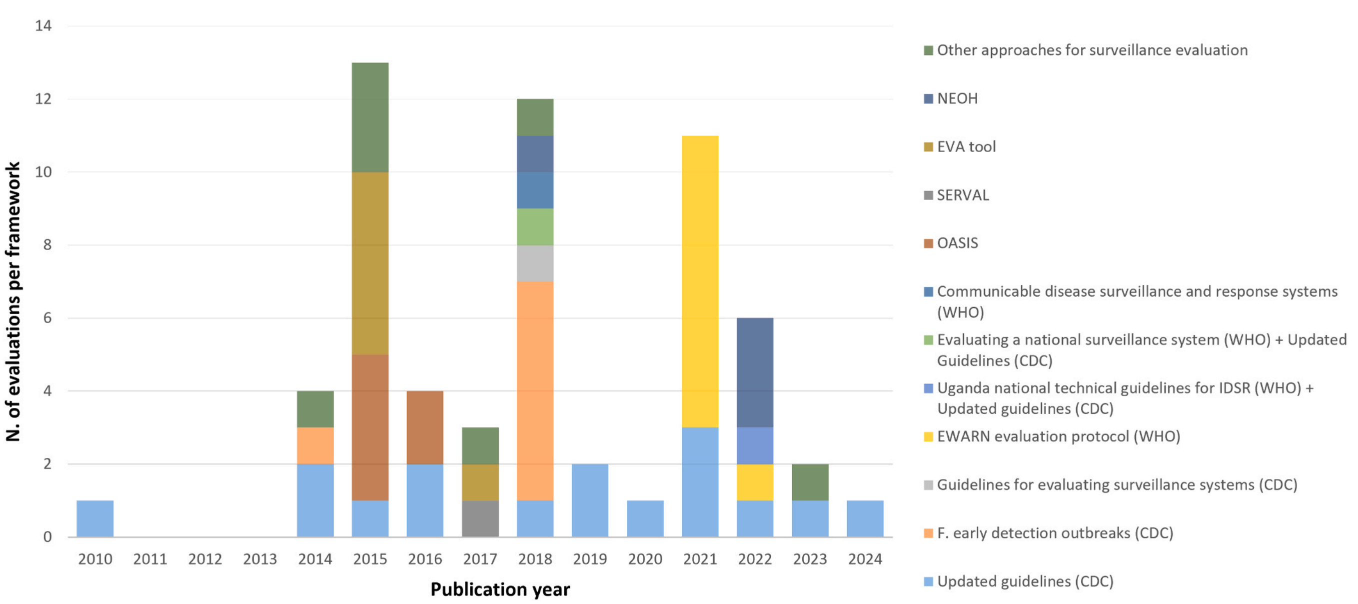

Fig. 5. Distribution of frameworks used in 60 surveillance system evaluations published between January 2010 and January 2025. Frameworks described in the literature without an accompanying technical report are grouped as "Other approaches for surveillance evaluation".

semi-quantitative scoring with qualitative appraisal (Amat et al., 2015; Fonseca et al., 2018), and quantitative techniques such as the analytic hierarchy process (Ohashi et al., 2010) and system action model (Peyre et al., 2015). One Health related attributes combined descriptive/qualitative assessment with semi-quantitative scoring (Fonseca et al., 2018; Garcia-Vozmediano et al., 2022).

3.7. Frameworks for surveillance evaluation

In total, 60 (38.2%) evaluations used frameworks specifically designed for surveillance system evaluation. Fig. 5 shows the number of evaluations using each framework and the year in which the evaluation was conducted.

