REVISTA BRASILEIRA DE CIÊNCIAS DA AMAZÔNIA

SUIgPVH
Saúde Única de Igarapés

Edição especial
Saúde Única de Igarapés Urbanos

Artigo

Highlights of Medical and Veterinary Entomology in the One Health Approach: A Mini-Review

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Citation: Julião, G.R.; Meireles, A.C.A.; Rios, F.G.F.; da Silva, M.S; Ríos-Velásquez, C.M.; Pessoa, F.A.C.; Medeiros, J.F. Highlights of Medical Entomology in the One Health approach: an AI mini-review. *RBCA* **2025**, *14*, 1. p.1-14

Section Editors: Dra. Karen Janones da Rocha e Dra. Marcela Alvares Oliveira
Received: 27/03/2024
Accepted: 07/09/2024
Published: 04/04/2025

Abstract: Medical and Veterinary Entomology are pillars of One Health studies, since many diseases that affect animals and humans are vector-borne diseases, e.g., malaria, dengue fever, lymphatic filariasis, Chagas disease, onchocerciasis, leishmaniasis, chikungunya, Zika, yellow fever, Japanese encephalitis, and schistosomiasis. Epidemics and outbreaks of these diseases may become more frequent due to climatic and landscape changes and effects of globalization, increasing the exposure of humans and animals to arthropod vectors. Moreover, climate and environmental changes can affect the geographical distribution patterns of vectors and the diseases they transmit, causing continuous outbreaks worldwide. In this mini review, we highlight arthropods with medical and veterinary relevance, some key factors in pathogen transmission, and ecological importance of insects. We also evaluated an AI tool for literature research on Medical Entomology and One Health. We found that mosquitoes and ticks predominate in the papers, and the effects of deforestation and urbanization, of extreme temperature and rainfall indices on these organisms must be considered in the planning for preparedness, capacity-building, and risk assessment of disease transmission, contributing to strengthening the One Health strategy.

Keywords: Arthropods, Vector-Borne Diseases, Vector Ecology, Amazon Ecosystem, Research Rabbit.

Resumo: A Entomologia Médica e Veterinária são pilares dos estudos em Saúde Única, uma vez que muitas doenças que afetam animais e humanos são aquelas transmitidas por vetores, como malária, dengue, filariose linfática, doença de Chagas, oncocercose, leishmaniose, chikungunya, zika, febre amarela, encefalite japonesa e esquistossomose. As epidemias e surtos destas doenças podem tornar-se mais frequentes devido às mudanças paisagísticas e climáticas e aos efeitos da globalização, aumentando a exposição de seres humanos e animais aos vetores artrópodes. Além disso, as alterações climáticas e ambientais podem afetar os padrões de distribuição geográfica dos vetores e das doenças que transmitem, causando surtos contínuos em várias regiões do mundo. Nesta minirevisão destacamos artrópodes com relevância médica e veterinária, alguns fatores-chave na transmissão de patógenos e importância ecológica dos insetos. Uma ferramenta de IA foi testada para pesquisa de literatura sobre Entomologia Médica e Saúde Única. Verificou-se que mosquitos e carrapatos predominam nos estudos, e os efeitos do desmatamento e da urbanização, dos índices extremos de temperatura e pluviosidade sobre esses organismos devem ser considerados no planejamento da preparação, capacitação e avaliação de risco de transmissão de doenças, contribuindo para fortalecer a estratégia de Saúde Única.

Palavras-chave: Artrópodes, Doenças Transmitidas por Vetores, Ecologia de Vetores, Ecossistema Amazônico, Research Rabbit

1. One Health concept

The term "One Health" (One Health, Una Salud, Salud Unica, Une Santé) is defined as "the collaborative effort of multiple disciplines – working locally, nationally and globally – to achieve optimal health for people, animals and the environment". Disciplines include Education, Biological Sciences, Medicine, Veterinary, Biomedicine, Anthropology, Sociology, Nursing, Dentistry, Public Health, not restricted to these fields, and extending to environmentalists and various segments of civil society (Aguirre *et al*., 2016; Carneiro *et al*., 2021; Pettan-Brewer *et al*., 2021).

