EVALUATION OF BRUCELLOSIS SURVEILLANCE IN NORTH MACEDONIA USING A ONE HEALTH APPROACH

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Abstract

Brucellosis is an important zoonotic disease that continues to represent a public health and socio-economic concern in North Macedonia despite a substantial decline in incidence over recent decades. This study aimed to evaluate the human brucellosis surveillance system in North Macedonia and assess its performance according to standard surveillance attributes. The evaluation was conducted through a review of the National Program for Prevention and Control of Brucellosis, national surveillance reports, legislation, and epidemiological data from 1980 to 2023. Surveillance system attributes assessed included data quality, sensitivity, predictive value positive, representativeness, timeliness, stability, flexibility, and usefulness. The surveillance system is based on mandatory passive reporting with laboratory confirmation and coordination between the Institute of Public Health and the Food and Veterinary Agency under a One Health approach. Human brucellosis incidence declined markedly following implementation of livestock vaccination programs, reaching only six reported human cases in 2023. The system demonstrated strengths including national coverage, legal support, standardized case definitions, and integration with veterinary surveillance. However, important limitations were identified, including reliance on paper-based reporting, lack of integrated electronic databases, incomplete reporting indicators, and possible under-reporting in rural areas. Limited epidemiological staffing in some regional centers for public health may also affect surveillance performance. The surveillance system remains effective and useful for monitoring and control of brucellosis, but modernization is needed to sustain elimination efforts. Strengthening electronic integration, improving timeliness and completeness of reporting, maintaining livestock vaccination, and increasing epidemiological capacity are essential to ensure continued control and prevention of brucellosis in North Macedonia.

Keywords: Brucellosis, Surveillance system, One Health, Zoonotic disease

Introduction

Brucellosis is a zoonotic bacterial infection of major public health and socio-economic concern. In North Macedonia, the disease was first recorded in epidemic form in 1980 in Bitola municipality and peaked in 1992 with 922 cases across 22 municipalities. Since the introduction of livestock vaccination in 2008, incidence in humans has declined markedly. In 2023, only 6 cases were reported (0.3 per 100,000), compared to annual averages of more than 270 in the 1980–2000s period. Despite this decline, brucellosis remains a priority zoonosis due to its chronic health effects, hospitalisation burden, and risk of recurrence.

Table 1. Reported brucellosis cases and incidence in North Macedonia, 2012–2023

Year	Cases	Incidence (per 100,000 population)
2012	82	4.0
2013	20	1.0
2014	18	0.9
2015	15	0.7
2016	16	0.8
2017	10	0.5
2018	7	0.3
2019	9	0.45
2020	7	0.34
2021	6	0.29

2022	4	0.19
2023	6	0.3

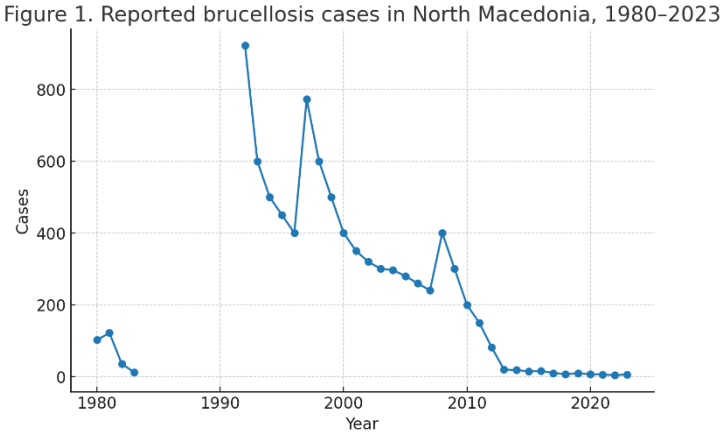


Figure 1. Reported brucellosis cases in North Macedonia, 1980–2023

North Macedonia has implemented a National Programme for Prevention and Control of Brucellosis, integrating veterinary and human health actions. This programme for 2025 outlines objectives, measures, and indicators to sustain low incidence. Evaluation of the surveillance system is critical to assess its capacity to detect, monitor, and respond to brucellosis, in alignment with ECDC guidance and MediPIET standards.
Objectives of this evaluation:
- To describe the surveillance system for brucellosis in North Macedonia.
- To assess its performance according to standard attributes (data quality, sensitivity, predictive value positive, representativeness, timeliness, stability).
- To provide recommendations to strengthen the system.

