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Exploratory actor mapping of social interactions within tick risk surveillance networks in France

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ABSTRACT

Ticks are important zoonotic disease vectors for human and animal health worldwide. In Europe they are the principal vector of public health importance, responsible for Lyme disease, the most prevalent and widespread tick-borne disease (TBD). Tick presence and TBD incidence are increasing, questioning the effectiveness of existing surveillance systems. At the European level TBD burden is likely underestimated as surveillance differs amongst and within countries. France created its first national public health policy in 2016 to tackle TBDs, prompted by growing concern from the public, medical professionals and the scientific community for the lack of knowledge on tick-borne pathogen risk on the population. With global changes, France currently faces risk for TBD emergence (e.g. Crimean-Congo hemorrhagic fever) and re-emergence (e.g. tick-borne encephalitis), in addition to increasing Lyme disease cases. We conducted 13 semi-structured interviews with French tick risk surveillance actors to characterize how the national surveillance system functions. Qualitative descriptive analysis was conducted on interview transcripts to create actor maps and identify the barriers and levers for actor interactions. We identified four tick risk surveillance processes: surveillance-oriented research, risk evaluation, policy creation and policy application, to which interdisciplinary, intersectoral and multi-level actor interactions contribute. Actors express a pervasive need to reinforce intersectoral interactions between human, animal and environmental sectors for early risk detection, as well as multi-level interactions to accurately estimate risk and disseminate prevention information. Transdisciplinary, social-ecological system approaches may offer an adaptive framework for locally relevant surveillance activities in diverse social-ecological contexts.

1. Introduction

Ticks are responsible for transmitting the highest diversity of pathogens to both humans and domestic animals (livestock and companion animals) and are therefore considered among the most important disease vectors for public and animal health worldwide (Parola and Raoult, 2001; Jongejan and Uilenberg, 2004). Tick-borne diseases (TBDs) are some of the world's most rapidly expanding vector-borne diseases (VBDs), representing 40% of documented emerging vector-borne pathogens (Swei et al., 2019). Ticks are the principal vector of diseases to domestic animals and a source of important economic damage for livestock production across the world (Jongejan and Uilenberg, 2004; Estrada-Peña and Salman, 2013; Johansson et al., 2020). In temperate regions of North America and Europe ticks are of particular concern for their role as the principal vector of zoonoses affecting public health (Randolph, 2010; Eisen and Stafford, 2021; Marques et al., 2021).

In Europe's temperate regions, the most notable TBDs of public health concern are Lyme borreliosis (commonly referred to as Lyme disease) and tick-borne encephalitis (TBE), both considered public health priorities in many central and western European countries (Zeman and Beneš, 2004, 2013; Lindgren and Jaenson, 2006; Heyman et al., 2010; Burn et al., 2023; Van Heuverswyn et al., 2023). In addition, Crimean-Congo hemorrhagic fever (CCHF) has been declared a priority disease by the European Union due to its high mortality rate and the geographical spread of both the tick vector species (*Hyalomma* spp.) and the viral agent to non-endemic southern and western European countries (Vial et al., 2016; Fanelli and Buonavoglia, 2021; Estrada-Peña, 2023). Monitoring TBD risk is essential in Europe as contact opportunities between humans, domestic animals, wildlife, ticks and pathogens are increasing due to changes in climate, land use, human and animal

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movement, and social behavior (Medlock et al., 2013; Vu Hai et al., 2014; Boulanger et al., 2019; Fanelli and Buonavoglia, 2021). Despite a European-wide tick and TBD surveillance system under the European Center for Disease Prevention and Control (ECDC), optimal risk management has proven difficult at the European level. Studies attribute this to inter- and intra-country differences in entomological and epidemiological surveillance methods (e.g. tick-borne pathogen transmission risk measurements, TBD diagnostic criteria, TBD case reporting, TBD prevention tools), leading to an underestimation of true TBD disease burden at national and sub-national levels (Burn et al., 2023; Nagarajan et al., 2023; Van Heuverswyn et al., 2023).

As TBD surveillance lacks standardization, and gaps remain in our ecological and epidemiological knowledge, increased awareness and effective tick bite prevention at the individual and communal level are the most promising measure to reduce infection risks until effective public health management programmes are developed (Eisen and Stafford, 2021). In regions where ticks pose serious threats to animal health and livestock production, acaricides are commonly used on animals; however they are not considered feasible for long-term or widespread use due to the potential adverse consequences for human, animal and environmental health (Mahefarisoa et al., 2021), as well as the economic and ecological burden associated with repetitive application and potential acaricide resistance in certain tick populations (Jongejan and Uilenberg, 2004; Dzemo et al., 2022). Anti-tick vaccines are considered a more environmentally friendly tool for animals but are often tick species-specific and pathogen-specific (Jongejan and Uilenberg, 2004; Githaka et al., 2022; de la Fuente and Rutaisire, 2024). Regarding public health, there is currently no accessible vaccine on the market to prevent TBDs in humans (Johnson et al., 2024).

Fu et al. (2023) argue that TBD incidence estimation throughout Europe could benefit from a framework that combines environmental, animal, meteorological, and anthropogenic risk factors. A One Health approach has been proposed to tackle the complex, interconnected social and ecological drivers of TBD risk. It aims to address health challenges at the human-animal-ecosystem interface by recognizing the interconnectedness of the health of humans, animals and the ecosystems in which they live and calls for interdisciplinary, cross-sectoral and multi-level collaboration to design and implement programmes, policies, legislation and research (Joint Tripartite (FAO, OIE, WHO) and UNEP, 2021). Regarding TBD risk, the framework can (i) provide a promising bridge between the often divided human and veterinary medicine sectors (i.e. intersectoral), (ii) assess all possible components of the complex epidemiological transmission chain of TBDs (i.e. interdisciplinary), and (iii) foster TBD surveillance systems to improve diagnosis, treatment, prevention and control measures at local, regional and national and even international levels (i.e. multi-level) (Dantas-Torres et al., 2012; Vayssier-Taussat et al., 2015; Laing et al., 2018; Banović et al., 2021; Lane, 2021; Garcia-Vozmediano et al., 2022; Bouchard et al., 2023; Zortman et al., 2023).