The most frequently used framework was the *CDC's Updated Guidelines for Evaluating Public health Surveillance Systems* (German et al., 2001). Published in 2001 as an updated version of *CDC's Guidelines for Evaluating Surveillance Systems* (Klaucke et al., 1988), this framework was designed to address evolving needs such as integrating surveillance with health information systems, establishing data standards, facilitating electronic data exchange, and supporting public health responses to emerging threats. It was mainly applied to public health surveillance systems in Africa and Asia (Alemu et al., 2019; Awekeya et al., 2021; Ba et al., 2024; Babaie et al., 2015; Grills et al., 2010; Hunduma and Leulseged, 2021; Mtema et al., 2016; Pham et al., 2021; Prajapati et al., 2023; Qurat ul Ain et al., 2019; Randriamiarana et al., 2018; Schwind et al., 2014; Stolka et al., 2018; Umeozuru et al., 2022; Van Boetzelaer et al., 2020). Two evaluations in the veterinary sector also applied this framework (Lopes et al., 2016; Waziri et al., 2014). The *CDC's Framework for Evaluating Public Health Surveillance System for Early Detection of Outbreaks* (Buehler et al., 2004; Maponga et al., 2014; Thomas et al., 2018) complements the previous CDC guidelines by focusing on early detection approaches, including traditional disease reporting, aberration detection analytics and syndromic surveillance systems.

The *World Health Organization (WHO) Early Warning Alert and Response Network in Emergencies (EWARN)* evaluation protocol (World Health Organization Regional Office for the Eastern Mediterranean, 2018), based on CDC's guidelines (German et al., 2001; Klaucke et al., 1988), was used to assess EWARN systems in Africa and Asia (Mala et al., 2021; Rumunu et al., 2022), designed for emergency situations, when conventional surveillance systems are disrupted (World Health Organization Regional Office for the Eastern Mediterranean, 2018). The *WHO Guidelines for Evaluating a National Surveillance System* (Randriamiarana et al., 2018; World Health Organization, 2013), developed for assessing Human Immunodeficiency Virus (HIV) surveillance, and the *National Technical Guidelines for Integrated Disease Surveillance and Response (IDSR)* (Ario et al., 2022; Uganda Ministry of Health, 2012) were used in conjunction with the CDC's guidelines (German et al., 2001; Klaucke et al., 1988) assessing respectively an Integrated Disease Surveillance and Response System (IDSR) (Randriamiarana et al., 2018) and surveillance in refugee settlements in Africa (Ario et al., 2022). The *Communicable disease surveillance and response systems – Guide to monitoring and evaluating* (World Health Organization, 2006) was used to assess a surveillance app in a pilot project in Africa (El-Khatib et al., 2018).

These frameworks, conceived to evaluate public health surveillance systems, provide structured guidance for conducting evaluations. While each has its own structure, they share core components, including specifying the health event under surveillance and the scope of the evaluation, describing the surveillance system and its objectives, assessing the performance attributes, engaging stakeholders and summarizing findings with recommendations to support system improvement (Buehler et al., 2004; German et al., 2001; Klaucke et al., 1988; Uganda Ministry of Health, 2012; World Health Organization, 2013, 2006).

Seven studies used frameworks specifically designed for animal health and veterinary public health surveillance. Among these, the *OASIS tool*, particularly its streamlined version, OASIS *flash* (Hendrikx et al., 2011), was the most widely applied. The evaluation is conducted using a scoring grid supported by a detailed scoring guide, which assesses 78 criteria grouped into 10 functional sections (e.g., objectives and scope of surveillance, surveillance procedures and data management). These criteria are used to calculate scores for eight critical control points (CCPs), identified through the Hazard Analysis and Critical Control Point method, as well as for 10 attributes assessing surveillance quality. The *RISKSUR EVA tool* (Comin et al., 2016; Peyre et al., 2019), applied during its validation and later implementation (Peyre et al., 2015; Schulz et al., 2017), offers a web-based interface to describe systems, define evaluation questions and select context specific attributes and assessment methods. *SERVAL* (Drewe et al., 2015) provides a generic framework that guides through defining evaluation scope, characterizing the system, prioritizing attributes using a selection matrix and reporting results. The Grosbois et al. (2015) framework proposes a conceptual rationale comparing decisions made with perfect epidemiological knowledge versus those based on surveillance data focusing on minimizing *type I* (false positive) and *type II* (false negative) errors to ensure effective control responses.