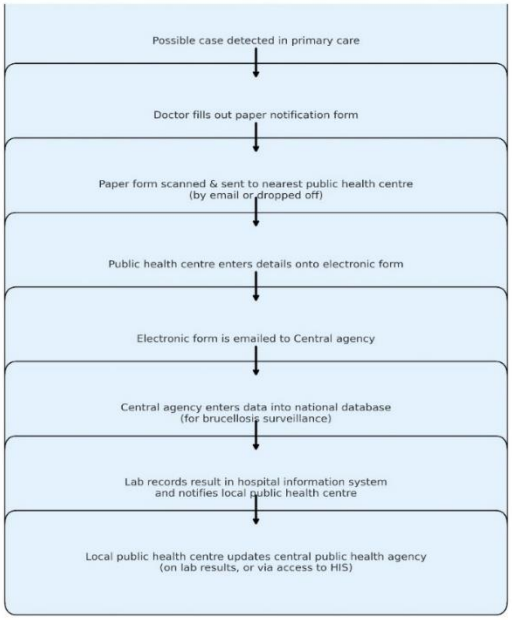
Methods

2.1 Description of the surveillance system: The evaluation was based on review of the 2025 National Brucellosis Programme, IPH surveillance reports, and relevant legislation. Stakeholders include the Ministry of Health, Institute of Public Health (IPH), 10 regional Centres for Public Health (CPH), local epidemiological units, and the Food and Veterinary Agency (AHV).
Population under surveillance: the entire population of North Macedonia, with focus on rural and livestock-exposed groups. Case definitions follow the national communicable disease regulations and WHO/ECDC standards. The surveillance system is primarily passive with stimulated and active elements during outbreaks.
Data flow: cases are detected and reported by clinicians to regional CPH epidemiologists, entered into the national database managed by IPH, and shared with the Ministry of Health and AHV. Feedback is provided quarterly and annually in aggregated reports.

2.2 Analysis of the surveillance system: Attributes assessed: Data quality, Sensitivity, Predictive Value Positive (PVP), Representativeness, Timeliness, Stability. Methods included document review, analysis of surveillance data (1980–2023 trends, 2012–2021 incidence), and comparison with programme indicators.

Results

3.1 Description of the surveillance system: Objectives: To prevent and control brucellosis in humans, reduce incidence, avoid complications, achieve microbiological confirmation of all suspected cases, and improve awareness among health workers and the population.



Case definitions: Standard case definitions for acute, recurrent, and reinfection cases are applied. All cases must be notified to the epidemiological service of the local CPH.
System type: The system is based on passive surveillance with mandatory case reporting, complemented by active outbreak investigations when clusters are suspected. No formal statistical outbreak detection algorithms are applied; instead, outbreaks are identified through routine review of case reports and temporal/geographic clustering, as case numbers are generally low and focus remains on detecting sporadic cases quickly.
Data structure: Individual case reports, including epidemiological questionnaires, are first completed on paper by healthcare providers and sent to the regional Centres for Public Health, which forward them to the Institute of Public Health (IPH). At IPH, data are entered into the national surveillance database for brucellosis, which is currently not linked with the national electronic health record system ("Moj Termin"). Laboratory data are recorded separately at IPH and CPH laboratories and then matched manually with case reports before analysis. Laboratory confirmation is performed using Brucelacapt, a serum agglutination test for detecting anti-Brucella antibodies, and the BAB test (Buffered Acidified Antigen test), a rapid slide agglutination screening test. Positive screening results are confirmed with Brucelacapt before cases are classified.
Indicators: Indicators include incidence, coverage of awareness activities, and laboratory confirmation rates. Distinguishing new infections from recrudescence or reinfections is not routinely performed, as only serological methods (BAB and Brucelacapt) are used for confirmation. Molecular typing is not part of routine surveillance; therefore, cases are classified based on clinical and epidemiological information and timing of onset, rather than definitive laboratory differentiation.
Feedback: CPHs submit quarterly reports to IPH; IPH provides quarterly and annual reports to MoH and AHV. Annual summary reports include epidemiological commentary and recommendations.

Actions: Surveillance data guide awareness campaigns, risk communication, and coordination with the Food and Veterinary Agency (AHV) under a One Health approach. Human surveillance data are shared with AHV, which uses this information—together with its own animal surveillance data—to target livestock vaccination and implement control measures in affected areas. Non-human cases are recorded in AHV's animal health database by farm and location, and these data inform culling, movement restrictions, and intensified animal vaccination to reduce the risk of human infection.

