Brussels, 27 May 2022

COST 084/22

DECISION

Subject: Memorandum of Understanding for the implementation of the COST Action "Prevention, anticipation and mitigation of tick-borne disease risk applying the DAMA protocol" (PRAGMATICK) CA21170

The COST Member Countries will find attached the Memorandum of Understanding for the COST Action Prevention, anticipation and mitigation of tick-borne disease risk applying the DAMA protocol approved by the Committee of Senior Officials through written procedure on 27 May 2022.

MEMORANDUM OF UNDERSTANDING

For the implementation of a COST Action designated as

COST Action CA21170
PREVENTION, ANTICIPATION AND MITIGATION OF TICK-BORNE DISEASE RISK APPLYING THE DAMA PROTOCOL (PRAGMATICK)

The COST Members through the present Memorandum of Understanding (MoU) wish to undertake joint activities of mutual interest and declare their common intention to participate in the COST Action, referred to above and described in the Technical Annex of this MoU.

The Action will be carried out in accordance with the set of COST Implementation Rules approved by the Committee of Senior Officials (CSO), or any document amending or replacing them.

The main aim and objective of the Action is to disseminate knowledge and promote the application of the Stockholm paradigm in order to anticipate and mitigate disease risk associated with the presence and probable spread of hard ticks.. This will be achieved through the specific objectives detailed in the Technical Annex.

The present MoU enters into force on the date of the approval of the COST Action by the CSO.

OVERVIEW

Summary
Emerging infectious diseases (EIDs) represent a national security threat for every country, exacerbated by climate change, human population expansion, urbanization, and globalization. Based on theoretical expectations previously EIDs were thought to be rare and impossible to anticipate because they require novel genetic mutations to infect novel hosts. A new conceptual framework has been developing for nearly 40 years and has recently been articulated in a manner that leads directly to a protocol for taking proactive or anticipatory steps in coping with EIDs, especially those numerous high probability/low impact pathogens. The framework is called the Stockholm paradigm, which shows that a major trigger of emerging disease, now and in the past, has been climate change. The PRAGMATICK COST action aims to disseminate knowledge and promote the application of the Stockholm paradigm in order to anticipate and mitigate disease risk associated with the presence and spread of ticks and tick-borne pathogens (TBPs) under anthropogenic pressure and changing climate. This research network will apply the comprehensive and highly focused DAMA (Document, Assess, Monitor, Act) protocol that allows to “anticipate to mitigate” emerging diseases. The main focus is on urban tick and TBP hotspots and the spread and establishment of ticks and TBPs. PRAGMATICK will find new ticks and tick-borne pathogens before they find us. By applying citizen science and supporting capacity building in the domain of tick and tick-borne disease prevention, the Action will eventually lead to new and improved insights in the potential threats related to this important group of vectors across Europe.

Areas of Expertise Relevant for the Action	**Keywords**
● Biological sciences: Ecology ● Health Sciences: Infectious diseases ● Health Sciences: Public and environmental health ● Health Sciences: Epidemiology ● Biological sciences: Microbiology	● disease ecology ● prevention ● tick-borne diseases ● DAMA (Document, Assess, Monitor, Act) protocol ● climate change

Specific Objectives
To achieve the main objective described in this MoU, the following specific objectives shall be accomplished:

Research Coordination
● Application of the DAMA protocol to identify risk factors for tick and tick-borne pathogen presence and introduction in cities and habitat interfaces and comparison of the epidemiological situation in different cities and countries.
● Application of the DAMA protocol to recognise tick and tick-borne pathogen introduction to new areas.
● Involvement of citizen scientists into the documentation, monitoring and act phases.
● Facilitate the communication of research results including building and maintenance of a website and social media accounts (Facebook, Twitter) of the Action to provide a unique portal to the general public and stakeholders.
● Disseminate the Action’s outputs as widely as possible including dedicated activities to represent PRAGMATICK at national and international conferences and the organisation of workshops with the concerned stakeholders as well as through scientific and public media.

Capacity Building

● Enhance education and exchange of information about documentation of urban risk of ticks and TBPs, emergence of ticks and TBPs in new areas, encourage Inclusiveness Target Country and Near Neighbour Country participation, connect to upcoming conferences and organisations working in the field of TBD.

● Foster knowledge-exchange by organising networking events such as meetings, web conferences for researchers, students, relevant stakeholders and policymakers.

● Training and active involvement of Young Researchers and Innovators by organising Training Schools and Short Term Scientific Missions.

● Develop a media strategy, including social media, press releases and media coverage, in order to improve the public knowledge about the health risks of ticks and tick-borne pathogens identified in connection with anthropogenic influence and climate change and about the DAMA protocol.

● Special emphasis will be given to training of the next generation of young scientists capable of continuing DAMA projects in the future.

● Targeted citizen scientist education in the field: teach good practices how to take photos, collect, preserve and send tick specimens with emphasis on personal protection and prevention.

● Enhance collaboration with stakeholdes such as hunters and ornithologists for data and sample collection, in line with the Birds Directive.

● Establish long-term research collaboration by initiating large-scale international research consortia aimed at developing targeted DAMA projects.

TECHNICAL ANNEX

1. S&T EXCELLENCE

1.1. SOUNDNESS OF THE CHALLENGE

1.1.1. DESCRIPTION OF THE STATE OF THE ART

Humans have created a largely – and increasingly – technological niche for themselves, but that niche is embedded in a complex biosphere that permits technological humanity to exist. That complex biosphere is now rapidly changing, in ways that threaten the future of technological humanity. We need to know more about how the biosphere functions, how it is changing, and how it is likely to change in the future in order to provide enough information to produce workable adaptive policies. More than anything, we need to buy time to enable us to adapt to those changes[1].

An important element of the interaction between humanity, climate change and biodiversity is the phenomenon of emerging infectious disease (EID). EIDs include all pathogens exacting a socio-economic cost as a result of infection in humans, crops, livestock, and non-domesticated species of economic value across managed and wild ecosystems. Infectious diseases are emerging at an unprecedented rate with significant impacts on global economies and public health [3]. They represent a national security threat for every country, exacerbated by land use change, climate change, human population expansion, urbanization, and globalization[4]. They are also threat multipliers for other climate threats; for example, changes in the quantity and quality of water available to humans is a major climate threat, impacting upon both water and vector-borne pathogen transmission. In addition, insufficient action on EIDs will impede achieving other climate goals. Pathogens are more than agents of disease; they are also compact units of information about bio-complexity, as well as being agents of emerging and emerged disease. Knowledge about pathogens and their ecological interactions offers cost-effective information essential for understanding our ecosystem and providing tools for mitigating adverse consequences.

The ongoing COVID-19 pandemic painfully illustrates what was already obvious before: EIDs will have an increasing impact onto everyday life for every one of us. Therefore, it is crucial to better understand disease ecology and identify drivers behind the emergence of pathogens in order to have a chance for their prevention. We can categorise EIDs into two classes. The most sensational ones are low probability/high impact pathogens. They occur rarely, and are thus difficult to anticipate, but a given outbreak can wreak havoc. Consequently, they are the ones that produce headlines, and drive the public perception of emerging disease. The second class of EIDs are high probability/low impact pathogens. They occur often, but rarely cause mortalities, especially mass mortalities. Many are considered simple nuisances and yet, they result in lost work days by adults, lost school days by students, reduced crop and livestock productivity, and high control costs. Although we are living in the midst of a pandemic caused by a low probability/high impact pathogen, all the other EID agents are still around, even if we are distracted from them. These are the impediments to socio-economic sustainability, development, food security, and safety. The sheer number of these EIDs, coupled with their persistence, once established in a novel area or host (called pathogen pollution), can lead to unsustainable socio-economic costs by a kind of “death by a thousand cuts” scenario. Tick-borne pathogens belong to this second group of EIDs . Without doubt it is essential to take precautionary steps against both classes of EIDs.