In France, TBD concern has been intensifying amongst the public, medical professionals and the scientific community regarding the controversies of Lyme borreliosis (the most common and widespread TBD), as well as the risk of TBD emergence (e.g. CCHF) (Vial et al., 2016; Stachurski and Vial, 2018) and re-emergence (e.g. TBE) (Velay et al., 2018; Botelho-Nevers et al., 2019; Figoni et al., 2019). This concern prompted the public Health Ministry to create the country's first national policy in 2016 to combat TBDs (*Le plan national de lutte contre la maladie de Lyme et les maladies transmissibles par les tiques*). The national plan aimed to (i) improve tick surveillance and control within a One Health approach, (ii) reinforce TBD surveillance and prevention, (iii) improve and standardize patient care, (iv) improve TBD diagnoses, and (v) mobilize research around TBDs (Ministère des Solidarités et de la Santé, 2016). However, surveillance data collected from a national sentinel network of public health professionals (*Réseau Sentinelles*) have shown that TBDs remain a concern, as evidenced by an increase in visits to general practitioners for Lyme borreliosis consultations (Septfons et al., 2021).

In this study, we sought to explore the social landscape of a tick risk surveillance network using a case study in France. The aim of our study was purely exploratory, as no previous study has attempted to identify the interdisciplinary, intersectoral, and multi-level actors' interactions involved in tick risk surveillance throughout the country. Based on semi-structured interviews with 13 TBD surveillance actors, we sought to answer the question "*Who* [actor] *is doing what* [action]*, how* [resource] *and with whom* [interaction]*?* to characterize France's tick risk surveillance landscape. Qualitative thematic analysis and actor network mapping was used to describe actor interactions and identify challenges for future interventions that may improve the social landscape of the surveillance system (Stuyfzand et al., 2022). Our analysis does not seek to provide a comprehensive representation of the system but rather serves as an entry point to reveal potential gaps and areas to be further explored. Likewise, we did not attempt to quantify nor qualify risk, instead leaving interpretation up to the study participants. While the literature provides many definitions of "tick risk", they often quantify risk using environmental, ecological, or social variables (Labruna et al., 2001; Zeman and Beneš, 2013; Vu Hai et al., 2014; Imhoff et al., 2015; Fanelli and Buonavoglia, 2021; Aenishaenslin et al., 2022). Throughout our study we employ "tick risk" as a neutral term to signify any potential negative effect, whether that be direct or indirect, that ticks may have on public or animal health, as well as the potential environmental impact of tick population control strategies.

2. Materials and methods

2.1. Sampling

A qualitative semi-structured interview approach was used as the central form of data collection. In contrast to more systematic interview styles (e.g. questionnaires) for which questions and possible answers are predefined, semi-structured interviews offer a flexible framework to discuss predetermined subject matter through loosely formulated open-ended questions. This ensures that relevant topics are discussed without explicitly directing or influencing the interviewees' responses and favors the exploration of topics deemed important by the participant that may not otherwise be addressed using structured enquiry methods (Davis-Case, 1990; Van Campenhoudt et al., 2017). An interview guide, composed of major themes to be addressed with each participant, provided the general framework of the interviews to ensure that relevant topics associated with the research question regarding tick risk surveillance in France were discussed. The major themes included: (i) expertise and knowledge; (ii) the One Health approach; (iii) multi-actor collaborations; (iv) territorial approaches; and (v) COVID-19 crisis and TBD surveillance.

As the study took place during the first COVID-19 confinement in France, interactions with potential participants were severely limited. The convenience sampling method was therefore implemented in the early interview stages to construct the participant pool by prioritizing accessibility, efficiency and relevancy (Naderifar et al., 2017). Exploratory interviews were first conducted with three colleagues of the research team who work predominantly on tick entomological and epidemiological surveillance. These exploratory interviews: (i) tested the relevance, comprehensibility and fluidity of the interview guide; and (ii) used expert knowledge to compile a list of relevant actors (as specific individuals or entities) and potential participants. Subsequent participants were then contacted using the snowball sampling method to identify potential future participants based on the previous participant's suggestions (Atkinson and Flint, 2001).

Thirteen participants identified as actors in the tick risk surveillance system in France were interviewed between May and July 2020. The sampling methods largely skewed the participant pool toward tick risk researchers ($n = 9$); however, interviews were also conducted with a VBD policy officer for national public health vector risk assessment, a

VBD specialist for a regional public health agency, a project manager for a regional environmental education association network and a field veterinarian. Participants largely intervene within the Occitanie region ($n = 6$); followed by Ile-de-France ($n = 4$) and Auvergne-Rhone-Alps ($n = 3$) regions. Our study did not include interviews with medical, environmental or ministerial actors due to logistical challenges related to COVID-19 restrictions and limitations due to the study time frame. All interviews were conducted in French by telephone or the online videoconference meeting platform Zoom and audio recorded. Interviews lasted between 41 minutes and 2 hours, with an average duration of 1 hour and 7 minutes.

2.2. Data analysis

Actor network mapping is considered a strategic tool to generate a holistic view of the actors and components of a system, as well as indicate areas that require more research or system innovation (Stuyfzand et al., 2022). The data analysis methods were inspired by Companion Modelling (ComMod), a transdisciplinary participatory modelling approach established by researchers from the French Agricultural Research Centre for International Development (CIRAD) to understand complex social-ecological problems and support collective decision-making for management solutions (Bousquet et al., 2005). The ComMod approach proposes multiple iterative participatory steps to identify, model and test collective decisions about a system (Bousquet et al., 2005; Etienne, 2014). Due to the exploratory nature of this study, we focused primarily on diagnosing problem (P) and identifying the relevant actors (A), resources (R), dynamics (D) and interactions (I) that contribute to the problem using the PARDI mapping tool (Etienne, 2014). PARDI maps are normally a participatory tool used in collaboration with actors and stakeholders; however, due to the logistical challenges mentioned above, PARDI mapping was conducted *à posteriori* by the research team using interview transcripts.

