One Health 19 (2024) 100896

Contents lists available at ScienceDirect

One Health

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

Leishmaniasis in Greece: Prospects of transitioning to a One Health surveillance system

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ARTICLE INFO

Keywords:
Leishmaniasis
Surveillance
One health
Greece

ABSTRACT

Leishmaniasis is a high burden neglected disease in the Mediterranean ecoregion, lacking surveillance attention. We aimed to provide an overview of the state of leishmaniasis surveillance in Greece, investigating the prospect of transitioning to a One Health surveillance system.

We conducted a narrative review describing human and animal leishmaniasis data from Greece, including entomological findings. Through a separate review process, we describe the current leishmaniasis surveillance system pertaining to humans, animals, vectors and the environment. Additionally, we distributed likert-scale questionnaires to key informants, capturing expert-view on the necessity, existing levels and barriers of OH leishmaniasis surveillance in Greece. We identified key system strengths, weaknesses, opportunities and threats respective to a OH transition through SWOT analysis.

Greece is endemic for zoonotic visceral leishmaniasis (VL) and canine leishmaniasis (CanL), displaying an increasing VL trend in recent years and high national *Leishmania* seroprevalence rates in dogs (range: 13.8–23.4 %). Mandatory leishmaniasis notification in humans and animals, human case-based investigations, and active case finding activities in stray dogs, comprise valuable system components of high OH operational relevance. Conversely, the existing CanL surveillance governance and the lack of systematic entomological surveillance constitute important drawbacks. Moreover, the current context of public health and animal health financial constraints in Greece may impede a strategic OH transition in leishmaniasis surveillance. On the contrary, Greece's OH experience in West Nile Virus surveillance in conjunction with leishmaniasis-expert consensus on the necessity of OH surveillance and key barriers to its realization, compose important transition opportunities.

Despite shortfalls in human, animal and vector surveillance, existing system characteristics, structures and practices comprise a promising basis for developing OH cross-sectoral leishmaniasis surveillance activities in Greece.

1. Introduction

Leishmaniasis is a neglected tropical disease caused by parasitic protozoa of the genus *Leishmania*, transmitted to human and animal hosts through bites of infected sand flies.

Human leishmaniasis occurs in 2 main forms: visceral leishmaniasis (VL), a systemic disease which is fatal if left untreated in over 95 % of cases, and cutaneous leishmaniasis (CL) which causes skin ulcers [1]. Canine leishmaniasis (CanL) affecting dogs, comprises a chronic viscerocutaneous disease with infection outcomes ranging from subclinical to life threatening [2]. To date, the majority of available therapeutic drugs for CL and VL are accompanied by severe side-effects whilst vaccines are only available for CanL, conferring partial protection against infection and clinical manifestations [3,4].

Leishmaniasis poses a significant public and animal health challenge in Mediterranean basin countries. Concomitant to high *Leishmania* infection rates reported in local dog populations [5,6], over 1200 new VL cases and 240,000 new CL cases are estimated to occur annually in

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https://doi.org/10.1016/j.onehlt.2024.100896
Received 12 July 2024; Received in revised form 15 September 2024; Accepted 15 September 2024
Available online 17 September 2024

the region [7], with Greece ranking amongst the European countries reporting the highest number of VL cases [8]. Nonetheless, leishmaniasis lacks surveillance attention in the region [9,10].

Leishmaniasis transmission dynamics are conditioned and evolve on the human-animal-environment interface, necessitating holistic approaches for disease surveillance [11]. Recognizing the interconnectedness between human health, animal health and the shared human/animal environment, One Health (OH) surveillance comprises a collaborative, multisectoral and transdisciplinary surveillance strategy aiming at achieving optimal disease preparedness, prevention and response in both humans and animals [12].

In recent years OH surveillance strategies are increasingly gaining international attention for the surveillance of zoonoses and vector borne diseases. Indicatively, OH West Nile Virus (WNV) surveillance in European countries has enhanced early pathogen detection, response action timeliness, and overall surveillance system cost-effectiveness [13,14].

Assessing the integration of OH components in existing leishmaniasis surveillance systems and analysing the prospects of transition to robust OH surveillance approaches can support policy in designing and implementing holistic surveillance programs [9,15,16].