As veterinary and human medicine entered the late 20th century, there was a growing and explicit understanding of the connectivity between animal and human disease, facilitated by environmental opportunities. This led veterinary scientists and clinicians to embrace what is called One Health, more recently also Planetary Health. In the 1940s, this brought together a coalition of veterinarians, physicians, and a broader range of organismal biologists. In some ways, this was a natural evolution from the vaccine world of the 19th and 20th centuries. Planetary Health is a complementary, and more explicit approach to understand the connection between accelerating climate change and unprecedented environmental perturbation. What is common to all these approaches is the recognition that trans-boundary and interdisciplinary cooperation is needed, bringing ecology, biodiversity, environmental science, veterinary health and medicine to the forefront in addressing increasingly complex challenges for humanity and the human landscape. Scientific evidence suggests that EIDs and pandemics have their origins in diverse microbes carried by animal reservoirs, but their emergence is entirely driven by human activities[5]. In contrast with earlier independent and limited explorations emphasizing single organisms or regions, our understanding that rapidly changing environments from which viral, bacterial, fungal, arthropod and helminth pathogens emerge demonstrates the urgency for new ways to coexist and live with our world. Pathogens emerge often at the interface of societies and ecosystems[4] and are strongly influenced by larger threat multipliers driven by climate change and sweeping environmental perturbation.

This Action endorses this perspective wholeheartedly and plans to operationalise the One Health concept. In order to cope with the onrushing multiple threats associated with climate change and biodiversity loss – of which EID is only one - we must integrate diverse human activities on multiple scales, e.g. apply the Sustainable Development Goals (SDGs) of United Nations[6]. This calls for truly long-term planning – not just beyond the event horizon of most politicians, decision-makers and other relevant stakeholders. We have to assume that these changes will be permanent and evolving over time. Coping with changes of that magnitude requires the cooperation of many people within and among countries on an unprecedented scale.

1.1.2. DESCRIPTION OF THE CHALLENGE (MAIN AIM)

The past decade has witnessed a dramatic increase in focus on the emerging disease crisis, and on the role climate change plays in it. This has led to remarkable successes along traditional lines – development of new antibiotics to medicate the ill, development of new vaccines to vaccinate those at risk, and eradication of portions of biodiversity associated with pathogen transmission to the extent allowed by other biodiversity considerations. What has been lacking until now is a complementary anticipatory approach. This is beginning to change, especially with respect to known viral pathogens of humans, with programs and paradigms such as *One Health*, *Planetary Health*, *Predict*, *Ecohealth* and *Virome*. But these efforts are not enough. Recent statements from the World Health Organization, the World Bank, and the International Monetary Fund make it clear that we are losing the battle to cope with emerging diseases in an economically sustainable manner[1].

There has been a strong sense that EIDs cannot be anticipated because they require novel genetic mutations to infect novel hosts, and such mutations occur at random[7]. By this reasoning, if EIDs cannot be anticipated, they should be rare. However, they are not rare, either in contemporary or evolutionary time, so our theoretical expectations must be wrong. This has led evolutionary biologists to recognize the Parasite Paradox. We need a new conceptual framework for understanding pathogen evolution, one that anticipates the high rate of EIDs in a world experiencing climate change. Such a framework has been developing for nearly 40 years and has recently been articulated in a manner that leads directly to a protocol for taking proactive, or anticipatory steps in coping with EIDs, especially those numerous high

probability/low impact species. The framework is called the Stockholm paradigm, which shows that climate change has been a major trigger of emerging disease, now and in the distant past[8].

The Stockholm paradigm suggests a path to proactive risk management that augments our traditional reactionary approach in a way not thought possible previously. We can anticipate disease occurrences and mitigate the damage by learning the lessons of history – our own as well as those of pathogens. If the traits associated with pathogen survival are both specific and conservative, we have a chance to anticipate the ways in which pathogens can be introduced to a new area, how they will be transmitted within that new area, and how they might be exported to other areas.

The main aim of the PRAGMATICK Action is to disseminate knowledge and promote the application of the Stockholm paradigm in order to anticipate and mitigate disease risk associated with the presence and probable spread of hard ticks (Ixodidae). These blood-feeding arthropods transmit causative agents of not only the most common vector-borne pathogen in the Northern hemisphere (Lyme borreliosis spirochetes) but also a wide range of other bacteria (*Anaplasma*, *Neoehrlichia*, *Rickettsia* spp.) and viruses (TBEV-Tick-borne encephalitis virus, CCHFV-Crimean Congo haemorrhagic fever virus)[2,9,10]. Many of these pathogens are known, but a large number of pathogens and potential pathogens have been described during the last two decades. The ability of ticks to transmit a wide range of emerging pathogens and to easily spread[11] to new areas with their hosts (e.g. migratory birds, humans, and dogs) makes them a perfect model organism to apply the Stockholm paradigm. The greatest challenge is to switch into a proactive mode and prepare for the unavoidable threats posed by the emergence of ticks and Tick-Borne Diseases (TBDs) in new areas and new hosts.

During recent years, considerable changes in distribution of *Ixodes ricinus* and *Ixodes persulcatus* ticks in Northern Europe have been reported, which in some cases led to the changes in the eco-epidemiology of tick-borne encephalitis (TBE) and other tick-borne diseases (TBDs). For example, in Arkhangelsk region in Russia, an increase both in mean annual air temperatures and temperatures during tick active season led to the northward expansion of *I. persulcatus*, which resulted in nearly 50-fold rise in TBE incidence when compared with 1980-1989[12]. In Finland, compared with the previous nationwide distribution map drawn almost 60 years ago, the extent of spatial distribution for *I. ricinus* and *I. persulcatus* ticks has shifted 200–300 km northwards and populations have become established in new locations, mainly in coastal areas of the Bothnian Bay and in the eastern part of central Finland[13]. In Sweden during the almost 30-year period from the early 1980s to 2008, *I. ricinus* has expanded its distribution range northwards. In the early 1990s ticks were found in new areas along the northern coastline of the Baltic Sea, while in a 2009 study, ticks were reported for the first time from many locations in North Sweden. Also, the abundance of ticks had increased markedly in South (Götaland) and Central Sweden[14,15]. Both in Finland and Sweden ticks expansion led to the appearance of new TBEV foci. Also, the geographical distribution of human pathogenic spirochaetes, *Borrelia burgdorferi* sensu lato, coincides with that of their main vector, *I. ricinus*. In other words, changes in tick distribution and tick density are likely to have increased the risk of human Lyme borreliosis and TBE and are likely to lead to further changes in risk areas of these and other tick-borne infections. *Ixodes ricinus* was also shown to spread into higher areas in the mountains[16,17].

Other tick species, like *Hyalomma* spp, vectors of CCHFV are regularly carried by migratory birds from Africa and the Mediterranean areas to temperate Europe[10]. With milder autumns and winters, however, they have recently been documented to overwinter in the Czech Republic[18,19], Germany[20], the UK[21] and even in Northern-Europe[22]. Another African tropical tick, *Amblyomma variegatum*, a proven vector and reservoir of pathogenic *Rickettsia africae*, has recently been also reported to overwinter in Sardinia. The finding of adults of this tick species introduced by birds as immatures is another example for elevated EID risk due to climate change[23]. *Rhipicephalus sanguineus* sensu lato (s.l.), the brown dog tick is being

also reported from many new locations[24]. Another species on the spread is *Dermacentor reticulatus* that has recently been introduced and established in many new areas (including the UK) raising the risk for canine babesiosis[25]. These examples show an adaptive answer from the hard ticks to anthropogenic pressure and changing climate.

1.2. PROGRESS BEYOND THE STATE OF THE ART

1.2.1. APPROACH TO THE CHALLENGE AND PROGRESS BEYOND THE STATE OF THE ART

The planet is a minefield of pathogens with pre-existing capacities to infect susceptible but unexposed hosts, needing only the opportunity for contact[7]. Climate change has always been a major catalyst for such new opportunities, because it disrupts local ecosystem structure and allows pathogens and hosts to move. Once pathogens expand to new hosts, novel variants may emerge, each with new infection capacities. Mathematical models and real-world examples uniformly support these ideas[26]. A recent expert report concluded that the underlying causes of EIDs and pandemics are the same global environmental changes that drive biodiversity loss and climate change[5]. These include anthropogenic influences such as land-use change, agricultural expansion and intensification, habitat fragmentation, wildlife trade and non-sustainable consumption. These drivers of change bring wildlife, livestock, and people into closer contact, allowing animal microbes to move into people and lead to infections, sometimes outbreaks, and more rarely into true pandemics that spread through road networks, urban centres and global travel and trade routes. The emergence of some tick species and tick-borne pathogens (TBPs) has been already associated with habitat fragmentation, human disturbance and urbanization[2,27,28].