Interviews were first transcribed from the recordings. Transcripts were then analyzed using qualitative descriptive analysis (Vaismoradi et al., 2013, 2016) to extract information discussed by the participants relating to five predetermined PARDI themes. PARDI data were organized in an Excel sheet and used to create PARDI maps, using Draw.io, a free online diagram tool. PARDI maps were then converted into grid maps for readability purposes, following the Actions and Actors system mapping approach proposed by Lomax (2022). Our grids provide an alternative representation of the actors, resources, interactions (and actions) and dynamics extracted from interview data and depicted in the PARDI diagrams (Supplementary Tables S1–S3).

3. Results

3.1. Actors

Twenty-three tick risk surveillance actors were identified by the participants. Table 1 shows how these actors were grouped into larger actor categories according to the sector in which they intervene: research (R); public health (PH); veterinary health (VH); environmental management (EM); agriculture (AG); associations (A); and the general public (P).

The Research category consisted of actors involved in entomological and epidemiological research and represented various scientific disciplines, including acarology, evolutionary ecology, microbiology, veterinary and medical entomology, veterinary medicine, meteorology, public and animal health management and social sciences. The One Health approach was mentioned as a key element in guiding research project proposals notably through prioritizing interdisciplinary collaborations amongst various scientific institutions and research laboratories. These interdisciplinary collaborations analyze tick risk within its public, veterinary, and environmental health dimensions. National reference centers (CNR/LNR) for disease were mentioned for their role in the surveillance, diagnosis, and research of pathogenic agents of public health importance.

The public health (PH) category consisted of the Ministry of Health, its subnational delegations, national reference centers for disease, and doctors and/or medical specialists. The Ministry of Health and its subnational delegations were mentioned for their responsibility regarding public health policy creation and commissioning public health interventions at subnational levels. As part of their surveillance role, national reference centers for disease collaborate with French public health institutions, as well as international health institutions in case of disease outbreaks. Doctors and medical specialists were not commonly mentioned by participants, presuming that participants had limited knowledge of existing interactions involving practitioners and medical specialists within the tick risk surveillance landscape.

The veterinary health (VH) category consisted of field veterinarians, subnational veterinary laboratories and a professional veterinarian

Table 1

Actor and surveillance system processes interaction grid map. Actors are organized across the top rows by category (actor type) and individuals and groups (actors) and surveillance processes are organized down the first two columns. Grid dots represent which actors intervene in what surveillance process. Actors that belong to more than one category are indicated in italic.

Actors	Actor type	Researcher (R)	Public health (PH)	Veterinary health (VH)	Environmental management (EM)	Agriculture (AG)	Associations (A)	General public (P)
	Actor	Mixed research units; *National reference centers*	ARS; *ANSES*; Regional PH agency; Ministry of Public Health; *National reference centers*; Doctors/specialists	Veterinarians; Veterinary laboratories; Sentinel veterinarians; GTV	*DRAAF*; ONF; *ANSES*; Ministry of Environment and Energy Transformation; *Ministry of Agriculture and Food*	DGAL; *DRAAF*; *ANSES*; *Ministry of Agriculture and Food*; FR GDS; GDS	GRAINE	Citizens; Farmers; Hunters
Surveillance system processes	Surveillance-oriented research	•	•	•	•	•		•
	Risk evaluation	•	•		•	•		
	Policy creation		•		•	•		
	Policy application	•	•		•	•	•	

Abbreviations: ARS, Regional public health agency; ANSES, National Food, Environmental and Occupational Health and Safety Agency; GTV, Professional veterinary network; DRAAF, Regional Directorate for Food, Agriculture and Forests; ONF, National Forest Office; DGAL, General Directorate for Food; FR GDS/GDS, Farmer representatives; GRAINE, Regional environmental education network.

network. Veterinarians are responsible for overall animal welfare. Participants specifically described their role in administering yearly prophylaxis on livestock, including preventative prophylaxis against TBDs. Some veterinarians also participate in a voluntary epidemiological sentinel network for equine piroplasmosis. Department-level veterinary laboratories are responsible for livestock prophylaxis analysis. Finally, professional veterinary networks (GTV) ensure veterinarian recognition at regional and national levels, as well as oversee veterinary practice according to national standards.

Environmental management (EM) and agriculture (AG) fall under a joint ministerial tutelage involving the Ministry of Environment and Energy Transition and the Ministry of Agriculture and Food Sovereignty. Two institutional actors mentioned by the participants intervene in both sectors: (i) Regional Directorate for Food, Agriculture, and Forests (DRAAF), which oversees regional implementation of national agriculture policy; and (ii) the National Agency for Food, Environmental and Occupational Health and Safety (ANSES), responsible for assessing and managing public health risks linked to food environmental conditions and work environments. In connection with the Ministry of Agriculture, participants identified the General Directorate for Food (DGAL) which oversees risks related to food and animal health and welfare. Regarding EM, participants also mentioned the National Forest Office (ONF) which is responsible for all forest management activities. Like the professional veterinary networks, farmer support organizations (GDS) were also mentioned as actors that aid farmers with managing and prevent disease, as well as serve as a representing body when interacting with veterinary serves and agriculture institutions.

Associations (A) were discussed pertaining to regional environmental education networks (GRAINE) and their territorial members; their responsibility is to promote environmental awareness and stewardship to community groups. This includes educating at-risk populations about VBD risk and fostering partnerships amongst a range of actors and stakeholders.

Finally, the general public (P) forms the final category of actors mentioned by participants. This group is described as non-institutional actors, such as local farmers, hunters and hikers who are considered to play both active and passive roles in the tick risk surveillance system through engaging with tick risk awareness campaigns, implementing preventative behavior at individual and communal levels, and participating in research activities.