We aimed to provide an overview of the Greek leishmaniasis surveillance system structures, characteristics and processes pertaining to humans, animals, sand flies and the environment in 2023; investigating the prospect of transitioning towards an integrated OH surveillance approach. Additionally, we describe the leishmaniasis burden and spatiotemporal distribution of human and animal cases in Greece for the period 2004–2022, including entomological data.

2. Materials and methods

2.1. Surveillance system description

We performed a narrative literature review (end of search: July 2023) to describe the existing leishmaniasis surveillance system in Greece in 2023, focusing on humans, animals, vectors and the environment. We conducted an electronic search of international and Greek literature in the databases of PubMeD/MEDLINE®, Scopus and Google Scholar (end of search: July 2023). Key search words included "leishmaniasis surveillance", "phlebotomine surveillance", "one health surveillance", "xenomonitoring", "canine", "visceral", "cutaneous" and "Greece". Research and surveillance articles, as well as reviews, meta-analyses and reports were included. Only articles published in English or Greek were examined. We carried out complementary searches in several other databases and websites described in detail in Supplementary Section 1.

To enhance our understanding on the structure and processes of the surveillance system, we conducted between May and June 2022 a series of in person and online meetings in the form of unstructured interviews with public health professionals (from the human health and animal health sectors) actively involved in the surveillance and control of leishmaniasis in Greece.

We used a comprehensive set of surveillance system descriptor elements listed in the European Centre for Disease Prevention and Control (ECDC) and US Center for Disease Control and Prevention (CDC) technical documents for surveillance system evaluation [17,18], as a framework for describing the leishmaniasis surveillance system characteristics.

2.2. Epidemiological and entomological setting

Using the aforementioned electronic databases and through applying the same inclusion-exclusion criteria we conducted a narrative literature review to describe human and animal leishmaniasis epidemiological data from Greece with emphasis on the period 2004–2022, as well as entomological data on the species composition, abundance, and spatiotemporal distribution of phlebotomine sandflies, including xenomonitoring data. Key words/terms used to guide the searches included "leishmaniasis", "canine", "visceral", "cutaneous", "sandflies", "phlebotomus(−ines)", "Leishmania", "Greece".

In addition, we carried out a focused search in several national and international public health and animal health websites (Supplementary section 2). As a complementary data enrichment step we retrieved cumulative CanL data for 2016–2021 from the Directorate of Veterinary Center of Athens.

The epidemiological data obtained from the literature and other sources did not undergo any further statistical processing for the purposes of this study. We present frequencies, proportions and annual or period specific mean/median incidences per 100,000 population by disease type (CL or VL), region and prefecture of notification, age group, risk group and sex.Seroprevalence, seropositivity and PCR positivity rates are provided for CanL.

2.3. Key informant interview questionnaire

We designed and distributed electronically likert-scale questionnaires (Supplementary Section 3) to twenty eight key informants with extensive experience in the human, animal or entomology sectors pertaining to leishmaniasis and sand fly surveillance in Greece. Key questionnaire themes included the necessity of adopting OH approaches for the surveillance of leishmaniasis in Greece; the existing levels of operational collaboration between the different sectors partaking in the leishmaniasis and vector surveillance system (adapted from [12]); and potential obstacles in the design and implementation of an integrated OH leishmaniasis surveillance system in Greece.

The questionnaire was accompanied by a consent form and a summary text describing the leishmaniasis surveillance system in Greece and the corresponding available epidemiological and entomological data. All questionnaire responses were completely anonymous. We controlled for potential information bias during the questionnaire response analysis phase, as described in Supplementary Section 4. The questionnaire was developed and distributed via the EUsurvey system [19].

2.4. SWOT analysis

Based on all collated information we conducted a SWOT analysis, also considering several contextual factors (e.g. socioeoconomic reality of Greece, technological advancements in the field of public health), to identify the existing surveillance system's strengths, weaknesses, opportunities and threats, in respect to transitioning to an integrated OH surveillance system.