Even without deadly global catastrophes on the scale of the 1918 Spanish Influenza pandemic, or the current COVID-19 situation, emerging diseases cost humanity more than a trillion dollars per year in treatment and lost productivity[1]. The cost of the ongoing coronavirus pandemics has been estimated at US$ 24 trillion globally by February 2021. Clearly, the cost of prevention would be by many magnitudes lower than the damage caused by the next pandemic[5]. The Stockholm paradigm offers hope for coping with the crisis. The DAMA (Document, Assess, Monitor, Act) protocol allows us to “anticipate to mitigate” emerging disease, buying time and saving money while we search for more effective ways to cope with this challenge. Thus, the novel approach of the DAMA protocol is both comprehensive and highly focused[1].

Documentation focuses on the intersection of *means of pathogen maintenance and transmission,* primarily *vertebrate reservoirs* and ticks. The best place to find reservoirs is in critical *habitat interfaces.* These are the overlapping areas between wildlands and agricultural lands, agricultural and urban settings, and in wildlands settings within urban areas. The probability of contact between humans and pathogens, their vectors and reservoir hosts is clearly higher here.
Assessment is designed to (1) anticipate the *arrival of known pathogens*, given what we know of anticipated climate change, migration, habitat fragmentation, urbanization and trade connections; (2) *identify known pathogens* before they produce disease; and (3) *identify close relatives of known pathogens that might cause disease.* Assessments produce recommendations about:
Monitoring hosts, vectors and pathogens of significance, and
Action to mitigate their impact – making their arrivals less certain and mitigating their impacts where they occur. DAMA approaches would also take advantage of self-interest and emerging cell phone applications to get local people (*citizen scientists*) involved in documenting what is going on in their own backyards or while they are hiking, reporting that information to national and international initiatives in

which specialists can assess what they report, and suggest additional monitoring and mitigation activities.

1.2.2. OBJECTIVES

1.2.2.1 Research Coordination Objectives

The main objective of the PRAGMATICK action is to establish and coordinate a multi-disciplinary research network for the application of the DAMA (Document, Assess, Monitor, Act) protocol in order to anticipate and mitigate disease risk associated with the presence and probable spread of hard ticks. By bringing together experts from different countries with diverse professional background, the Action will allow identifying critical knowledge and data gaps, and setting up DAMA approach studies for which international coordination is needed. This will be achieved through the following activities:

- Identification of risk factors for tick and tick-borne pathogen (TBP) presence and introduction in cities and habitat interfaces and comparison of the epidemiological situation in different cities and countries through application of the DAMA protocol;
- Recognition of tick and TBP introduction to new areas through application of the DAMA protocol;
- Involvement of citizen scientists into the documentation, monitoring and act phases;
- Provision of a unique portal to the communication of research results to the general public and stakeholders by building and maintenance of a website (tentative domain name: http://pragmatick.org) and social media accounts (Facebook, Twitter) of the Action;
- Represent PRAGMATICK at national and international conferences and the organisation of workshops with the concerned stakeholders;
- Dissemination of the results and conclusions of the PRAGMATICK Action through both scientific and public media.

1.2.2.2 Capacity-building Objectives

- Enhance education and exchange of information about documentation of urban risk of ticks and TBPs, emergence of ticks and TBPs in new areas, and encourage ITC (Inclusiveness Target Country) and Near Neighbour Country (NNC) participation, as well as connect to upcoming conferences and organisations working in the field of TBD, all of which will be supported by establishing a website;
- Foster knowledge exchange by organising networking events such as meetings, web conferences for researchers, students, relevant stakeholders and policymakers;
- Training and active involvement of Young Researchers and Innovators (YRIs) by organising Training Schools, and Short-Term Scientific Missions (STSMs);
- Develop a media strategy, including social media, press releases and media coverage, in order to improve the public knowledge about the health risks of ticks and TBPs identified in connection with anthropogenic influence and climate change and about the DAMA protocol;
- Special emphasis will be given to training of the next generation of young scientists capable of continuing DAMA projects in the future. To this end, at least two new YRIs per WG will be recruited, altogether a minimum of 8 new young researchers.
- Targeted education of citizen scientists in the field: experts involved in the studies working with citizen scientists will teach good practices: how to take photos, collect, preserve and send tick specimens with special emphasis on personal protection and prevention. All of these will be available in an easy-to-read form at the designated part of the PRAGMATICK website;
- Collaboration with hunters and ornithologists for data and sample collection, in line with the Birds Directive;
- Establish long-term research collaboration by initiating large-scale international research consortia aimed at developing targeted DAMA projects. We will apply for external funding within the course of the Action based on the accumulated knowledge of our collaborative network of scientists targeting Horizon Europe, Bill and Melinda Gates Foundation and others.

2. NETWORKING EXCELLENCE

2.1. ADDED VALUE OF NETWORKING IN S&T EXCELLENCE

2.1.1. ADDED VALUE IN RELATION TO EXISTING EFFORTS AT EUROPEAN AND/OR INTERNATIONAL LEVEL

The Intergovernmental Panel on Climate Change (IPCC) is best known to the general public as the organization that develops a comprehensive global assessment of the processes and impacts of climate change. An array of meetings contributes to discussion and consolidation of observations and for planning options involving mitigation and adaptation which are summarized in a series of Assessment Reports. One of those IPCC documents suggested that there were no adaptive anticipatory processes on earth[29]. From this it follows that there is no way we can anticipate particular responses to climate change and have no option but to explore ways to respond ever more rapidly to events after they occur. Fortunately, their assessment was incorrect – Darwinian evolution is an adaptive process with considerable anticipatory capacities.

Pathogens survive and flourish in conditions that allow them and their hosts to co-exist. This is often associated with co-evolutionary interactions that produce highly specialized ecologies associated with how the pathogens are transmitted from host to host and in what parts of the environment they thrive. For more than a century, biologists took comfort in the belief that the more highly coevolved a given pathogen's association with its host, the less likely it would be able to survive in other hosts. Even as our knowledge of the diversity of pathogens grew, we continued to be comforted by the fact that almost all of them infected only one or a few hosts [8]. As a consequence, we were unprepared for the EID crisis. Until recently, we continued to assume that each new disease would be the last such emergence. Now, we must face the Parasite Paradox – if our theories about coevolution of pathogens and hosts are correct, emerging diseases should be rare. But they are not rare. In fact, emergences accelerate.

How can this happen? The answer is surprisingly simple. The conditions that permit a pathogen to thrive, no matter how specific in one place, often occur in other places that are not accessible to the pathogen. Let us consider a pathogen that requires a rodent host to survive and lives in an area where there is only one species of rodent. We could easily think that the rodent and pathogen are so tightly coevolved that the pathogen could not exist without that rodent. We might even believe that if the rodent went extinct, so would the pathogen. In reality, the world is full of rodents, and if the pathogen is highly specialized on some characteristics of its rodent host that is shared by closely related rodents, we can anticipate that those other rodents would be susceptible to infection if they ever came into contact with the pathogen. Thus, if a pathogen is given the opportunity to move to such a place, it will immediately infect new hosts.

Evolutionary studies show that pathogen diversification has always begun with changes in geographic location permitted by climate change events that allow pathogens to move to places they have never been before, where they encounter hosts they have never seen before, and which have never had the opportunity to evolve resistance[26]. Once established in new hosts in new places, the stage is set for new specialized pathogens to evolve in isolation, each one having the potential to cause emergent disease in a new place the next time opportunity presents itself. PRAGMATICK uses this novel framework, the Stockholm paradigm: evolutionary diversification of pathogens occurs through episodes of geographic expansion triggered by climate change or by anthropogenic pressure, leading to emerging disease as a result of pathogens coming into contact with susceptible but previously unexposed hosts, leading to new specialized pathogens, setting the stage for new emergences the next time [30].