3.2. Actor interactions: Tick risk surveillance processes and practical examples

3.2.1. Description of surveillance system processes

Our analysis revealed four emergent tick risk surveillance processes that contribute to the overarching national surveillance system in France (Table 1). These processes were characterized as follows:

(i) *Surveillance-oriented research*, in which entomological and epidemiological research activities are funded to determine social, ecological and environmental drivers of tick risk, and guide surveillance, prevention and control interventions;
(ii) *Risk evaluation*, for which specialized scientific and medical expertise is mobilized to assess risk and recommend policy;
(iii) *Policy creation*, which uses evidence-based recommendations to develop surveillance and risk mitigation policy and guidelines; and
(iv) *Policy application*, for which surveillance and risk mitigation policies and guidelines are implemented by subnational governmental institutions.

The participants describe these processes as being interdependent and largely top-down, as decisions are made at the national level and implemented by regional institutions at territorial levels. System flow is described as follows: scientific projects conducted for surveillance-oriented research inform risk evaluation; these recommendations in turn guide policy creation, which is ultimately applied at subnational levels. Feedback from local policy applications may then inspire future research projects and so on and so forth (Fig. 1). Fig. 2 depicts how the actors described in Section 3.1 interact and participate in the tick risk surveillance processes.

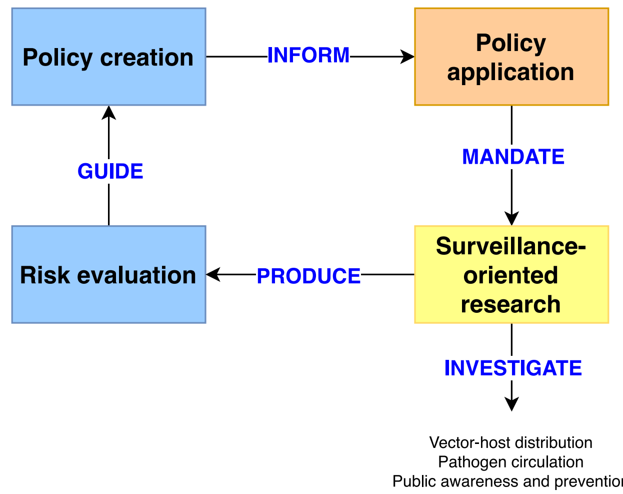

Fig. 1. Diagram of the major tick risk surveillance processes. Boxes represent surveillance processes and colors indicate the administrative level where process takes place (blue: national; orange: regional; yellow: local). Directional arrows and text indicate process flow and interactions.

3.2.2. Surveillance-oriented research for CCHF emergence risk

Participants discussed the potential risk of CCHF emergence in southern France (Vial et al., 2016; Bah et al., 2022; Bernard et al., 2022) as an example to illustrate how the surveillance-oriented research process functions. Fig. 3 illustrates the magnitude of actor diversity, actions performed, resources provided, and interactions (see also the grid map in Supplementary Table S1). Researchers are mandated and funded by a joint-ministry tutelage to collect data on *H. marginatum* distribution and CCHF-virus circulation. Researchers conduct livestock (e.g. bovine), horse and wildlife (e.g. birds, boar) surveys throughout the Occitanie region to determine vector distribution and ecology, as well as detect virus circulation. Blood samples from livestock are collected from veterinarians during annual prophylaxis campaigns and are tested by departmental veterinary laboratories. Researchers request and recuperate serum samples from laboratories to be tested and verified by national reference laboratories for viral antibody presence. As these laboratories specialize in human sample testing, one researcher expressed the hesitancy of these laboratories to verify livestock samples. Tick specimens collected from livestock, horses, and wildlife through partnerships with field veterinarians, local farmers and researchers, and contribute to determining species distribution. Throughout this process, researchers engage in One Health interactions with scientific colleagues, local and national institutions and veterinary actors, as well as transdisciplinary interactions with non-institutional actors, such as farmers, hunters and abattoirs.

3.2.3. Risk evaluation for CCHF emergence risk

To discuss how the risk evaluation process functions, participants described the role of a vector working group under the authority of the National Food, Environmental and Occupational Health and Safety Agency (ANSES). This public health actor brings together medical and scientific experts of vector and VBDs to assess risk, provide recommendations to influence policy and address research gaps. Within the vector working group, participants described a punctual *ad-hoc H. marginatum* group created in 2020 to evaluate the growing risk of CCHF-