To this day, there is no consensus as to where the term "One Health" originated, and who proposed it, but historically, this term was preceded by the establishment of the concept of "One Medicine", at the end of the 19th century and beginning of the 20th century. The German pathologist Rudolf Virchow carried out research on the helminth *Trichinella spiralis* in the muscle tissue of pigs, and cysticercosis and tuberculosis in cattle. From his studies, Virchow proposed the need to integrate human and animal medicine and created the term "zoonosis". Virchow's student, the Canadian William Osler, consolidated these concepts and published studies on the relationship between animals and man, and comparative pathology, being credited with spreading the "One Medicine" concept, although there is no evidence for this (Kahn *et al*., 2008; Zinsstag *et al*., 2011; Gyles, 2016).

The idea of a single health was already conceived in Antiquity, by the Egyptian civilizations, the Babylonians, the Arabs, the Greeks and the Romans, in addition to the ancestral peoples of Latin America (Larsen, 2021; Pettan-Brewer *et al*., 2021). In Brazil, there are several research groups dedicated to the One Health approach, and this movement was officially recognized in 2007, with the "One World, One Health" presentation by Dr. William B. Karesh during the "One Health Symposium" event. In 2016, a management committee was created, and the "One Health" network in Brazil was established in 2019, (see https://onehealthbrasil.com), and presented its concepts, mission, vision, values and strategic objectives (Pettan-Brewer *et al*., 2021).

Currently, there are two main schools of thought in One Health, one focusing on human-animal-plant-environment interfaces; and another focusing the system, including human, animal, vegetation and environmental components (Laing *et al*., 2023).

2. Vector-Borne Diseases

Medical and Veterinary Entomology are pillars of One Health studies, since many diseases that affect animals and humans are vector-borne diseases (VBDs) with great economic and social impacts. The prevention and control of VBDs requires knowledge of the basic biology of organisms – pathogens, hosts and vectors, in addition to the environment and context in which they are located (Marcondes, 2017).

The main causal agents of VBDs are bacteria, protozoa, helminths and viruses. Malaria, dengue fever, lymphatic filariasis, Chagas disease, onchocerciasis, leishmaniasis, chikungunya, Zika, yellow fever, Japanese encephalitis and schistosomiasis are considered the diseases that have the most impact on human populations. Epidemics and outbreaks of these diseases may become more frequent due to unplanned urbanization, landscape changes and globalization as the exposure of humans and animals to arthropod vectors increases. Moreover, climate and environmental changes have affected the geographical distribution patterns of vectors and the diseases they transmit, causing continuous outbreaks in various regions of the world (Figure 1) (WHO, 2017).