The Stockholm paradigm does not deny the action of co-evolutionary interactions between pathogens and hosts, it simply recognizes that such interactions rarely involve all possibilities. The PRAGMATICK Action aims at applying the Stockholm paradigm for the first time to anticipate and mitigate the emerging threats posed by ticks and TBPs. The Action proposes a general protocol that can be a blueprint for many different cooperative efforts. DAMA - Document-Assess-Monitor-Act – is an integrated proposal to build a proactive capacity to understand, anticipate and respond to tick-borne emerging diseases.

DAMA is well suited to a world in flux from biodiversity loss and climate change. Disease hot spots are not going to be stationary, and we need to anticipate where they will go and how they will change. DAMA is linked directly to the Stockholm paradigm, which shows how we can take advantage of the evolutionary biology of pathogens to find them before they find us, to anticipate their arrivals, and to mitigate their impact on us. Fully implemented, therefore, DAMA adds to, and complements other approaches (e.g. One Health) in a number of ways. It focuses on the high probability/low impact pathogens that are not the target of larger-scale efforts but are the primary components of pathogen pollution.

The geographic focus of PRAGMATICK is on the *ecological interfaces* between wildlands and the agriscape, urbanscape and agriscape, urbanscape and wildlands – where the chances of emerging diseases are most likely. This contrasts with, for example, the PREDICT project (https://ohi.vetmed.ucdavis.edu/programs-projects/predict-project/about), which focuses on a pre-selected “hot spots” of viral diseases. PRAGMATICK will go beyond new pathogen discovery and will elucidate the eco-epidemiological background of disease emergence and provide possibilities of prevention. Should climate change and land use change lead to the emergence of new hot spots, the DAMA approach would be an early warning system. Interfaces between habitats provide maximum evolutionary opportunity for pathogens and hosts because they make new fitness space accessible. Climate change and anthropogenic activities alter existing habitats and the interfaces between them. As a consequence, documentation of interfaces, and their changes under climate change and anthropogenic activities, are essential if we are to understand emergences of new tick-borne diseases anywhere and of previously known TBDs in new places.

Currently there is no ongoing COST Action dealing with ticks or TBPs and only a few regional and European networks are or have been working on TBDs, but none of them focus on TBD eco-epidemiology-based prevention. An excellent COST Action, the European Network for Neglected Vectors and Vector-Borne Infections (EurNegVec) that closed years ago, focused on a broad range of vectors (ticks, mosquitoes, sandflies, midges and fleas) and transmitted pathogens under the framework of the One Health paradigm. PRAGMATICK will be able to build onto the experience of the ongoing COST Action called *Aedes* Invasive Mosquitoes that partly uses similar citizen science techniques for data collection that PRAGMATICK also plans to adapt to ticks. The former Scandinavian EU-interreg project ScandTick Innovation worked on prevention (TBE vaccine, risk maps, information material, surveillance, diagnostics (new tests, comparison of tests) and treatment (antiviral treatment) of TBDs in Nordic countries. In addition, a recently closed European anti-tick vaccine development project (ANTIDotE) has identified and characterized tick proteins involved in ‘tick immunity’ and TBP transmission, and explored the possibilities how to use this knowledge to develop anti-tick vaccines to prevent multiple human TBDs.

In contrast, the host focus of PRAGMATICK is the search for the reservoirs of tick-borne pathogens, not just the hosts that are of socio-economic importance when infected. The Action focuses on where they are when they are not infecting us or our livestock or pets. DAMA does geographically focused and site-intensive studies capable of finding rare or atypical TBPs or rare variants of pathogens, rather than site-extensive sampling associated with global inventory projects such as PREDICT. Those hosts that are

most diseased are often not the reservoirs, the hosts in which long-term persistence of a pathogen occurs. It is essential to focus on the reservoirs if we are to understand disease recurrences and the host-context of changes in host and geographic range for pathogens.

Finally, PRAGMATICK is envisioned to be a bottom-up approach, based on the activities of field scientists working in collaboration with citizen scientists and local health and community education personnel. Nonetheless, the Action will use the same technology and the same high-level molecular laboratory, analytic, and archival infrastructure as traditional top-down projects, emphasizing its fundamentally cooperative and integrative nature.

2.2. ADDED VALUE OF NETWORKING IN IMPACT

2.2.1. SECURING THE CRITICAL MASS AND EXPERTISE

The Action will establish a comprehensive knowledge network to address the challenges related to emerging tick and TBP threats with experts of diverse geographical and educational/professional background. PRAGMATICK will use the knowledge of biologists, veterinarians and physicians working in many areas of evolutionary biology, taxonomy, ecology, virology, bacteriology, parasitology, clinical microbiology, molecular biology, bioinformatics, modelling, GIS and predictive mapping, epidemiology, public health, climate research, urban planning etc. The Network of Proposers was designed to include all components needed to achieve the goals of the Action. Since ticks and TBPs do not respect political borders, it is essential to have a cross-border collaboration. For this reason, the Action will be substantially extended to new members with a special emphasis on ITCs and YRIs. The Action network already includes 24 countries that encompass a wide latitudinal (from Portugal to Norway) and longitudinal gradient (from the Netherlands to Turkey) across Europe. The Action Management Committee will coordinate the Action to establish and maintain a smooth-running relationship and efficient cooperation between all members and provide a common base for work and knowledge exchange between all the Action partners. The PRAGMATICK Action will enable its members to successfully apply for additional national and large international research grants and extend the network to other emerging infectious diseases.

2.2.2. INVOLVEMENT OF STAKEHOLDERS

The stakeholders for the Action are a diverse group of academic scientists, public health professionals, physicians, veterinarians, climate scientists, urban planners and citizen scientists (volunteer non-professional participants) interested in prevention and anticipation of risks associated with ticks and TBPs. Many of these stakeholders are already involved as Action members and during the course of this Action we plan to involve the missing stakeholders by inviting them to join the Action meetings and subscribe to the Action's newsletters, and informing them about the Action's website and social media platforms. We will tightly collaborate with the ECDC vector surveillance and control group. PRAGMATICK will directly inform public health authorities to prepare clinical scientists for possible new emerging diseases. With the involvement of urban planners we can facilitate the establishment of city parks and green spaces with reduced EID risk in the future.

To have real impact, we need to reach out beyond the scientific community. As PRAGMATICK will employ a considerable number of citizen scientists, the public outreach via different media sources will be in focus. Civil society will be involved by direct consultation, through established and developing programmes via brochures and fliers, creation of dedicated pages on social networks, articles in popular science journals, press releases, participation in scientific TV and Radio programmes, conferences and

lectures in schools. In most cases, at the local level, it will involve getting the word out to people about a particular threat and how to minimize their (and their family's) exposure to it. This requires input from local residents who can place scientific data within the appropriate cultural context. The monitoring aspect of DAMA is perfect for engaging the help of local citizens, neighbours of the parataxonomists (i.e. less-qualified or unqualified field workers who can aid taxonomists) and other locally based support personnel who are the focus of efforts to mitigate tick-borne disease impacts. It is they who likely have reported some of the information leading to an "act" recommendation in any event. Consequently, not only are they in the best position to implement an "act" recommendation, but by being recognized for doing so provides public approval that represents positive feedback for the people involved, encouraging them to continue and others to participate[31]. PRAGMATICK will seek opportunities to enhance this valuable volunteer monitoring activity by developing an appropriate, easy-to-use mobile application. E.g. high-resolution images taken by smartphones of citizen scientists will produce valuable georeferenced data to be analysed by professional researchers. Citizen scientists can broaden our sampling effort both geographically and quantitatively and at the same time, they will be informed about the results through the same mobile application.

To this point, we have emphasized grassroots, or bottom-up activities. The EID crisis is a global concern, however so, "act" recommendations must also be shared with relevant governmental and NGOs that can spread an alert as widely as is necessary and take appropriate action. In return, those organizations bear the responsibility of getting DAMA projects off the ground.

The website and social media accounts of the Action will provide a unique portal to the dissemination of research results to the general public and stakeholders. In addition to this passive dissemination of information and results, dedicated activities will be set up, including active presence at national and international congresses and the organisation of workshops with the concerned stakeholders. The latter will be of particular importance for supporting the work on knowledge translation even for specific communities like hunters, ornithologists and pest controllers. Indeed, creating awareness and understanding emerging TBD risk requires close interaction with the stakeholders. These workshops will also allow us to learn from the stakeholders on what they conceive to be the most appropriate and effective way of transferring knowledge.