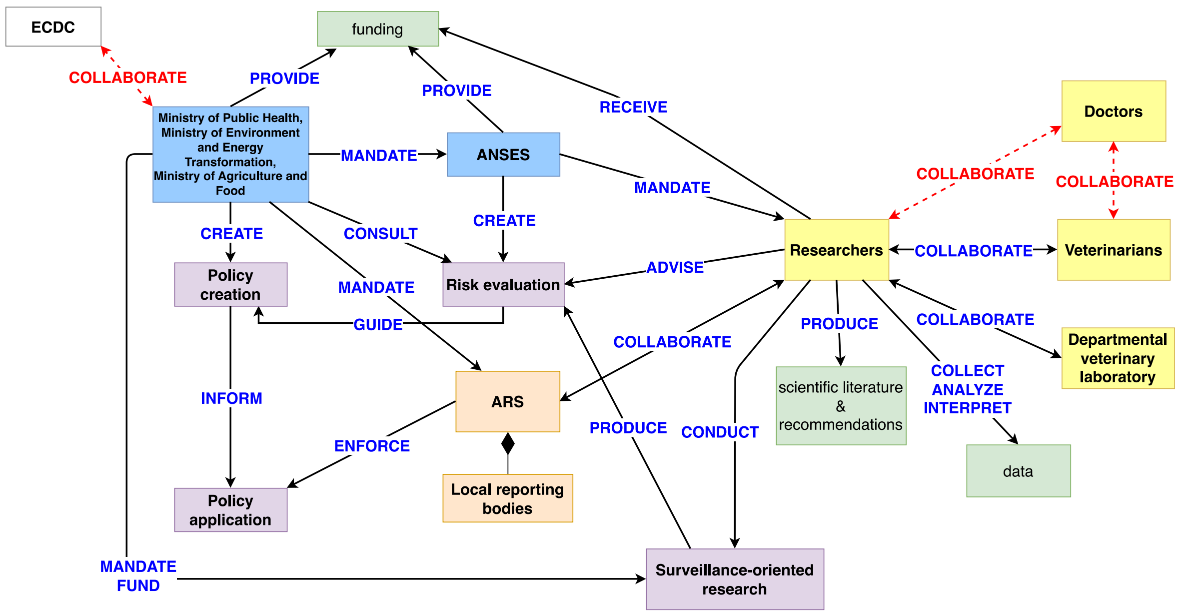

Fig. 2. Tick risk surveillance processes and how actors intervene. *Key: purple boxes*: surveillance processes; *white boxes*: international actors; *blue boxes*: national actors; *orange boxes*: regional actors; *yellow boxes*: local actors; *green boxes*: resources used or produced. Directional arrows indicate interactions: *black arrows* indicate interactions mentioned by actors interviewed, in which they participate or have knowledge of; *red dotted arrows* indicate interactions mentioned in interviews but could not be confirmed; *black diamond* indicates dependent items (i.e. a subnational reporting body). *Abbreviations*: ANSES, National Food, Environmental and Occupational Health and Safety Agency; ARS, regional health agency; ECDC, European Center for Disease Prevention and Control.

virus introduction in France. Fig. 4 shows that the risk evaluation process is largely characterized by few interactions between actor categories; instead, risk evaluation actions are carried out by individual actor categories (see also the grid map in Supplementary Table S2). Experts are described as both scientific and medical; however, participant knowledge did not allow us to conclude if working groups foster intersectoral interactions amongst human and animal health actors. Finally, risk evaluation does not aim to produce new knowledge but rather relies on existing scientific research to influence policy and guideline creation. No actors involved in the policy decision-making participated in the study; therefore, policy creation is the least detailed surveillance process in our analysis.

3.2.4. *Policy application for the national policy for Lyme and other TBDs*

Fig. 5 illustrates participants' understanding of how tick risk prevention and awareness campaigns for at-risk populations were organized and implemented throughout the Occitanie region, as part of the strategic focus areas of the national TBD policy (see also the grid map in Supplementary Table S3). Territory-based prevention and risk awareness actions were mandated by the Ministry of Health and delegated to regional public health agencies (ARS). The regional public health agency is the key coordinator and is responsible for organizing territory-based actions to facilitate prevention and risk awareness activities according to needs, available resources, and operational actors. In the Occitanie region, the regional public health agency solicited a regional network of environmental education associations (GRAINE) and researchers to co-develop pedagogical prevention and awareness training and tools, as well as identify at-risk populations. Training and tools included in-person workshops, fair stands, tick bite prevention videos, pamphlets, and flyers. At-risk populations were identified as forest workers, members of outdoor activity associations, general practitioners, and members of the general public. Participants also described the citizen science initiative CiTIQUE and the phone application *Signalment Tique*, which aims to mobilize the public to participate in tick monitoring and research through geolocation and sending captured tick specimens to a specialized laboratory and mentioned that nature associations may provide *Signament tique* pamphlets and tick collection kits to at-risk actors. While prevention and risk awareness campaigns rely on interdisciplinary and multi-level interaction, Supplementary Table S3 shows that few actors intervene in the process and that actions are largely dependent on regional public health actors. Notably, environmental management actors only engage in the process as at-risk target populations, while no veterinary health nor agriculture actors have any involvement in the process.

4. Discussion

In this paper we characterized the social landscape of the tick risk surveillance system in France to understand how the social interactions function throughout the system. We conducted semi-structured interviews with relevant actors and used qualitative descriptive analysis on interview transcripts to visually depict the social landscape of the surveillance system. We identified actors that engage in the system, the resources that they use or provide, their actions and interdisciplinary, intersectoral and multi-level interactions, as well as the barriers and gaps to organizational innovation through actor maps.

While France has monitored TBDs for decades (Velay et al., 2018; Klopfenstein et al., 2019; Septfons et al., 2019) a need to improve surveillance was largely mobilized by public frustration with the lack of (or inconsistent) risk, diagnosis and treatment information, as well as a need from medical professionals for standardized diagnosis and treatment guidelines (Guittard, 2019). Today, France's TBD surveillance system is multifaceted, integrating a sentinel network of general practitioners for systematic reporting of Lyme disease diagnoses (Septfons et al., 2019), the citizen science initiative, CiTIQUE, to enlist the public in geolocated tick bite reporting (https://www.citique.fr/), the creation of five regional reference centers specializing in a pluridisciplinary approach for TBD diagnosis and treatment (Patrat-Delon et al., 2023) and the recent status change regarding TBE, for which mandatory reporting of cases to public health authorities is now required (Santé Publique France, 2024). Despite advancements in surveillance, Lyme disease consultations continue to increase (Septfons et al., 2019), recurrent and novel TBE outbreak hot spots are on the rise (Velay et al., 2018; Botelho-Nevers et al., 2019), and traces of CCHF-virus have been detected for