The remaining frameworks targeted specific surveillance types, such as syndromic surveillance systems (Colón-González et al., 2018), and hazard-specific livestock surveillance (Guo et al., 2014). Four studies used One Health oriented frameworks. The most prominent was the *Network for the Evaluation of One Health (NEOH)* (Fonseca et al., 2018; Garcia-Vozmediano et al., 2022; Rüegg et al., 2018a), which includes four steps: describing the initiative and context, defining expected outcomes via a theory of change, assessing "OH-ness" (integration across sectors and disciplines), and comparing outcomes with "OH-ness" scores. Additional frameworks include Rivers et al. (2023), outlining a model for output-based zoonotic threats surveillance, and Babo Martins et al. (2016), presenting a conceptual framework to quantify the economic value of One Health integration by assessing both tangible and intangible *cost* and *benefits*.

Among the studies that did not conduct empirical evaluations, additional frameworks were identified. *SurF* is designed to support the evaluation of biosecurity and animal health surveillance systems, by guiding attribute selection through a dedicated matrix. *OH-EpiCap* (Tegegne et al., 2023) is a semi-quantitative tool that assesses One Health epidemiological surveillance capacity using indicator-based scoring and produces a radar chart summarizing performance by attribute. In addition, Crawley et al. (2024) proposed *an indicator framework for the monitoring and evaluation of event-based surveillance systems (EBS),* structured around indicators assessing inputs (resources), activities, outputs (deliverables), outcomes (changes achieved) and impacts (long-term effects).

The different attributes included in the previously listed frameworks are illustrated in Supplementary material 4.

4. Discussion

This scoping review updates and extends the review by Drewe et al. (2012) by providing a comprehensive overview of the attributes and frameworks applied to surveillance system evaluations between 2010 and 2025, contributing to a clearer understanding of how surveillance performance is currently assessed across animal, human and One Health domains, and where methodological gaps remain.

Surveillance evaluations were unevenly distributed across regions, with most studies conducted in Europe, Africa, North America, and Asia. This pattern likely reflects differences in surveillance capacity, institutional organization, and evaluation culture, as well as regional priorities (Graziosi et al., 2026). Human health surveillance evaluations were more frequently undertaken in Africa and Asia compared to the other regions of the world, and often in settings experiencing an increasing burden from public health emergencies or facing humanitarian crises (Alemu et al., 2019; Sparrow et al., 2016). In these contexts, evaluations are commonly supported by external funding and implemented as rapid, targeted assessments to guide system strengthening and resource allocation, despite limitations in routine surveillance resources. In contrast, veterinary public health surveillance evaluations were more frequent in Europe and North America, where surveillance systems are strongly linked to regulatory requirements, trade, and animal and welfare protection (Alba et al., 2010). These differences illustrate how surveillance evaluation priorities are shaped by the intended use of surveillance outputs and by broader socio-economic and regulatory contexts.

A considerable proportion of evaluated systems targeted multiple diseases or syndromes simultaneously. This reflects the increasing adoption of integrated surveillance approaches, particularly in settings where resources are constrained or where coordinated responses to multiple hazards are required. Initiatives such as the WHO's IDSR strategy (WHO AFRO) and EWARN (Mala et al., 2021), as well as surveillance systems implemented in resource-limited settings, such as refugee camps or disaster-affected areas (Babaie et al., 2015; Van Boetzelaer et al., 2020), exemplify this trend and highlight the importance of evaluating surveillance systems that operate across diseases rather than within single-disease silos. The remaining systems focused mainly on zoonoses such as AI, bTB and rabies. This trend reflects the importance given to these diseases, which are typically regulated under mandatory frameworks and pose significant risks to public and animal health, as well as, in some cases, to trade and economy.

Across the reviewed studies, a large number of distinct attributes was identified. The implementation and performance categories contained the largest number of attributes, reflecting the strong focus on evaluating multiple operational aspects, functional efficiency, and overall system performance. Conversely, considerably fewer attributes addressed the systems structure, economic and non-economic impacts or the integration of One Health principles, suggesting either that these areas have received comparatively less attention in evaluations studies, or that fewer attributes are sufficient to capture these categories.