2.2.3. MUTUAL BENEFITS OF THE INVOLVEMENT OF SECONDARY PROPOSERS FROM NEAR NEIGHBOUR OR INTERNATIONAL PARTNER COUNTRIES OR INTERNATIONAL ORGANISATIONS

The main focus has been on developing a network of secondary proposers among the COST Member Countries. In the meantime, we have extended our invitations to various non-COST Member Countries and we will continue this extension in the first three years of the Action. The inclusion of NNCs will allow leveraging current collaborations and funding opportunities. The inclusion of International Partner Countries will allow bringing in additional expertise on various level of the DAMA protocol. New expertise on knowledge translation can be a crucial asset for the Action and will allow promoting transdisciplinarity and moving beyond the classical research on ticks and TBPs.

3. IMPACT

3.1. IMPACT TO SCIENCE, SOCIETY AND COMPETITIVENESS, AND POTENTIAL FOR INNOVATION/BREAKTHROUGHS

3.1.1. SCIENTIFIC, TECHNOLOGICAL, AND/OR SOCIOECONOMIC IMPACTS (INCLUDING POTENTIAL INNOVATIONS AND/OR BREAKTHROUGHS)

Due to the length of the project and the complexity of the expected impacts, an auditory board will be set up that will be responsible for observing and giving immediate feedback of the results during the process of Action.

In the short-term, the Action will have several relevant and realistic scientific and technological impacts:

- The Action will establish a competent network of international experts in the field of tick-borne disease prevention. The Action's website will serve as a portal to the network and its outputs, and will be maintained even after the Action will have come to an end.
- Throughout the course of the Action, relevant tools and training materials about the application of the DAMA protocol will be developed, and standardised training materials that will be disseminated within and beyond the network.
- Accelerated dissemination of state-of-the-art epidemiological knowledge through the Actions' meetings and website, reaching out to both expert and non-expert stakeholders.
- The Action will lead to new DAMA approach studies through Short-Term Scientific Missions and other collaborations; these studies will lead to new insights in the prevention and anticipation of threats posed by ticks and TBDs or risk factors at local, national or regional level. This will not only lead to high-impact scientific publications and scientific conference presentations but also provide an innovative approach to switch from the current reactive to a proactive way of thinking in both EID research and public health measures.
- The Action will foster methodological advances (e.g. citizen science, new mobile application) in the domain of TBD prevention and will allow for cross-boundary studies.

In the long-term, the network and insights will support major impacts for science, society and competitiveness. It will reduce health care costs, and improve quality of life for thousands of people, underscoring the potential societal impact of our Action:

- Overall, the idea of PRAGMATICK is finding new ticks and tick-borne pathogens before they find us. By supporting capacity building in the domain of tick and TBD prevention, the Action will eventually lead to new and improved insights in the potential threats related to this important group of vectors across Europe. This will allow policy makers, industry, and other stakeholders, to identify unmet health needs and prioritise research, prevention and control accordingly. In the long run this should lead to improved and more sustainable population health in Europe. To support this interaction between research and decision making, an explicit focus will be laid on knowledge translation.
- The different innovative tools developed by the Action will lead to a further harmonisation of TBD prevention studies within Europe and beyond. This will lead to improved preparedness and substantial cost reduction compared to the current post-hoc reaction to a disease emergence in the human population.
- The Action will enable Europe to play an active and leading role in the rapidly developing and growing field of EID threat anticipation and mitigation.
- While the scope of the current Action is limited to DAMA application for ticks and tick-borne pathogens, it will lay the foundation for broad-range application of the DAMA protocol for other EIDs in other geographical regions as well.

- Education of the general public about potential TBD risks. Field biologists, taxonomists, ecologists can train parataxonomists, local people with a high degree of knowledge about the biodiversity in their neighbourhoods. Given that no country is self-sufficient with respect to taxonomic expertise, proper documentation activities, no matter where they occur, will almost always involve cross-boundary cooperation. Parataxonomists have been shown to be essential support staff for professional taxonomists working outside their own countries. This kind of collaboration with residents of local communities where DAMA projects are being carried out also creates community goodwill and support for scientific activities.
- PRAGMATICK will seek opportunities to include its results and know-how into national education and training portfolios.

3.2. MEASURES TO MAXIMISE IMPACT

3.2.1. KNOWLEDGE CREATION, TRANSFER OF KNOWLEDGE AND CAREER DEVELOPMENT

Knowledge creation, transfer of knowledge and career development will be a necessary consequence of the PRAGMATICK Action:

- The network places an explicit focus on the inclusion of Young Researchers and Investigators (YRIs), and teams and countries with less capacity in the field of ticks and TBPs, particularly those originating from ITCs. The current composition already guarantees an appropriate mix of experienced researchers and those wishing to gain further experience and expertise. We will continue expanding our network to ensure maximum coverage and inclusion across Europe. Our innovative approach will create specific and usable knowledge regarding the prevention of tick-borne pathogens.
- The Action will actively build on the COST mechanisms to support capacity building across Europe. Training schools and workshops will preferably be held in ITCs to maximise participation rates, and Short-Term Scientific Missions that will strengthen capacity among YRIs and ITC partners will be given priority over exchanges between experienced partners.
- The Action can be an important contribution to the YRI's career development due to the international and collaborative nature of the network. Young investigators will have the opportunity to gain experience in different high-quality research institutes and learn from top scientists in the field. This is an essential asset of the Action since they will be capable of applying and offering training on the DAMA tools in their own countries and regions.

3.2.2. PLAN FOR DISSEMINATION AND/OR EXPLOITATION AND DIALOGUE WITH THE GENERAL PUBLIC OR POLICY

The dissemination of the Action results will be designed to inform and engage different interest groups: academic scientists (field and molecular biologists, virologists, ecologists etc.), public health professionals, public health decision makers, physicians, veterinarians, undergraduate and graduate students in related fields, urban planners, citizen scientists (e.g. volunteer monitoring participants) and the general public

The Action challenges, approaches and objectives will be presented by creating a website at the beginning of the Action that will also include information on the Action network and on the possibility to contribute data and expertise by joining the Action. The state-of-the-art website will serve as the major dissemination hub including:

- General information on objectives and Working Groups (WGs);
- Informing about news and events;
- Reports about media appearance of the Action;

- Database of studies related to anthropogenic pressure, climate change, urbanisation influencing tick and TBD risk factors;
- Hosting of tools and training materials and
- Central contact point for PRAGMATICK experts.

The PRAGMATICK Action will be also present actively on social media (Facebook and Twitter) to reach as wide an audience as possible.

Specific dissemination activities for the scientific community will include:

- Sending regular announcements regarding its activities (conferences, workshops, training schools, publications, reports) to international mailing lists, newsletters and social media platforms;
- Participation in international workshops and conferences (hosted by related communities) and presenting the Action's activities and results;
- Organising two major international conferences at the end of the 2nd and 4th year of the Action;
- Organising workshops throughout the Action's operation;
- Production of peer-reviewed papers (e.g., research papers, perspectives and review papers).

In addition to the scientific community, dialogue with public health policy, industry, urban planners, citizen scientists and other possible end users of PRAGMATICK will be a key objective of the Action. The Action Management Committee will explore and examine what the best mechanisms are to translate information and knowledge resulting from PRAGMATICK studies to the concerned stakeholders. By promoting transdisciplinarity and moving beyond the classical tick and TBD studies, the Action will provide more effective answers to the key societal questions regarding the possible public health impact of ticks and TBDs under changing climate, changing habitats and changing human behaviours. Specific mechanisms may include the following:

- Outreach to decision makers, ministries of health, environment and agriculture following the application of the DAMA protocol;
- Elaboration of policy briefs, i.e., concise summaries of particular studies and key messages;
- Active interaction between researchers, knowledge brokers, and end users, e.g. through organisation and/or participation in interactive workshops, discussion platforms, fairs and roundtables.