3. Results

3.1. Description of the Leishmaniasis surveillance system in humans

Leishmaniasis was included in the mandatory notification system of the National Public Health Organization (NPHO) in 1998. Human case notification forms underwent several reformations in 2003–2004, whilst the post diagnosis reporting window was reduced from 1 month to 1 week [20]. To date, no national surveillance plan exists. Key surveillance objectives include monitoring the spatial distribution and temporal trends of VL and CL incidence in the general population, assessing disease burden, and determining risk factors for infection [21]. Visceral leishmaniasis and CL are currently subject to a comprehensive, passive (in terms of case finding and reporting), indicator-based surveillance system of national geographic coverage. Core indicators include the number and incidence of VL and CL cases by importation status, calendar date, and several demographic factors; and the proportion of cases by demographic characteristics, immunosuppression status, infection outcome, and (aetiological) infectious agent at species level. The system runs throughout the year and focuses on the country's general population. Case reporting is compulsory (Table 1). In the past ad hoc active

Table 1
Leishmaniasis surveillance in humans and dogs: surveillance system characteristics; Greece, 2022–2023 (summary table).

	Humans	Dogs
Disease forms under surveillance	VL and CL	CanL
Target population	General population	Owned/Stray/military working dogs
Geographical coverage	National	National
Compulsory reporting	Yes	Yes
Comprehensive or Sentinel system	Comprehensive	Comprehensive (owned dogs) / Sentinel (stray dogs)
Passive or Active case finding	Passive	Passive (owned dogs) / Active (stray dogs)
Passive or Active case reporting	Passive[1]	Active[2]
Indicator based	Yes	Yes
Event based	No	No
Laboratory based diagnosis	Yes	Yes
Case-based or Aggregated data	Case-based	Case-based
Electronic database for reporting	Yes	Yes
National surveillance plan	No	No

[1] Yet cases are followed up by the NPHO.
[2] The Animal Health authorities conducting the diagnostic analyses report the cases.

case finding actions coordinated by the NPHO have been performed in selected refugee camps [22].

Greece distinguishes VL form CL, using distinct case definitions. Both case definitions comprise of a single definition category (i.e. confirmed case) and include clinical and laboratory criteria (described in Supplementary section 5) [23,24]. Individual cases are reported electronically by clinical doctors and microbiologists to the NPHO and regional/local public health authorities. Notification forms include variables specifying the disease form (i.e. VL versus CL), case-demographic characteristics, risk factors, clinical characteristics and laboratory findings [25]. All notified cases are investigated under the coordination of the NPHO and classified as imported or autochthonous events. Case-data and communication feedback loops exist between NPHO, the regional regional/local public health authorities and the hospitals/diagnostic centres. To date, systematic epidemiological information communication to the general public is not foreseen.

Following an evaluation of the surveillance system in 2018 reporting suboptimal hospital capacity in leishmaniasis diagnosis in Greece (especially in hospitals outside Attica region, where the capital Athens is located) [26], the NPHO entered a convention agreement with the National Reference Laboratory for Leishmaniasis of the Hellenic Pasteur Institute for the systematic diagnosis of cases with clinical suspicion of VL or CL as well as *Leishmania* species identification in confirmed cases [22]. Moreover, as of 2018 the NPHO annually publishes health professional information forms on leishmaniasis diagnosis and case management [22]. Finally, the NPHO recently established a specialized database for documenting each case's probable area of exposure.

3.2. Description of the Leishmaniasis surveillance system in animals

According to the World Organization for Animal Health (WOAH), leishmaniasis was included in the Greek mandatory notification system of animal diseases (at least) from 2005 [27,28], yet a national surveillance plan remains to be established. To date, organized surveillance efforts predominantly focus on dogs. Current surveillance activities include passive CanL case finding and reporting by private sector veterinarians, targeting primarily owned dogs; and occasional active case-finding activities focusing on stray and military/law enforcement working dogs (Table 1).

All verified leishmaniasis cases in dogs and cats (both stray and owned) should be reported in the National Register of Pet Animals, currently under the management of the Ministry of Interior [29,30]. An explicit case definition is not available, however the majority of dog samples are analysed via serological or rapid immunochromatographic testing, following the WOAH laboratory based case definition for leishmaniasis infection [31].

The majority of leishmaniasis diagnoses in Greece are conducted by the private veterinarian sector, with suspected high levels of underreporting [32]. In regards to active case-finding activities, stray dog samples are collected in specific prefectures by the respective public veterinary services and analysed for *Leishmania* infection at the Directorate of Veterinary Center of Athens [29]. The geographic coverage of collected samples varies between years, hence temporal trends are difficult to estimate. Overall, the majority of notified cases lack pathogen identification and typing information. Epidemiological data reporting to the general public is not foreseen through either system, however active case finding summary serological reports, including information on blood sample positivity rates for *Leishmania* specific antibodies, are reported annually to EFSA [33].