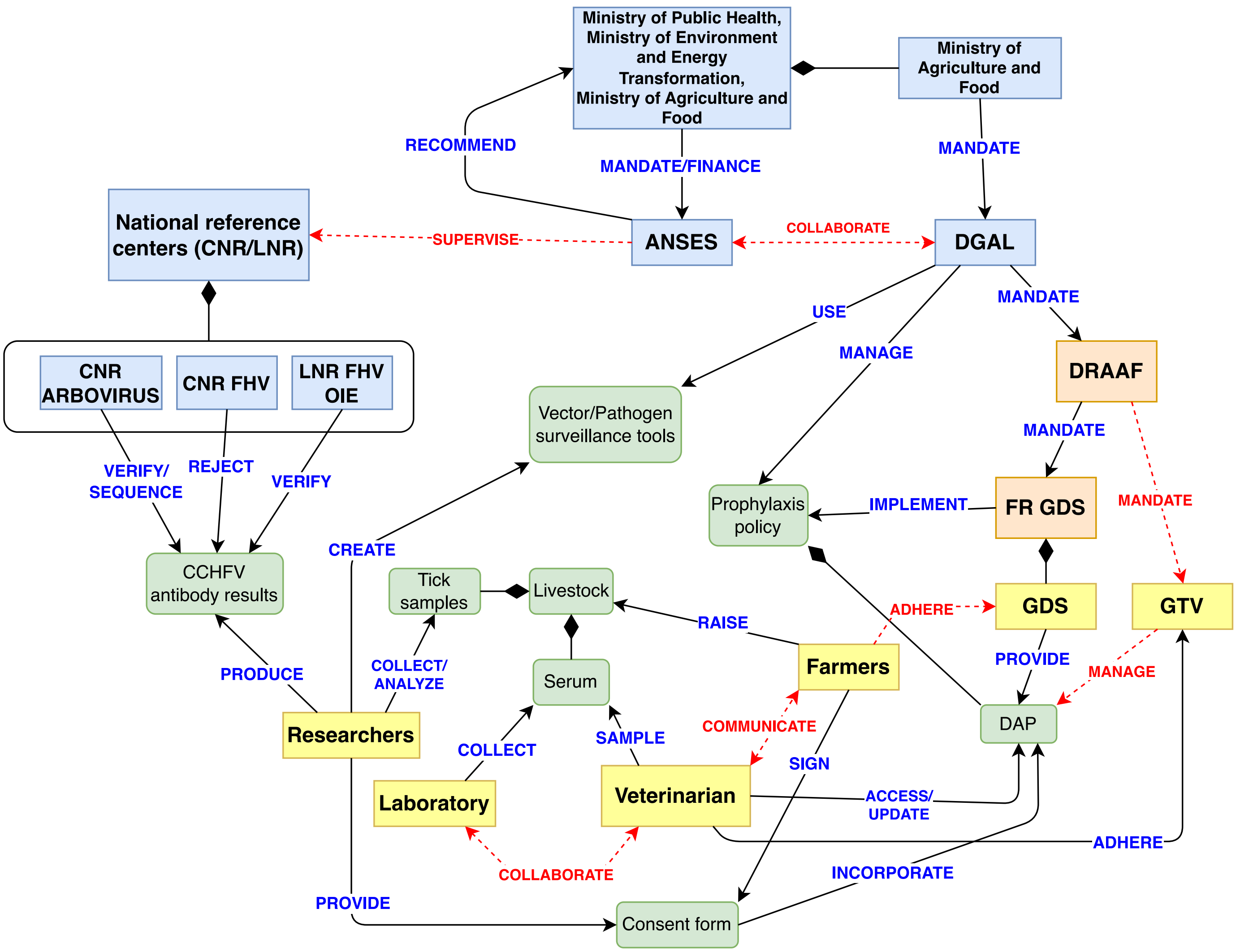

Fig. 3. Surveillance-oriented research process for *H. marginatum* distribution and CCHFV emergence. *Key*: *blue boxes*: national actors; *orange boxes*: regional actors; *yellow boxes*: local actors and local delegations; *green boxes*: resources used or produced. Directional arrows indicate interactions: *black arrows* indicate interactions mentioned in interviews in which interviewees participate or have knowledge of; *red dotted arrows* indicate interactions mentioned in interviews but could not be confirmed or remained unclear; *black diamond* indicates dependent items (i.e. reporting body or resource). *Abbreviations*: ANSES, National Food, Environmental and Occupational Health and Safety Agency; CNR/LNR, National reference centers; DAP, legal document for the movement of biological samples; DGAL, General Directorate for Food; DRAAF, Regional Directorate for Food, Agriculture and Forests; FR GDS/GDS, farmers associations/representatives; GTV, veterinary associations/representatives.

the first time in continental France (Bernard et al., 2024).

The importance of early detection and response are considered key elements to tackle emerging VBDs (Morens et al., 2004). Indeed, filling communication and knowledge sharing gaps between medical professionals and veterinarians can accelerate diagnosis, treatment plans and preventive measures, as TBD epidemiology in humans often involves wildlife and domestic animals (Dantas-Torres et al., 2012; Lane, 2021). Our results show that actors do indeed recognize a necessity to reinforce intersectoral communication between human and animal health actors, with one participant clearly echoing this sentiment: "*There is a need to connect field veterinarians and general practitioners to detect a disease*". Indeed, operationalizing intersectoral interaction between public and veterinary health sectors is essential; however, Destoumieux-Garzón et al. (2018) argue that the disconnect of the medical and veterinary sectors from ecology and environmental domains remains a consistent challenge for a One Health approach to VBDs, given the inherent complexity of the biophysical drivers of TBDs. Our actor map analysis confirmed that environmental management actors are severely underrepresented within TBD surveillance activities, despite their indispensable role in natural resource management and landscape modification. Such human-induced changes to the environment are strongly linked to complex tick life cycles, ecology, and TBDs (Bonnet et al., 2015). Participants recognize the importance of tackling TBDs within their ecological and environmental dimensions, illustrated by one participant stating "*tick management [must] be integrated into a larger question that is environmental management and ecological stakes*".