Interaction with the general public will serve a direct purpose of informing about the TBD health threats for the population and the most important diseases and risk factors; it will also serve an important indirect purpose as a mechanism to inform and influence decision makers. The interaction with the general public will happen through press statements, media appearances, and other mechanisms (e.g., social media). Last but not least, bids and proposals for dissemination efforts at national and local levels of network members will be supported. Thereby, PRAGMATICK will also trigger a substantial multiplication effect at national and local levels.

4. IMPLEMENTATION

4.1. COHERENCE AND EFFECTIVENESS OF THE WORKPLAN

4.1.1. DESCRIPTION OF WORKING GROUPS, TASKS AND ACTIVITIES

The management of the PRAGMATICK Action will be carried out as per the regulations and procedures described in the COST Annotated Rules and with the aim of ensuring the Action objectives are achieved. The Action Management Committee (MC) formed by up to two national experts of each of the COST Full/Cooperating countries will be in charge of implementing, supervising and coordinating the activities

of the Action, as well as promoting capacity building, managing the budget and disseminating the results. Based on the security of data, audition of the Action and the permissions required for each Action partner country's legislation and EU Directives will be rigorously followed by the MC. A Chair and Vice Chair of the Action will be elected at the first MC meeting and a Grant Holder and Grant Holder Scientific Representative will be selected. In the designation of these leadership positions, we will ensure a balance with respect to age, gender and geographical location. The assigned Grant Holder Scientific Representative will assign persons to the positions of Grant Holder Legal Representative, Grant Holder Financial Representative and Grant Holder Manager (who will provide the necessary administrative support to organise, amongst others, the travel reimbursement requests). The MC will oversee the composition of various WGs, ensuring that the objectives can be achieved, accounting for the possible non-participation of some network members at certain key times as detailed in the contingency plans. The deliverables and tasks are spread evenly over the 4 years and between different areas of expertise to avoid overloading network members. Each network member will be involved in at least two WGs, so their expected tasks within each will be clearly defined. The MC will ensure that funds are distributed accordingly in order to achieve the objectives and deliverables of the Action in a timely and efficient manner. It will also coordinate between the WGs and oversee the dissemination of results and the planning of network activities (e.g. meetings, conferences, workshops, training schools, and STSMs).

Each WG will be supervised by a WG leader and co-leader. The WG (co)leaders will ensure that activities run smoothly. These persons will be MC members who are able to commit the necessary time, but diversity will also be considered to ensure there is input from YRIs, ITCs, as well as a good gender balance. We will achieve this by striving for representation of YRI, ITC, and the minority gender within each leader/co-leader pair (e.g., a female ITC leader and an YRI co-leader). The leadership pair will be responsible for reporting on progress at meetings and helping prepare annual reports as well as identifying any targets that are unlikely to be met, so the MC can put contingency plans into action (e.g. identify other/new network members to complete tasks). WG leaders will need to communicate effectively with each other for smooth operation of the network. There will be a flow of knowledge exchange between WGs over the Action lifetime and it is expected that the WG leaders will be in regular contact, both formal and informal. They will also be expected to keep the network informed of relevant developments within their WG topic over the full four years of the network, not just when they are ‘active’. A Communication Manager (COMM) will be identified to support the Action’s dissemination activities, including the management of the website and the Action’s online/social media profile. Finally, a Short-Term Scientific Mission Manager (STSMM) will be responsible for managing the process of offer and demand of STSMs, and will be specifically tasked with encouraging participation from ITCs and YRIs. The Action Chair, Vice Chair, Grant Holder representatives, WG leaders, COMM and STSM, will coordinate the preliminary activities to be approved by the MC. MC meetings will be held at each of the annual meetings, with additional communication on-line as necessary.

The work that is foreseen within the PRAGMATICK Action will be conducted within four different WGs. Several methods will be used to achieve good communication within WGs and excellent integration between WGs. There will be frequent formal and informal contact moments both within and between the WGs. Two meetings (face-to-face or online, depending also on the coronavirus pandemics) will be held each year to share the progress and results of all WGs between the participants and to discuss the findings; these meetings will be combined with MC meetings and COST conferences to increase participation and save budget.

Working Group 1: Non-typical and elusive TBPs

Tasks & activities

T 1.1 Documenting the appearance of non-typical and elusive tick-borne bacterial pathogens with special emphasis on pathogenic spirochete species;

T 1.2 Assessment of risk amplifiers that increase the establishment of non-typical bacterial pathogens in Europe;

T 1.3 Monitoring of distribution of atypical or non-usual spirochete species for Europe promoted by migration of vertebrate hosts or tick vectors and human-mediated activities;

T 1.4 Assembly of genetic tools to understand the population structure and gene flow of spirochetes from *Borrelia burgdorferi* s. l. complex, the cause of human Lyme borreliosis;

T 1.5 Taking actions in education and awareness of scientific, medical communities and the general public with the aim to reduce the risk of elusive TBP contraction;

T 1.6 Develop a joint elusive or non-typical TBD research agenda, including a summary of identified common essential key challenges, bottlenecks, knowledge and data gaps.

Deliverables

D 1.1 Identification and involvement of researchers in the domain of non-typical and elusive TBPs;

D 1.2 Design and carry out studies about non-typical and elusive TBPs;

D 1.3 Workshop on isolation, cultivation, visualization and molecular detection techniques of non-typical and elusive TBPs (including Lyme borreliosis spirochetes);

D 1.4 Training School about non-typical and elusive TBPs;

D 1.5 At least 4 Short-Term Scientific Missions completed for non-typical and elusive TBPs;

D 1.6 Peer-reviewed scientific publications and international conference presentations reporting on new findings, common key challenges, knowledge and data gaps and methodological advances about non-typical and elusive TBPs.

Working Group 2: Urban tick and TBD hotspots, effect of anthropogenic pressure

Tasks & activities

T 2.1 Documenting current risk of infection with ticks and TBPs in urban parks and suburban recreational areas;

T 2.2 Assessment of risk amplifiers for TBDs, e.g. vertebrate reservoirs, vegetation, habitats, human behaviours, seasons etc.;

T 2.3 Monitoring of risk factors (vegetation, tick and reservoir community composition, degree of park maintenance, human behaviour etc.) for TBDs;

T 2.4 Suggestions for taking actions to anticipate and to reduce the disease risk;

T 2.5 Involvement of urban planners to suggest future preventing and mitigating actions within cities;

T 2.6 Taking actions in education and awareness of scientific, medical communities and the general public with the aim to reduce the risk of TBD infections.

Deliverables

D 2.1 Identification and involvement of researchers with diverse professional background in the domain of urban tick and TBD risk;

D 2.2 Design and carry out DAMA-based studies to prevent urban tick and TBD risk;

D 2.3 Workshop on the application of the DAMA approach to prevent tick and TBD risk in urban and suburban areas;

D 2.4 Training School about application of the DAMA approach to prevent tick and TBD risk in urban and suburban areas;

D 2.5 At least 4 Short-Term Scientific Missions completed in the domain of the DAMA approach to prevent tick and TBD risk in urban and suburban areas;

D 2.6 Peer-reviewed scientific publications and international conference presentations reporting on results, common key challenges, knowledge and data gaps and methodological advances in applying the DAMA approach to prevent tick and TBD risk in urban and suburban areas;
D 2.7. International scientific congress about the DAMA approach and its application to prevent tick and TBD risk under changing climate (in collaboration with all WGs).

Working Group 3: Spread and establishment of ticks and TBDs under changing climate
Tasks & activities

T 3.1 Involvement of climate specialists to assess possible climate scenarios that enhance tick and TBP establishment;
T 3.2 Documenting potential cases of tick (e.g. *Hyalomma* spp.) introductions via monitoring migrating bird populations;
T 3.3 Documenting potential cases of tick (*Rhipicephalus* and *Dermacentor* spp.) introductions via monitoring moving dog, fox and golden jackal populations;
T 3.4 Assessment of risk amplifiers for the geographic spread of ticks into and within (e.g. *D. reticulatus*) Europe
T 3.5 Monitoring of risk factors (ticks, reservoirs, habitats etc.) for ticks and TBPs influenced by climate change;
T 3.6 Monitoring of risk factors for spread and establishment of ticks and TBPs in new areas;
T 3.7 Taking actions to predict (involving GIS experts), anticipate and reduce the risk of introduction and establishment of non-indigenous tick species and TBPs;
T 3.8 Taking actions in education and awareness of scientific, medical communities and the general public with the aim to reduce the risk of non-indigenous tick and TBP infections.