3.3. Entomological and environmental surveillance

Regarding sand fly surveillance and xenomonitoring, there is no organized systematic surveillance action plan in place at the local, regional or national level. Available data predominantly derive from ad hoc studies with a limited temporal and geographical coverage [34,35]. Moreover, systematic leishmaniasis surveillance actions incorporating climatic or environmental indicators are currently lacking.

3.4. Leishmaniasis in humans: Infection burden, spatiotemporal distribution and case characteristics

Greece is endemic for zoonotic VL, with L. *infantum* as the key aetiological agent. Dogs comprise the main reservoir host for VL caused by L. *infantum* in the country. In 2004–2021, 976 VL cases (957 autochthonous) were notified, corresponding to a mean annual domestic incidence of 0.5 cases per 100,000 persons [21] (Table 2). The case fatality rate for the same period was estimated at 4 % [21]. Surveillance

Table 2
Human leishmaniasis domestic burden; Greece, 2004–2021 (summary table).

	Burden (mean annual incidence of notified cases)[1]	Incidence trend[2]	Geographical distribution
Visceral leishmaniasis	0.5/100,000 (annual range: 0.2–0.8/100,000)	increasing	13/13 regions
Cutaneous leishmaniasis	0.01/100,000 (annual range: 0.00–0.06/100,000)	stable	6/13 regions

[1] source: [21].
[2] Source: [23].

data indicated a significant increasing trend in the incidence of domestic VL cases over 2004–2018 ($p = 0.013$) and a seasonality pattern of slightly increased notification rates in the summer months [23].

Anthroponotic CL cases attributed to *Leishmania tropica* [20,23,36] and more seldom L. *infantum* [37] occur sporadically. In 2004–2021, 62 CL cases (37 autochthonous) were notified resulting in a mean annual domestic incidence of 0.01 per 100,000 [21], whilst no significant CL case count fluctuations have been observed over the years (Table 2).

Geographically, VL is endemic in all 13 regions (i.e. NUTS2 level) of the country [23]. Incidence is recorded highest in central Greece, the Ionian islands and in Crete, peaking in the region of Thessaly (1.28 cases per 100,000 persons for 2004–2021) [21]. In contrast, much lower incidences are recorded in northern Greece (≤ 0.21/100,000) [23]. Autochthonous CL cases are notified in 6 of the 13 regions (i.e. Crete, Attica, Ionian islands, Western Greece, Peloponnese and Central Greece) [21,23]. The territorial units of Greece are described in Supplementary Section 6.

The median age of VL cases for 2004–2021 was 43 years (range: 0–90) [21,23]. Incidence was highest in the age groups 0–4 years and ≥ 65 years, and in males compared to females [21]. For 2004–2010 and 2011–2018 the proportion of immunocompromised VL cases increased from 9 % to 25 % [23]. Domestic CL cases over the period 2004–2021 had a median age of 59 years (range: 5–88) with 76 % cases reported in individuals over 24 years of age [21]. Mean annual incidence was higher in females compared to males, at a 2:1 ratio [21].

3.5. Leishmaniasis in dogs and other animals: Infection burden and spatiotemporal distribution

Canine leishmaniasis is endemic in Greece and is predominantly attributed to L. *infantum* infections [36,38]. Stray and owned dog cases have been reported in all regions of the country. PCR positivity in a sample of 77 clinically healthy dogs from Central Greece sampled in 1999 was 63 % [39] whereas studies from insular Greece have reported L. *infantum* seropositivity rates between 15.3 and 25.2 % [40,41]. Increasing CanL incidence (2.2–3.8 fold) has been reported in dogs from Crete over 1990–2006 [42], while a nationwide study conducted in 2012–2013 estimated an annual incidence of 56.3 CanL cases per 1000 dogs attending veterinary clinics [43].

Mean infection seropositivity rates recorded in nationwide surveillance activities and studies conducted within 2000–2021, range between 13.8 and 23.4 % Table 3.