3.2 Analysis of system attributes: Simplicity: The surveillance system uses standardized case definitions and a uniform notification form completed by physicians within 24h. Data remain case-level from the healthcare facility through the CPHs to the IPH, but IPH analyses are reported in aggregate. The process is simple, but reliance on paper forms and multiple reporting levels can slow transmission.
Flexibility: The system can adopt new diagnostics and case definitions, but lacks an integrated electronic platform. Currently:
Physicians: paper forms.
CPHs: receive, scan, and re-enter data into an electronic template.
IPH: transfers these to the national surveillance database.
Labs: record results in hospital systems and notify CPHs, which update the IPH.
Thus, reporting is case-based at all stages, but methods vary (paper, email, manual electronic entry), reducing efficiency.
Acceptability: The system is broadly accepted by clinicians and public health staff, as evidenced by continuous national reporting since 1980. No staff interviews were conducted, so this assessment is inferred; future work should include structured interviews with reporting staff (with sampling method, core questions, and interview guide provided as an appendix). Under-reporting in rural areas is plausible: 79.5% of patients reported village residence, and in 2020–2022 livestock infection in Poloshki and Northeastern regions remained ~5% while few human cases were reported. This discordance suggests potential gaps in case detection, particularly in rural areas, which are further explored under representativeness.
Data quality: Data quality is generally good, given the long history of mandatory notification and standardized reporting since 1980. However, limitations were noted: the reporting form lacks sufficient epidemiological and clinical details, preventing more detailed analysis, and there is no systematic linkage with clinical records or the national e-health database, which reduces completeness.
Sensitivity: The declining number of reported brucellosis cases over the past decade suggests a real reduction in disease incidence. Between 2010 and 2023, annual notifications decreased from 168 to just 6 cases. However, the possibility of under-detection of mild or chronic cases cannot be excluded, given the limitations in notification completeness and laboratory confirmation.
To illustrate these trends, Figure 2 shows the annual case numbers for 2010–2023, alongside the 3-year moving average percentage change. The graph confirms a sustained decline, although small increases were observed in the most recent years (2022–2023), which may reflect localized outbreaks or improved detection. Seasonal peaks are also documented in the national study (highest incidence in April, May, July, and September), indicating that presentation of data as monthly aggregates could further highlight seasonal transmission dynamics.

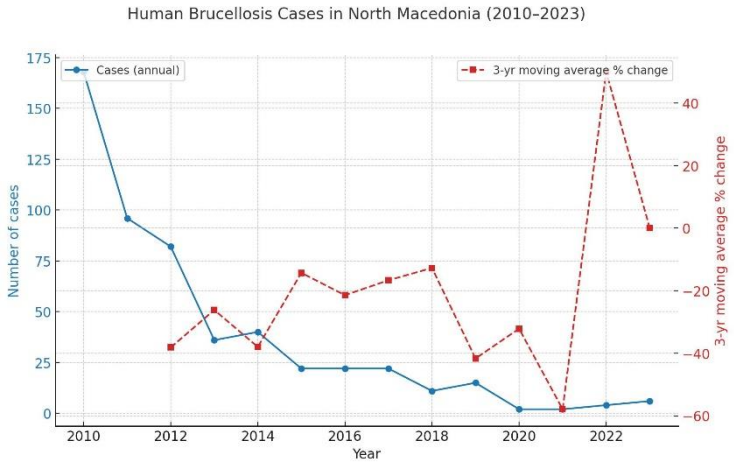


Figure 2. Number of cases during the period 2010-2023

The seasonal index shows marked peaks in April, May, July, and September, coinciding with periods of intensive livestock handling and consumption of fresh dairy products. The lowest activity is observed in March, October, and November. These consistent seasonal patterns suggest that the surveillance system is sensitive enough to capture temporal fluctuations, even if mild or chronic cases may be under-detected. (Figure 3).

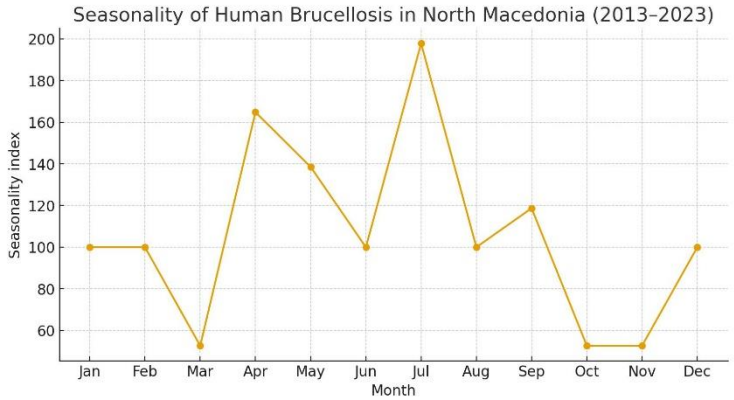


Figure 3. Seasonality of human brucellosis in North Macedonia (2013–2023).