Interconnected social and ecological drivers affect pathogen transmission between wildlife, livestock, humans and vectors (Jones et al., 2008; Rizzoli et al., 2011; Vu Hai et al., 2014). While the One Health framework has guided numerous TBD risk studies (Dantas-Torres et al., 2012; Vayssier-Taussat et al., 2015; Banović et al., 2021; Lane, 2021). Aguirre et al. (2019) argue to go beyond this paradigm toward social-ecological health frameworks and transdisciplinarity to manage TBDs persisting, emerging and re-emerging largely due to societal drivers undermining natural processes (Rizzoli et al., 2011; Bouchard et al., 2023). Transdisciplinarity can foster new interactions in surveillance networks amongst research, health institutions, governments and societal, non-academic actors; meanwhile, a social-ecological systems

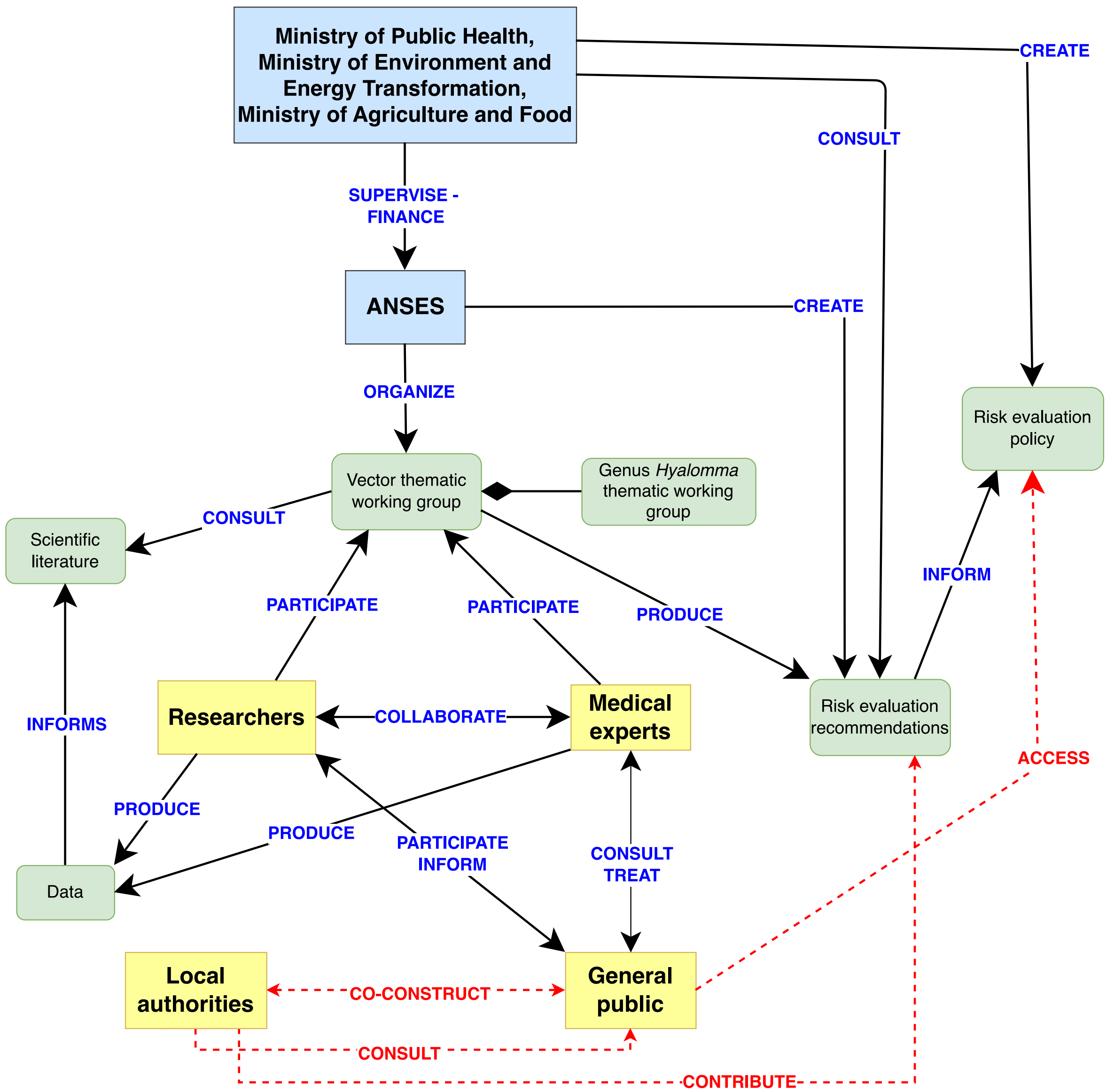

Fig. 4. Tick risk evaluation process for CCHF emergence. *Key*: *blue boxes*: national actors; *orange boxes*: regional actors; *yellow boxes*: local actors and local delegations; *green boxes*: resources used or produced. Directional arrows indicate interactions: *black arrows* indicate interactions mentioned in interviews in which interviewees participate or have knowledge of; *red dotted arrows* indicate interactions mentioned in interviews but could not be confirmed or remained unclear; *black diamond* indicates dependent items (i.e. reporting body or resource). *Abbreviations*: ANSES, National Food, Environmental and Occupational Health and Safety Agency.

framework can address the linked societal and biophysical drivers of TBDs within diverse social-ecological contexts (Aguirre et al., 2019; Wilcox et al., 2019; Zortman et al., 2023). Frustrations with the current top-down interactions of France's tick risk surveillance system were illustrated by statements such as "*the ARS [regional public health agency] does not have any guidance for how to put these measures in place at the territorial level*". Participatory approaches, such as ComMod (Etienne, 2014), propose a solution for top-down governance by simulating and testing alternative transdisciplinary interactions for health solutions within diverse social-ecological contexts. These approaches foster active collaborations amongst a diverse group of actors to identify a problem, develop new information and co-construct solutions, adapted actor expectations and needs (Charron, 2012; Binot et al., 2015; Duboz et al., 2018; Bordier et al., 2021; De Garine-Wichatitsky et al., 2021).