Deliverables

D 3.1 Identification and involvement of climate researchers and collaborative assessment of possible climate scenarios that enhance non-indigenous tick and TBP establishment;
D 3.2 Design and carry out DAMA-based studies to prevent the geographic spread of ticks and TBPs into and within Europe;
D 3.3 Workshop on the application of the DAMA approach to prevent the geographic spread of ticks and TBPs into and within Europe;
D 3.4 Training School about application of the DAMA approach to prevent the geographic spread of ticks and TBPs into and within Europe;
D 3.5 At least 4 Short-Term Scientific Missions completed in the domain of the DAMA approach to prevent the geographic spread of ticks and TBPs into and within Europe;
D 3.6 Peer-reviewed scientific publications and international conference presentations reporting on results, common key challenges, knowledge and data gaps and methodological advances in applying the DAMA approach to prevent the geographic spread of ticks and TBPs into and within Europe.

Working Group 4: Citizen science involvement in the DAMA protocol
Tasks & activities

T 4.1 Involvement of researchers applying citizen science successfully in other research projects;
T 4.2 Development of a user-friendly mobile phone application for photographic identification of the most common European tick species occurring on humans and pets (e.g. as a subproject within iNaturalist application);
T 4.3 Social media campaign to involve volunteer monitoring citizen scientists for broadening our sample and data collection efforts. This will include tick flagging campaigns performed by students trained by experts; on-line questionnaire and photograph/sample sending from animal keepers to

find introduced tick species and reporting road-hit wild animals at selected areas. The education of volunteers will have an emphasis on potential risk of infection and personal health protection;
T 4.4 Design and implementation of social media campaigns to monitor TBP reservoir vertebrates (e.g. hedgehogs, squirrels, rodents) and ticks within urban areas;
T 4.5 Community education about influence of climate change onto tick and TBD risk, proper prevention methods via social media campaigns, explanatory short videos.

Deliverables

D 4.1 Identification and involvement of researchers applying citizen science successfully and collaborative assessment of potential use of citizen science in PRAGMATICK Action;
D 4.2 Design and development of mobile application for documenting tick and TBD risk;
D 4.3 Workshop on the application of citizen science to prevent tick and TBD risk under changing climate and environment;
D 4.4 Training School about application of citizen science to prevent tick and TBD risk;
D 4.5 At least 4 Short-Term Scientific Missions completed in the domain of citizen science application to prevent tick and TBD risk under changing climate and environment;
D 4.6 Peer-reviewed scientific publications and international conference presentations reporting on results, common key challenges, knowledge and data gaps and methodological advances in application of citizen science to prevent tick and TBD risk;
D 4.7. International scientific congress about the strength and necessity of citizen science and the DAMA approach and its extension to other emerging infectious diseases under changing climate and environment (in collaboration with all WGs).

4.1.2. DESCRIPTION OF DELIVERABLES AND TIMEFRAME

The deliverables of the various work packages are listed in the chapter above and the timeframes of the deliverables are summarised by a GANTT diagram in chapter 4.1.4.

4.1.3. RISK ANALYSIS AND CONTINGENCY PLANS

The MC will be responsible for monitoring the overall progress of the WGs. Regular formal and informal communication within and between WGs will be key to detecting and mitigating potential problems. Two annual contact moments will be organised (face-to-face or online) between the WG leaders and co-leaders. MC meetings will be held at each of the annual meetings, with additional communication on-line as necessary. Whenever problems are detected, the WG leaders will immediately apply contingency measures, or, if necessary, hold additional meetings to identify and implement solutions.

Risk	Likelihood	Impact	Reduction of Risk	Response	Decision
Objectives not achieved at the time scheduled	Moderate	Moderate	Tight supervision. An expert and a vice expert for each Task.	Task re-assignment	Chair and Vice-Chair
A partner leaves	Moderate	**High**	Motivating by a focus on forthcoming publications. WGs' interaction.	An expert and vice-expert for each Task. Support from other WGs.	MC

Lack of communication among partners	**High**	Moderate	Encouraging regular interactive communications (calls, video calls and meetings)	Reassignment of Tasks	Chair and Vice-Chair
Cost limitations	Low	**High**	Regular monitoring of funds' administration	Redistribution of costs, application for additional travel grants	MC
Low participation to DAMA activities (e.g., STSM's and Training Schools)	Low	Moderate	Advertising the activities and establishing a waiting list.	Appointment of a coordinator, set specific participation targets.	Vice-Chair
Failure to reach the necessary stakeholders and impact	Low	**High**	Involving stakeholders from the beginning and set a focus on their own issues	Using proposers' resources to strengthen links and dissemination	Chair

4.1.4.

4.1.5. GANTT DIAGRAM

0	Description	Month																							
Tasks		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
	WG1: Non-typical and elusive TBPs																								
T 1.1	Documenting the appearance of non-typical TBPs																								
T 1.2	Assessing risk amplifiers for non-typical TBP establishment																								
T 1.3	Monitoring of distribution of atypical spirochetes																								
T 1.4	Assembly of tools for population genetics of B. burgdorferi s. l.																								
T 1.5	Taking actions in education																								
T 1.6	Develop a joint elusive or non-typical TBD research agenda																								
Deliverables																									
D 1.1	Identification and involvement of researchers for non-typical TBPs																								
D 1.2	Design and carry out studies about non-typical and elusive TBPs																								
D 1.3	Workshop on techniques of non-typical and elusive TBPs																								
D 1.4	Training School about non-typical and elusive TBPs																								
D 1.5	At least 4 STSMs completed for non-typical and elusive TBPs																								
D 1.6	Scientific papers, presentations of non-typical TBPs																								
Tasks		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
	WG2: Urban tick and TBD hotspots																								
T 2.1	Documenting risk of infection with ticks and TBPs in urban parks																								
T 2.2	Assessing risk amplifiers for TBDs																								
T 2.3	Monitoring of risk factors (ticks, reservoirs etc.) for TBDs																								
T 2.4	Taking actions to anticipate and to reduce the disease risk																								
T 2.5	Involvement of urban planners for preventing actions within cities																								
T 2.6	Actions in education and awareness to reduce TBD risk																								
Deliverables																									
D 2.1	Identification and involvement of researchers for urban tick and TBD risk																								
D 2.2	Design and carry out DAMA-based studies to prevent urban tick and TBD risk																								
D 2.3	Workshop about DAMA approach to prevent tick and TBD risk in urban areas																								
D 2.4	Training School about DAMA approach to prevent tick and TBD risk in urban areas																								
D 2.5	At least 4 STSMs in DAMA approach to prevent tick and TBD risk in urban areas																								
D 2.6	Scientific papers, presentations about DAMA approach, TBD prevention, urban areas																								
D 2.7	International congress: DAMA to prevent tick and TBD risk under changing climate																								
Tasks		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
	WG3: Spread and establishment of ticks and TBDs under changing climate																								
T 3.1	Involvement of climate specialists																								
T 3.2	Documenting cases of tick introductions via monitoring migrating bird populations																								
T 3.3	Documenting cases of tick introductions via monitoring moving canid populations																								
T 3.4	Assessment of risk amplifiers for geographic spread of ticks into and within Europe																								
T 3.5	Monitoring risk factors for ticks and TBPs influenced by climate change																								
T 3.6	Monitoring risk factors for spread and establishment of ticks and TBPs in new areas																								
T 3.7	Actions to reduce risk of introduction and establishment of tick species and TBPs																								
T 3.8	Education and awareness to reduce risk of non-indigenous tick and TBP infections																								
Deliverables																									
D 3.1	Identification and involvement of climate researchers for tick and TBP establishment																								
D 3.2	Design and carry out DAMA-based studies to prevent spread of ticks and TBPs																								
D 3.3	Workshop on DAMA to prevent spread of ticks and TBPs into and within Europe																								
D 3.4	Training School about DAMA to prevent spread of ticks and TBPs into and within Europe																								
D 3.5	At least 4 STSMs about DAMA to prevent spread of ticks and TBPs into and within Europe																								
D 3.6	Scientific papers, presentations of DAMA to prevent spread of ticks and TBPs into/within Europe																								
Tasks		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
	WG4: Citizen science involvement in the DAMA protocol																								
T 4.1	Involvement of researchers applying citizen science successfully in other research projects																								
T 4.2	Development of a mobile application for identification of the most common European tick species																								
T 4.3	Social media campaign to involve citizen scientists for tick flagging and reporting road-hit animals																								
T 4.4	Design and implementation of social media campaigns to monitor TBP reservoirs and ticks in cities																								
T 4.5	Education about influence of climate change onto tick and TBD risk, proper prevention methods																								
Deliverables																									
D 4.1	Identification and involvement of citizen science researchers in PRAGMATICK Action																								
D 4.2	Design and development of mobile application for documenting tick and TBD risk																								
D 4.3	Workshop on the application of citizen science to prevent tick and TBD risk under changing climate																								
D 4.4	Training School about application of citizen science to prevent tick and TBD risk																								
D 4.5	At least 4 STSMs completed in citizen science application to prevent tick and TBD risk																								
D 4.6	Scientific papers, presentations of citizen science to prevent tick and TBD risk																								
D 4.7	International congress about citizen science and DAMA approach and its extension to other EIDs																								
General Deliverables (MC and all WGs)		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
	Website development																								
	Regulations																								
	Yearly action reports																								
	MC meetings																								
	Annual meetings																								