Studies focusing on feline/cat populations from different areas of Greece show *Leishmania* seropositivity rates ranging between 2.0 and 14.7 % (peaking in Crete) [46–49], whereas PCR positivity ranges between 0 and 41 % [27,50]. A systematic review and meta-analysis including several studies from Greece published between 2008 and 2017 estimated the overall seroprevalence of *Leishmania* infections in cats in Greece at 11 % (95 % CI: 2.0–26.0) [51]. Finally, *Leishmania* infection PCR positivity prevalences of 60 % and 0–30 % have been reported in fox and lagomorph populations respectively [27,52–55] whilst *Leishmania* seropositivity in rodents has been found to range between 0 and 70 % [27,56,57].

3.6. Entomological findings

Important vector species have been reported in mainland and insular Greece including: *Phlebotomus neglectus*, *P. tobbi* and *P. perfiliewi*; competent vectors of L. *infantum*, *P. sergenti* and *P. similis*; vectors of *L. tropica*, and *P. papatasi*; vector of *Leishmania major* [58–64]. Several studies from Greece report a prevalence of *Leishmania* spp. infection in sand flies ranging between 0 and 0.5 % [27,37,63–66], whereas a study investigating *Leishmania* infection in *P. tobbi, P. perfiliewi* and *P. simici* specimen from two refugee camps in Thessaloniki reported infection rates of 28–34 % for L. *donovani* complex spp. and 15–18 % for L. *tropica* [66].

3.7. Key informant opinion: Leishmaniasis surveillance under a OH approach

Thirteen individuals responded to the questionnaire (response rate: 46 %). Question specific completeness ranged between 75 and 100 %. Amongst the respondents, seven stated their leishmaniasis relevant sector in human health, two in animal health, and three in

Table 3
Leishmania spp. infection burden in dogs; Greece, 2000–2021.

Source (ref)	Period	Sample type and size	Geographical area	Indicator	Estimate
[44]	2000–2012	39,489 owned and stray dogs (suspected cases)	Greece	Median annual seropositivity	23.4 % (annual range: 20.4–31.5 %)
[36]	2005–2010	5722 owned and stray dogs (random sample)	Greece	Seroprevalence	22.1 % (NUTS3 range: 6.5–50.2 %)
[45]	prior 2012*	2620 clinically healthy owned dogs (random sample)	Central and Northen Greece	Seroprevalence	19.5 % (NUTS3 range: 2.1–30.1 %)
DVCA[1]	2016-2021	23,195 stray dogs and military working dogs	Several regions and provinces[2]	Mean annual seropositivity	17.1 % (annual range: 13.15–20.21 %)
[33]	2020	1410 owned and stray dogs	Greece	Seropositivity	7 %
[38]	2020	1265 clinically healthy dogs	Greece	Seropositivity	13.8 % (95 %CI 12.0–15.8 %)

[1] Directorate of Veterinary Center of Athens.
[2] Attica, Central Greece, Central Macedonia, the Peloponnese, the North Aegean, Crete.
* The study samples analysed were obtained before 2012.

Table 4
Distribution of leishmaniasis surveillance key informant ($n = 13$) responses for the characterization of barriers to the planning and implementation of leishmaniasis surveillance in Greece under a OH approach (April 2023).

	Barrier importance			
Potential Barriers	Negligible	Small	Intermediate	High
Current financial resources for leishmaniasis surveillance	0 %	23 %	38 %	39 %
Lack of a national action plan for the surveillance/prevention/control of leishmaniasis under a OH strategy	0 %	8 %	31 %	61 %
Current intra-sectoral OH work culture levels	0 %	0 %	69 %	31 %
Existing communication and co-ordination mechanisms between sectors	8 %	15 %	38 %	39 %
Available data management, analysis and decision-making support tools	8 %	31 %	46 %	15 %

entomological surveillance/control. One respondent did not define his/her main sector of activity. Eleven participants (11/13) agreed to the statement that adopting a OH approach in the surveillance of leishmaniasis in Greece is necessary for the successful, effective and efficient disease surveillance, prevention and control.

Respondents reported low to moderate levels of cross sectoral collaboration across all surveillance stages. The majority of respondents (7/10) reported a lack of intersectoral collaboration for processes falling under the surveillance stages of data collection and data analysis/interpretation. On the other hand, cross sectoral collaboration appears strongest in data sharing, where 6/8 respondents described intermediate or strong levels of collaboration; and in results/information dissemination, where 6/10 of the respondents described intermediate or strong intersectoral collaboration.