Most evaluations relied on a limited subset of attributes. Fewer than one third of evaluations assessed six or more attributes, indicating that many studies focused on specific aspects of surveillance performance rather than conducting comprehensive evaluations (Babo Martins et al., 2017; Calba et al., 2016). This selective use of attributes is not necessarily a limitation, as targeted evaluations can be appropriate when addressing specific operational questions. However, it underscores the importance of clearly defining evaluation objectives to ensure that attribute selection is aligned with decision-making needs.

Sensitivity and *timeliness* were the most frequently assessed attributes, consistent with previous findings (Drewe et al., 2012), reflecting their central role in determining a surveillance system's capacity to detect health events (Peyre et al., 2019) and respond promptly (German et al., 2001). *Sensitivity* was assessed more often in veterinary public health, where surveillance often supports formal disease freedom claims and compliance with international standards (e.g., WOAH). This regulatory-driven focus contrasts with many human health surveillance systems, where guiding clinical/public health action often matter more than formal absence claims. In addition, it may also reflect inherent challenges in human health surveillance, such as the absence of a gold standard or uncertainty about the true occurrence of cases in the human population, as noted by some authors in specific contexts (Babaie et al., 2015; Van Boetzelaer et al., 2020). In contrast, human health surveillance evaluations more commonly emphasized attributes such as *timeliness*, *simplicity*, *usefulness*, *flexibility*, *acceptability*, *representativeness*, *data quality* and *completeness*, reflecting both the operational focus of public health surveillance and the influence of established evaluation frameworks (German et al., 2001).

Consistent with previous reviews (Calba et al., 2015b; Drewe et al., 2012) economic and sociological attributes were infrequently incorporated into surveillance systems evaluations. Altough *cost or cost effectiveness* was among the most frequently mentioned attributes, it was assessed only in a small proportion of the evaluations, mainly in Europe and Africa. Surveillance activities in both veterinary public health and human health entail a range of costs, including capital investments (e.g., infrastructure, equipment), recurrent operational costs (e.g., personnel, data collection and management), and additional expenses such as those associated with laboratory diagnostics. However, *cost or cost effectiveness* is more commonly evaluated in animal health surveillance. In the livestock sector, infectious diseases can have substantial economic impacts, leading to production losses and requiring additional mitigation measures, including trade movement restrictions (Häsler et al., 2011). The inclusion of *cost* is therefore particularly important in animal health surveillance, where economic considerations are central to prioritization and decision-making – for example, by reallocating budgets among activities or adjusting sampling strategies to maximize cost-effectiveness. Similarly, quantifying the economic impact of human diseases is pivotal since they impose substantial economic burdens through direct medical costs, costs related to preventive and prophylactic measures (Undurraga et al., 2017), and indirect costs associated with morbidity and premature mortality. Human health surveillance systems operate in complex health systems where outcomes (e.g., lives saved) are often valued in non-monetary terms (quality of life, equity, social value). Subsequently, human health surveillance evaluations tended to prioritize attributes supporting outbreak detection and response, such as *timeliness*, reflecting differences in how economic resources and outcomes are valued across domains. The limited assessment of *cost or cost effectiveness* may also be influenced by the focus of many studies on targeted evaluations (Calba et al., 2016; Cameron et al., 2020; Ferrer-Miranda et al., 2020) and by the absence of explicit cost-related attributes in widely used frameworks (German et al., 2001).

Sociological attributes, particularly *acceptability*, play a fundamental role in system performance, as they directly influence participation, *data quality*, *sensitivity* and *timeliness* (Auer et al., 2011; Calba et al., 2015b). Despite this central importance, such attributes are inconsistently assessed, suggesting that stakeholders' perspectives are not yet systematically integrated into surveillance evaluation.

Certain less frequently applied attributes – for example, *systemic organization*, *benefits* and *specificity* – were generally observed in animal health or One Health-oriented evaluations, which may indicate that their relevance is often considered context-specific or influenced by established evaluation practices, practical constraints or limited awareness, rather than a lack of relevance. However, a clear definition of the assessment scope, timeframe, and available human and financial resources is a critical prerequisite, as these factors fundamentally shape the selection of attributes (Drewe et al., 2017; Muellner et al., 2018; Peyre et al., 2019).