Positive Predictive Value: For the six documented outbreaks (2007–2010), all 74 notified cases were laboratory confirmed, giving a PPV of 100% for outbreak notifications. For routine surveillance notifications, PPV cannot be calculated from the published study because counts of false positive notifications are not reported. This gap highlights a limitation of the current system.

Representativeness: National coverage of human brucellosis surveillance is ensured. However, comparison with veterinary surveillance indicates possible rural under-reporting. For example, in 2020–2022, livestock brucellosis prevalence was around 5% in Poloshki and Northeastern regions, while human notifications were very low. This discordance suggests that rural surveillance may be less representative than urban surveillance.

Table 2. Human brucellosis cases and livestock prevalence by selected region, North Macedonia

Region	Region type	Human cases (1980–2023), n	Livestock herd prevalence (2020–2022)
Polog	Rural	1,236	~5%
Northeastern	Rural	563	~5%
Southeastern	Rural	4,009	Lower
Skopje	Urban	1,596	Very low

Human case counts represent cumulative notifications from 1980–2023. Livestock prevalence refers to farm-level data reported by the Food and Veterinary Agency for 2020–2022.

Cumulative surveillance data from 1980 to 2023 show marked regional variation in the burden of human brucellosis. The highest number of reported human cases was recorded in the Southeastern region (n = 4,009), while the lowest was recorded in the Northeastern region (n = 563). Despite this, livestock brucellosis prevalence of approximately 5% at farm level persisted in the Polog and Northeastern regions during 2020–2022, while recent human notifications remained very low. This discordance suggests potential under-detection of human cases in rural regions, affecting the representativeness of the surveillance system.

Timeliness: Quarterly reporting is adequate for long-term trend monitoring but not optimal for rapid outbreak detection. In surveillance evaluation, timeliness also refers to the delay between symptom onset and notification, onset and laboratory confirmation, and notification to database entry. The national study does not report these data, so calculation of median delays by year or region was not possible. This represents a limitation of the current system. Future analyses should use case-based data to quantify these delays, as they are critical for early outbreak detection.

Cost: The national study does not provide data on actual expenditures of the brucellosis surveillance system, so the true cost could not be assessed. Instead, the approximate 2025 programme budget was reported as 1,000,000 MKD (≈ 16,000 EUR), split between the Institute of Public Health (363,000 MKD) and the Centres for Public Health (637,000 MKD), primarily for laboratory testing and training activities. While cost and budget are not the same, the budget illustrates the resources allocated to sustain surveillance of a disease that may be close to elimination. This highlights a key challenge: maintaining adequate funding for the last few cases, when surveillance becomes more resource-intensive despite declining incidence.

Usefulness: The surveillance system is useful for decision-making and prevention, particularly through its One Health approach. Human case notifications are coordinated with veterinary surveillance, allowing rapid tracing to livestock sources, targeted herd-level interventions, and identification of rural areas where animal infection persists but human cases may be under-reported. This integration strengthens both human and animal disease control, especially important in the elimination phase.

Stability: The surveillance system is supported by a legal mandate and established institutional structure, which ensures continuity. A major challenge, however, is the limited number of epidemiologists at regional Centres for Public Health. As shown in the table 3, staffing varies considerably, ranging from only 1 epidemiologist in Strumica and Ohrid to 4 in Skopje and Shtip. Such uneven distribution may weaken regional capacity for case detection and reporting, and could partly explain lower notification numbers in some areas. Ensuring adequate epidemiological staffing across all regions is critical to maintain system stability, particularly in the context of elimination efforts.