As described in Table 4 all proposed obstacles were acknowledged as true barriers. The lack of a national action plan for the surveillance of leishmaniasis under a OH strategy was identified as a key obstacle in the process of transitioning to a OH surveillance system, followed by the available financial resources for leishmaniasis surveillance and the standing mechanisms for intersectoral communication and co-ordination.

3.8. System strengths, weaknesses, opportunities and threats for a OH transition

The SWOT analysis identified important system strengths, weaknesses, opportunities and threats towards transitioning to a OH surveillance model. A comprehensive list of the identified SWOT elements is described in Table 5.

4. Discussion

Greece displays an increasing trend of VL cases and consistently high *Leishmania* seroprevalence rates in dogs over the last two decades. In response, efforts are made to increase the human case system diagnostic capacity and enhance VL and CL case notification. On the contrary, the design and operation of CanL surveillance appears rudimentary, lacking systematic data flow. Moreover, we did not identify complementary entomological or environmental surveillance activities systematically implemented at the regional or national level.

Similar to Greece, elevated VL incidence has been observed in recent years in Italy [67]. In a recent modelling study the authors show an increased decadal climatic suitability for leishmaniasis transmission in southern Europe [68], possibly underlying the heightened incidence patterns recorded in Greece and neighbouring countries.

Notably, several countries neighbouring Greece (i.e. Turkey, Italy, North Macedonia. Albania and Bulgaria) are endemic for VL and CanL, yet exhibit diverse surveillance systems and associated control measures [27], likely reflecting differences in local epidemiological contexts and disease prioritization. For example in Italy, unlike other Mediterranean countries, human and animal case data are aggregated and co-evaluated in several regional leishmaniasis surveillance programs [27,69], enhancing risk mapping.

In view of strengthening leishmaniasis surveillance in Greece, our study highlights several system strengths, weaknesses, opportunities and threats for introducing a OH surveillance approach.

The established practices of mandatory notification in humans, currently absent in many endemic countries [10], alongside human case investigation and active case finding in stray dogs are highly valuable system components, fundamental to a robust OH surveillance system considering their potential for driving evidence-based public health and animal health action [70,71].

On the other hand, suspected CanL underreporting by private veterinarians (likely attributed to weak legislation enforcement) constitutes an important system drawback minimizing system responsiveness and cross-sectoral action potential [72]. Another critical system weakness lies in the absence of organized entomological surveillance. This results in significant knowledge gaps on the distribution, composition and dynamics of vector species in Greece, impeding evidence-based resource allocation, targeted vector control interventions and early transmission warning [73]. Applying comprehensive OH surveillance transformational frameworks [15] adapted to the Greek leishmaniasis surveillance context, could help overcome these shortfalls, optimizing future OH surveillance system transitioning and practice.

From a OH advocacy standpoint, key-informant consensus on the importance of the OH concept for leishmaniasis surveillance as well as

Table 5
Analysis of the Greek leishmaniasis surveillance system (2022–2023): System strengths, weaknesses, opportunities and threats in transitioning to a One Health surveillance system.

Strengths	Weaknesses
• Mandatory notification of VL and CL cases • Specialized databased for VL and CL with a focus on exposure area • Active case-based investigations (humans) • Recent system evaluation • Efforts to increase the system's diagnostic capacity (i.e. human cases) • Active CanL case-finding activities in stray and military/law enforcement working dogs	• Lack of national plan for the surveillance/prevention/control of leishmaniasis • Non-systematic VL, CL information communication to general public • Low VL and CL diagnostic capacity in regional hospitals • Lack of pathogen identification and typing information for the majority of detected CanL cases • Governance of passive surveillance system in dogs • Lack of organized-systematic sand fly surveillance • Lack of environmental/climatic surveillance activities relating to leishmaniasis • Overall low to moderate levels of cross sectoral collaboration across surveillance activities • Sub-optimal cross-sectoral communication and coordination mechanisms • Lack of robust OH work culture
Opportunities	**Threats**
• Collective experience from the surveillance of West Nile Virus in Greece • Consensus of key informants from different sectors on the necessity of adopting a OH surveillance approach • Overall consensus of key stakeholders from different sectors on the most important obstacles towards implementing a OH surveillance system • Leishmaniasis as a common PH and animal health threat in neighbouring countries • Overall advocacy for OH strategies in the surveillance and control of zoonoses by WHO, FAO, WOAH, EFSA • Fourth industrial revolution: capitalizing on technologies pertaining to artificial intelligence big data management, information and communication system, new diagnostic tools	• Available financial resources for leishmaniasis surveillance in Greece and chronic underfunding of the animal health and PH system • Lack of a comprehensive OH national plan for the surveillance of leishmaniasis • Lack of political will • Sole focus on high profile diseases in the absence of risk assessments for leishmaniasis