References

1. Brooks, D. R., Hoberg, E. P. & Boeger, W. A. *The Stockholm Paradigm: Climate Change and Emerging Disease*. (University of Chicago Press, 2019).
2. Rizzoli, A. *et al.* Ixodes ricinus and its transmitted pathogens in urban and peri-urban areas in Europe: New hazards and relevance for public health. *Frontiers in Public Health* **2**, (2014).
3. Jones, K. E. *et al.* Global trends in emerging infectious diseases. *Nature* **451**, 990–993 (2008).
4. Gibb, R. *et al.* Zoonotic host diversity increases in human-dominated ecosystems. *Nature* 1–5 (2020) doi:10.1038/s41586-020-2562-8.
5. Daszak, P. *et al. Workshop Report on Biodiversity and Pandemics of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES)*. https://zenodo.org/record/4147318#.X6j_4FNKhQI (2020) doi:10.5281/zenodo.4147318.
6. Braks, M., Giglio, G., Tomassone, L., Sprong, H. & Leslie, T. Making Vector-Borne Disease Surveillance Work: New Opportunities From the SDG Perspectives. *Front Vet Sci* **6**, 232 (2019).
7. Nylin, S. *et al.* Embracing Colonizations: A New Paradigm for Species Association Dynamics. *Trends Ecol Evol* **33**, 4–14 (2018).
8. Brooks, D. R. *et al.* Finding Them Before They Find Us: Informatics, Parasites, and Environments in Accelerating Climate Change. *Comparative Parasitology* **81**, 155–164 (2014).
9. Arteaga, L. M. *et al.* New circulation of genotype V of Crimean-Congo haemorrhagic fever virus in humans from Spain. *PLOS Neglected Tropical Diseases* **15**, e0009197 (2021).
10. Estrada-Peña, A., ĎAmico, G. & Fernández-Ruiz, N. Modelling the potential spread of Hyalomma marginatum ticks in Europe by migratory birds. *International Journal for Parasitology* (2020) doi:10.1016/j.ijpara.2020.08.004.
11. Pascucci, I. *et al.* Assessing the role of migratory birds in the introduction of ticks and tick-borne pathogens from African countries: An Italian experience. *Ticks Tick Borne Dis* **10**, 101272 (2019).
12. Tokarevich, N. K. *et al.* The impact of climate change on the expansion of Ixodes persulcatus habitat and the incidence of tick-borne encephalitis in the north of European Russia. *Glob Health Action* **4**, 8448 (2011).
13. Laaksonen, M. *et al.* Crowdsourcing-based nationwide tick collection reveals the distribution of Ixodes ricinus and I. persulcatus and associated pathogens in Finland. *Emerg Microbes Infect* **6**, e31 (2017).
14. Jaenson, T. G. T., Jaenson, D. G. E., Eisen, L., Petersson, E. & Lindgren, E. Changes in the geographical distribution and abundance of the tick Ixodes ricinus during the past 30 years in Sweden. *Parasit Vectors* **5**, 8 (2012).
15. Soleng, A. *et al.* Distribution of Ixodes ricinus ticks and prevalence of tick-borne encephalitis virus among questing ticks in the Arctic Circle region of northern Norway. *Ticks Tick Borne Dis* **9**, 97–103 (2018).
16. Danielová, V. *et al.* Integration of a tick-borne encephalitis virus and Borrelia burgdorferi sensu lato into mountain ecosystems, following a shift in the altitudinal limit of distribution of their vector, Ixodes ricinus (Krkonose mountains, Czech Republic). *Vector Borne Zoonotic Dis* **10**, 223–230 (2010).
17. Garcia-Vozmediano, A. *et al.* Ticks climb the mountains: Ixodid tick infestation and infection by tick-borne pathogens in the Western Alps. *Ticks and Tick-borne Diseases* **11**, 101489 (2020).
18. Hubálek, Z., Sedláček, P., Estrada-Peña, A., Vojtíšek, J. & Rudolf, I. First record of Hyalomma rufipes in the Czech Republic, with a review of relevant cases in other parts of Europe. *Ticks and Tick-borne Diseases* **11**, 101421 (2020).
19. Rudolf, I. *et al.* Probable overwintering of adult Hyalomma rufipes in Central Europe. *Ticks and Tick-borne Diseases* **12**, 101718 (2021).
20. Chitimia-Dobler, L. *et al.* Imported Hyalomma ticks in Germany in 2018. *Parasit Vectors* **12**, 134 (2019).
21. McGinley, L. *et al.* First report of human exposure to Hyalomma marginatum in England: Further evidence of a Hyalomma moulting event in north-western Europe? *Ticks and Tick-borne Diseases* **12**, 101541 (2021).
22. Grandi, G. *et al.* First records of adult Hyalomma marginatum and H. rufipes ticks (Acari: Ixodidae) in Sweden. *Ticks Tick Borne Dis* 101403 (2020) doi:10.1016/j.ttbdis.2020.101403.

23. Pintore, E. *et al.* First detection of Amblyomma variegatum and molecular finding of Rickettsia africae in Sardinia, Italy. *Ticks Tick Borne Dis* **12**, 101561 (2020).
24. Hansford, K. M., Phipps, L. P., Cull, B., Pietzsch, M. E. & Medlock, J. M. Rhipicephalus sanguineus importation into the UK: surveillance, risk, public health awareness and One Health response. *Vet Rec* **180**, 119 (2017).
25. Wright, I. Babesiosis in Essex, UK: monitoring and learning lessons from a novel disease outbreak. *Parasit Vectors* **11**, 132 (2018).
26. Araujo, S. B. L. *et al.* Understanding Host-Switching by Ecological Fitting. *PLoS One* **10**, e0139225 (2015).
27. Földvári, G., Široký, P., Szekeres, S., Majoros, G. & Sprong, H. Dermacentor reticulatus: a vector on the rise. *Parasites & Vectors* **9**, 314 (2016).
28. Millins, C. *et al.* Landscape structure affects the prevalence and distribution of a tick-borne zoonotic pathogen. *Parasit Vectors* **11**, 621 (2018).
29. Field, C. B. & Barros, V. R. *Climate Change 2014 – Impacts, Adaptation and Vulnerability: Regional Aspects*. (Cambridge University Press, 2014).
30. Hoberg, E. P. & Brooks, D. R. Evolution in action: climate change, biodiversity dynamics and emerging infectious disease. *Philos. Trans. R. Soc. Lond., B, Biol. Sci.* **370**, (2015).
31. Pasquini, L., Ziervogel, G., Cowling, R. M. & Shearing, C. What enables local governments to mainstream climate change adaptation? Lessons learned from two municipal case studies in the Western Cape, South Africa. *Climate and Development* **7**, 60–70 (2015).