Table 3. Number of epidemiologists by Centre for Public Health, North Macedonia

CPH	Number of epidemiologists
Shtip	4
Kumanovo	3
Ohrid	1
Kocani	2
Skopje	4
Tetovo	3
Bitola	3
Prilep	3
Strumica	1
Veles	2

Discussion

The surveillance system for brucellosis in North Macedonia largely meets its objectives of monitoring incidence and supporting prevention. Its strengths include a strong legal framework, established under the Law on Protection of the Population from Infectious Diseases (Official Gazette no. 37/2016, with amendments), which mandates 24-hour notification of suspected cases. The system benefits from national coverage, routine laboratory confirmation, and integration with veterinary services through the Food and Veterinary Agency. The declining trend in reported cases reflects the effectiveness of livestock vaccination programmes, which have been in place since the early 2000s. To illustrate this impact more clearly, vaccination campaigns should be marked on the time-series graph of human cases (2010–2023).

Nevertheless, important challenges remain:

1. Shortage of epidemiologists in regional and local Centres for Public Health (e.g. only 1 in Strumica and Ohrid, compared to 4 in Skopje and Shtip), which may weaken capacity for timely case detection and reporting.
2. Timeliness and completeness of data reporting, as the national study does not provide onset, notification, or laboratory confirmation dates, preventing calculation of median delays.
3. Absence of a fully integrated electronic information system linking the Ministry of Health, Institute of Public Health, Centres for Public Health, and the Food and Veterinary Agency. At present, case notifications and laboratory data are stored separately. Without a common patient episode identifier, linkage can only be done probabilistically, which reduces accuracy and limits evaluation of key attributes such as positive predictive value and timeliness.

Limitations of this evaluation include reliance on programme and report data rather than case-level validation, and the absence of detailed quantitative indicators (e.g. notification delays, routine PPV). To address these gaps, obtaining case-level national data for the last 10 years (including dates of symptom onset, notification, and laboratory results) is essential. Such data would allow calculation of sensitivity, timeliness, and PPV, as well as more detailed analyses by region and by rural versus urban classification. Linkage between human and animal surveillance data is currently descriptive rather than case-based, limiting the ability to quantify transmission pathways.

Conclusions and Recommendations

The brucellosis surveillance system in North Macedonia is effective and useful but needs strengthening in certain areas.

Key recommendations:

Develop an integrated electronic One Health information system linking human and veterinary surveillance. At present, case notifications and laboratory data are stored separately without a shared identifier. Integration would allow case-level linkage, reduce duplication, and improve analysis of sensitivity, timeliness, and positive predictive value.

Address human resource shortages in epidemiology. The national study highlights limited staffing as a weakness, with current CPH epidemiologist numbers ranging from only 1 in Strumica and Ohrid to 4 in Skopje and Shtip. Ensuring at least a minimal baseline (e.g. ≥2 per regional CPH, more in Skopje due to population size) would improve stability and local response capacity. These suggested figures are indicative and based on the observed gaps in the existing distribution, not on a formal workforce standard.

Improve timeliness and completeness of data reporting through digitalisation and staff training. At present, quarterly reporting is adequate for monitoring trends but insufficient for outbreak detection, and no systematic data are available on notification delays. A digital platform with mandatory entry of onset and notification dates would allow measurement of median delays and strengthen outbreak response.

Continue animal vaccination campaigns to maintain low incidence. Livestock vaccination, in place since the early 2000s, coincides with the steep decline in human brucellosis cases, as shown in the time-series analysis. This measure remains critical to sustain elimination.

Strengthen health education for rural populations and high-risk occupational groups (farmers, shepherds, abattoir workers), where the majority (≈80%) of human cases originate. Targeted education campaigns should focus on safe animal handling and dairy product consumption.

Ensure sustainable funding for laboratory testing and training activities. The 2025 budget of 1,000,000 MKD (≈16,000 EUR), split between IPH and CPHs, demonstrates continued investment but also highlights the challenge of sustaining resources in the elimination phase, when surveillance becomes more costly relative to the few remaining cases.

Conclusion

Brucellosis surveillance in North Macedonia has contributed to a marked decline in human cases, supported by livestock vaccination and integration with veterinary services. The system is legally grounded and nationally implemented, but faces challenges of limited epidemiology staffing, incomplete and delayed reporting, and lack of electronic integration. Sustaining high-quality surveillance in the elimination phase requires continued vaccination, improved digital data systems, and investment in human resources, education, and laboratories. These measures will ensure that the last sporadic cases are detected and controlled, safeguarding both public health and livestock production.

Abbreviations

AHV – Food and Veterinary Agency
CPH – Centre for Public Health
ECDC – European Centre for Disease Prevention and Control
IPH – Institute of Public Health
PVP – Predictive Value Positive
WHO – World Health Organization

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