on the potential obstacles hindering a future strategic OH transition, comprises an important opportunity to drive OH policy [15]. Furthermore, capitalizing on the Greek West Nile virus (WNV) experience through adopting OH mechanisms and tools from the country's WNV surveillance system may greatly enhance and support strategic and operational OH leishmaniasis planning [74]. Analytic OH oriented leishmaniasis risk assessments could prove highly useful in this direction, helping define the intensity and spatiotemporal coverage of future OH surveillance activities [75].

Additionally, international organization advocacy for OH strategies in zoonoses surveillance coupled with the cross-border leishmaniasis threat in Mediterranean countries, may promote inter-country leishmaniasis surveillance collaborations; strengthening current activities and the uptake of best OH surveillance practices [76].

Nontheless, contextual factors including chronic underfunding of the Greek Public Health system and lack of political will to establish a robust surveillance system pose eminent threats to the development of a sustainable OH surveillance system [77]. Moreover, potential future OH system transition endeavours in the absence of a holistic and target-based OH national surveillance plan may result in partial, non-sustainable system adaptations versus much needed comprehensive changes in a OH direction [12,15]. This is the first study in Greece investigating the prospect of transitioning towards a OH leishmaniasis surveillance approach through collating literature findings and key-expert opinion pertaining to leishmaniasis epidemiological/entomological data and human-animal-vector surveillance system characteristics, structures and processes. However, our study has several limitations. Firstly, available literature describing leishmaniasis surveillance in Greece is scarce, thus certain aspects of the standing surveillance system may not be captured and described here. Secondly, our study lacks information on environmental surveillance activities whilst no key informants from the environment sector were identified. Nevertheless, this factor likely reflects inherent limitations in the surveillance of leishmaniasis in Greece. Thirdly, the VL and CL incidences described in our study are probably an underestimation of the true burden of VL and CL in the country, reflecting an estimated under-reporting value of approximately 1.4 fold [20]. Finally, the response rate to our questionnaire was relatively low (<50 %) thus respective findings should be interpreted with caution.

5. Conclusions

Leishmaniasis is a neglected public and animal health threat in Greece. Considering the domestic disease burden in humans and animals, leishmaniasis should be prioritized under a OH surveillance approach in view of succeeding optimal human and animal health. The current surveillance system displays several strengths but also significant weaknesses within a dynamic context of internal-external threats and opportunities. Established surveillance system activities for human cases alongside several CanL surveillance system components (e.g. active case finding in stray dogs) constitute an important basis for developing cross-sectoral OH surveillance activities; guiding holistic evidence-based public health, animal health, and eco-health actions. Capitalizing upon current system strengths and opportunities and addressing identified weaknesses and threats, further supported by OH leishmaniasis surveillance cost-benefit analyses [78], may prove critical towards the successful design and implementation of an efficient and effective OH leishmaniasis surveillance system in Greece.

Funding

Article publication charges were funded by the MSc Program in Public Health, Department of Public Health Policy, University of West Attica.

CRediT authorship contribution statement

Emmanouil Alexandros Fotakis: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Dimitris Papamichail:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Sofia Boutsini:** Writing – review & editing, Resources. **Eleni Patsoula:** Writing – review & editing, Supervision, Methodology. **Takis Panagiotopoulos:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

All data used was retrieved from published material. Previously unpublished data regarding leishmaniasis infections in dogs is presented in the manuscript and respective tables.

Acknowledgements

We thank Danai Pervanidou from the National Public Health Organization in Greece, for providing information regarding the operation of the leishmaniasis surveillance system for humans in Greece.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.onehlt.2024.100896.

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