Trends observed over time indicate that evaluation activity increased alongside the development of new frameworks (Hendrikx et al., 2011; Peyre et al., 2015) and reviews exploring this topic (Calba et al., 2015b; Drewe et al., 2012), but has fluctuated in recent years, which may result from recent studies not being published or a reduction in budgets devoted to evaluating public policies, raising concerns given the essential role of evaluation in maintaining and improving surveillance systems' capacity. Together, these findings highlight the need for more purpose-driven evaluation strategies that explicitly consider stakeholders' engagement and long-term system sustainability.

A wide range of qualitative and quantitative assessment methods was used to evaluate surveillance attributes, reflecting the diversity of evaluation objectives. The observed patterns were largely consistent with the nature of the attributes themselves: qualitative approaches were mainly applied to sociological and organizational attributes, such as *acceptability*, while quantitative methods were more frequently used for performance- and impact-related attributes, including *sensitivity*, *timeliness,* and *cost or cost-effectiveness.* Combining qualitative and quantitative approaches remains relatively uncommon but offers clear added value by allowing comparison between perceived and measured system performance.

Across public health and animal health domains, surveillance evaluation frameworks ranged from general-purpose tools to highly specialized approaches. The *CDC's Updated Guidelines for Evaluating Public Health Surveillance Systems* (German et al., 2001) remained the most widely applied framework, with a consistent use over the years, particularly in public health, highlighting their continued influence despite being published in 2001. In contrast, frameworks developed within veterinary public health – although flexible and adaptable across species and diseases – were applied less consistently. This limited uptake may reflect factors such as lower awareness, perceived complexity, limited publications (potentially due to time or financial constraints, refusal by health authorities, or lack of interest from scientific journals) or insufficient training and dissemination, rather than a lack of relevance. Using the most appropriate framework enables evaluations to address specific needs – such as conducting comprehensive assessment or focusing on specific evaluation questions – and prioritize attributes, optimizing the efficiency of the assessment.

The growing emphasis on One Health has led to the development of dedicated frameworks aimed at assessing the system's capacity and capability to generate and share relevant information for all domains, identifying areas of improvement (Rüegg et al., 2018a; Tegegne et al., 2023), and assessing economic benefits of cross-sectoral collaboration (Babo Martins et al., 2016). While these frameworks provide structured approaches to evaluating integrated surveillance, their application remains limited, suggesting that One Health evaluation is still an emerging practice rather than a routine component of surveillance assessment. These tools can be combined with complementary evaluation frameworks, such as *ECoSur* (Bordier et al., 2019), which provides a matrix assessing multisectoral collaboration, enhancing the comprehensiveness of evaluations.

Several frameworks developed for veterinary public health were specifically tailored to particular surveillance types, such as syndromic surveillance (Colón-González et al., 2018), output-based surveillance systems (Rivers et al., 2023), and economic optimization models in livestock production chains (Guo et al., 2014). Their high degree of specialization likely explains their narrow application beyond their original contexts.

Although gray literature was consulted, no additional evidence of the application of surveillance evaluation frameworks was identified. This may suggest that these may be applied operationally without formal reporting – for instance, for confidential reasons (Tegegne et al., 2023), reducing opportunities for methodological learning and comparison.

The attributes most frequently included in evaluation frameworks closely matched those most commonly applied in the reviewed studies, even when evaluations did not explicitly draw upon a framework. This convergence suggests the existence of a shared core set of attributes – such as *sensitivity, timeliness, simplicity, flexibility, representativeness, acceptability,* and *data quality* – perceived as broadly relevant and adaptable across diverse surveillance contexts. Differences across frameworks primarily concerned the level of granularity with which certain components, particularly data-related elements, were defined and grouped. While some frameworks assessed *data collection, management* and *analysis* as distinct attributes (Drewe et al., 2015; Hendrikx et al., 2011; Muellner et al., 2018), others incorporated these aspects into broader categories such as *data quality* and *simplicity* (Klaucke et al., 1988; World Health Organization, 2013). Generally, nomenclature and terminology are fairly consistent; however, discrepancies remain, as similarly named attributes may differ in scope and definition, while equivalent definitions are sometimes assigned to differently labeled attributes. Clear reporting of attribute definitions, included components, and assessment methods is therefore essential to ensure transparency, comparability, and interpretability of evaluation findings.