The limitations of our study are related to the data collection and analysis methods. The convenience sampling method is advantageous when accessing target subjects is difficult (Naderifar et al., 2017). In our study, research colleagues were the most accessible actors and therefore made up a majority of the interview participants. On the other hand, decision-making actors, medical professionals, environmental management actors and the public were inaccessible or unidentifiable and are missing from our participant pool. Therefore, actor maps were largely influenced by researcher knowledge on the social landscape of the surveillance system. As a result,certain surveillance processes, such as policy creation, are minimally detailed, representing a gap in our overall understanding of the system. In addition, the PARDI diagrams were created *à posteriori* from interview transcripts by the research team and were not validated by the participants. The PARDI method requires interaction diagrams to be co-created with actors to validate the accuracy of the system (Etienne, 2014). This is a method of triangulation which enhances social science rigor by verifying data using different methods, approaches and sources to overcome research bias or limitations (Patton, 1999). Triangulation was not possible in the scope of our research in large part due to logistical challenges (e.g. COVID

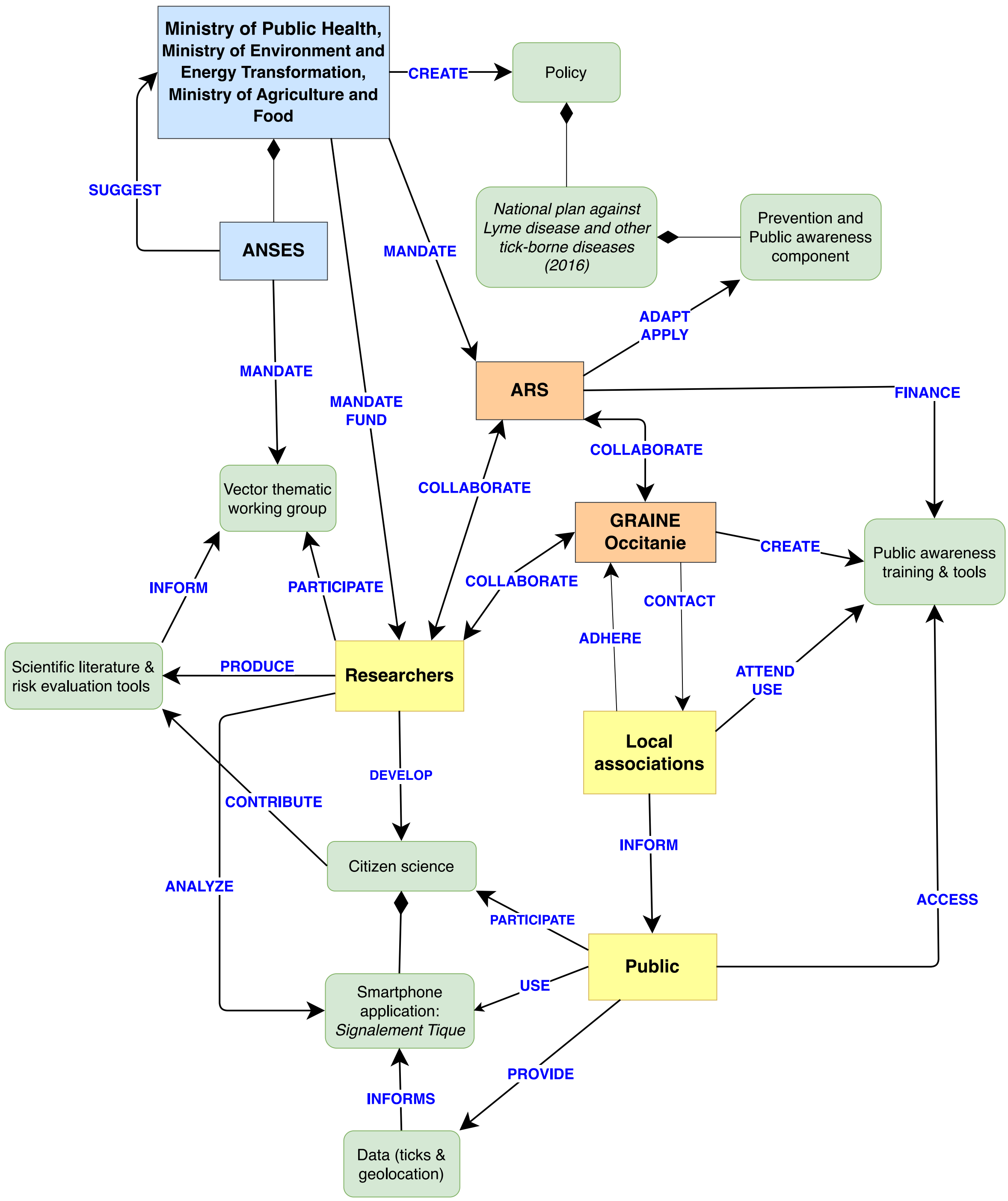

Fig. 5. Tick risk policy application process for the national Lyme and other TBDs plan. *Key*: *blue boxes*: national actors; *orange boxes*: regional actors; *yellow boxes*: local actors and local delegations; *green boxes*: resources used or produced. Directional arrows indicate interactions: *black arrows* indicate interactions mentioned in interviews in which interviewees participate or have knowledge of; *black diamonds* indicate dependent items (i.e. reporting body or resource). *Abbreviations*: ANSES, National Food, Environmental and Occupational Health and Safety Agency; ARS, regional health agency, GRAINE, regional network of environmental education associations.

restrictions, short time frame for study). A future follow-up study is necessary to resolicit participants to verify and build on our surveillance system maps, as well as test the benefit of a transdisciplinary, social-ecological systems framework to foster alternative interactions within diverse social-ecological contexts.

5. Conclusions

France's tick risk surveillance system is multifaceted and depends on various research, public health, veterinary health, environmental management, agriculture, educational, and societal actors who contribute to a nationwide effort in combating TBDs. Our study showed that actors' desire for intersectoral and multi-level interactions needs to be reinforced and requires tools to operationalize multi-actor partnerships. This is essential to ensure that risk is accurately measured and management strategies are adapted to the social-ecological context. We recommend a transdisciplinary, social-ecological systems framework to foster new interactions between research and non-research actor categories, while reinforcing existing partnerships to adapt tick risk surveillance, prevention and control to local social-ecological contexts.

CRediT authorship contribution statement

Iyonna Zortman: Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Laurence Vial:** Resources, Supervision, Validation, Writing – review & editing. **Thomas Pollet:** Supervision, Validation, Writing – review & editing. **Aurélie Binot:** Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Validation, Writing – review & editing.

Ethical approval

Not applicable.

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Declaration of competing interests

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.

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Appendix. A Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crpvbd.2024.100222.

Data availability

The data supporting the conclusions of this article are included within the article and its supplementary files.

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