Although several attributes were consistently prioritized, others (e.g. *risk-based criteria definition, early detection capacity, area specificity, training, communication* and *information distribution*) were either applied infrequently in the reviewed evaluations or included in frameworks without being utilized. The *risk-based criteria definition* attribute, included in the *EVA tool* (Peyre et al., 2019), is particularly relevant for risk-based surveillance, especially in contexts where this approach is legally required (Regulation (EU) 2016/429). A feasible method to assess this attribute could involve qualitative assessment through consultation with relevant stakeholders to evaluate the appropriateness of selected risk factors and identify potential improvements. *Communication* and *information distribution* (or *external communication and dissemination*) could be broadly implemented to evaluate the exchange of information and feedback among all levels of the surveillance system, including stakeholders, field workers and external partners (Amat et al., 2015; Drewe et al., 2017; Hunduma and Leulseged, 2021). Effective communication is essential to raise awareness about disease surveillance and to promote public participation, particularly in passive surveillance activities that rely on community cooperation.

Their limited use appears to reflect feasibility costraints, established evaluation practices, and methodological challenges rather than a lack of relevance. While some of these attributes may be applicable for all evaluations – such as *communication*, as recommended by Drewe et al. (2017) – others (e.g. *risk-based criteria definition*) may offer valuable insights in specific contexts and should be considered selectively, based on evaluation objectives and decision-making needs, rather than systematically included in all assessments.

Overall, this review highlights that surveillance evaluations tend to prioritize operational performance while giving less attention to organizational, sociological, and impact-related dimensions. Moving towards more purpose-driven evaluations, where attribute selection, methods, and frameworks are explicitly aligned with evaluation objectives and available resources, would strengthen the contribution of surveillance evaluation to decision-making across human, animal, and One Health domains.

Surveillance evaluation plays a critical role in strengthening system performance by identifying weaknesses, informing system redesign, and supporting more effective and efficient surveillance strategies. However, evidence on how evaluation findings are translated into corrective actions remains limited, highlighting the need for future research to assess the practical impact of surveillance evaluations. Further studies should also compare the strengths and limitations of existing evaluation frameworks across human, animal, and One Health surveillance systems, considering factors such as feasibility, time and resource requirements, attribute coverage, and potential complementarity. Such work would support more informed framework selection and combination, ultimately enhancing the effectiveness and utility of surveillance systems evaluations.

4.1. Limits of the study

The main limitation of this study is the possibility of missing relevant reports or technical documents on surveillance evaluations, since gray literature searches returned no results, and contacting individual institutions was not feasible given the global scope of this study. In addition, evaluations focusing exclusively on entomological surveillance, aquaculture, and antimicrobial resistance were excluded to maintain a clear and manageable scope, which may limit the generalizability of findings to these domains.

5. Conclusion

This scoping review examined surveillance systems evaluations for animal infectious diseases and zoonoses conducted worldwide in the last 15 years, with a focus on the use of evaluation attributes and frameworks used to guide these assessments. The findings confirm that surveillance evaluation is a globally relevant activity across human health, animal health and One Health domains, providing a structured overview of current evaluation practices and highlighting attributes that, although less commonly used, may offer substantial added value in specific surveillance contexts.

Funding

Funded by the European Union – NextGenerationEU under the National Recovery and Resilience Plan (PNRR), Mission 4, Component 2, Investment 3.3 (Ministerial Decree No. 630/2024), and by the Istituto Zooprofilattico Sperimentale delle Venezie (IZSVe) – CUP: J33C24001480009.

CRediT authorship contribution statement

Mulatti Paolo: Writing – review & editing, Methodology, Conceptualization. **Cattoli Giovanni:** Writing – review & editing, Conceptualization. **Lupini Caterina:** Writing – review & editing, Conceptualization. **De Nardi Marco:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Martella Liliana:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Scolamacchia Francesca:** Writing – review & editing, Writing – original draft, Methodology.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevetmed.2026.106879.

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