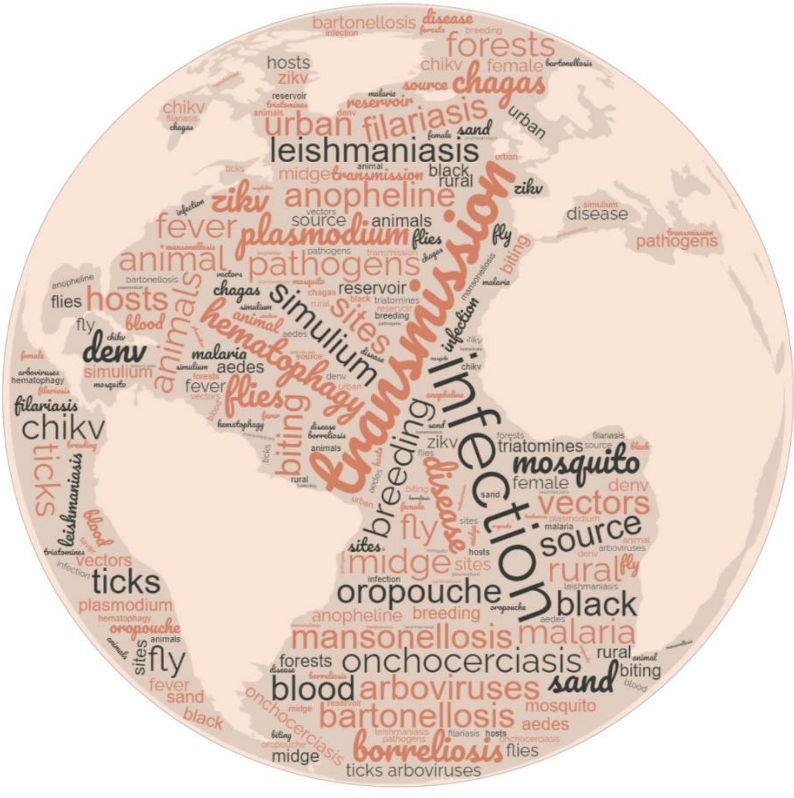

Figure 1. Illustrative word cloud for vector-borne diseases (VBDs). Source: https://www.wordclouds.com/. Access: 03/24/2023.

3. Arthropods and Pathogen Transmission: Key Factors

Mosquito genera *Aedes*, *Anopheles*, and *Culex* are considered the main arthropods associated with VBDs, but pathogen transmission is also carried out by sandflies, biting midges, black flies, kissing bugs (triatomines), ticks, fleas, flies, mites, lice and snails (Figure 2).

Figure 2. Main arthropod groups associated with pathogen transmission that cause diseases in animals and humans. Source: Images by ECDC/Photographer, Fiocruz Images, Fiocruz Rondônia, IOC – Fiocruz, H. Navarro (2007), Gorayeb and Barros (2006).

The patterns and mechanisms relating to the emergence and re-emergence of infectious diseases have been the focus of investigations, including the debate on the spatial and temporal scales adopted in epidemiological studies. This is due to the nature of pathogenic systems (pathogen – vector – host + environment + interactions) and the factors that determine the occurrence/frequency of their components, at different levels (Reisen, 2010).

The epidemiological triad composed by Pathogen, Vector and Host is dependent on environmental and climatic conditions, and processes and changes of anthropogenic origin, such as extreme droughts and floods, deforestation, globalization, urbanization, migration, have resulted in new vector distribution configurations, and interfering with the geographic distribution of the pathogen (Christofferson *et al*., 2020).

The emergence of leishmaniasis, transmitted by sandflies, has been attributed to several factors, such as the insertion of new hosts and vector species, dissemination of infection in humans or animals in the domestic environment, human invasion or increased contact with cycles zoonotic diseases, expansion of the distribution limits of natural reservoirs (Ashford, 2000).

Ceratopogonids of the genus *Culicoides* have epidemiological importance because they are vectors of Oropouche virus in addition to the filariae *Mansonella ozzardi* and *M. perstans* (Beaty; Marquardt, 1996). These insects are also the main vectors of the Bluetongue virus, a disease that affects cattle, goats and wild ruminants. The emergence and re-emergence of the disease in Europe, Australia and the southeast of the United States of America has been related to climate changes, mainly linked to storms, typhoons and hurricanes which can favor wind-dispersed vectors (Maclachlan; Guthrie, 2010).

Currently, the emergence of Chagas disease in several locations previously disease-free and the re-emergence in regions where control programs still exist draws attention, highlighting some changes in the disease's transmission patterns. Recent disease globalization resulted in thousands of cases in non-endemic countries as the United States of America, Canada, Europe, Australia, and Japan. The geographical expansion of Chagas disease has been explained by human migration triggered by political, health, environmental, and economic crises in the endemic countries (Hotez *et al*., 2012; Sousa *et al*., 2024). In Brazil, during the period 2000-2010, more than 1,000 acute cases were recorded in 138 outbreaks, mainly in the Brazilian Amazon region. Ingestion of contaminated drinks and food was the main form of transmission (71% of cases) (Shikanai-Yasuda; Carvalho, 2012).

Mosquito-borne diseases, such as those caused by DENV and *Plasmodium* spp., have dynamics regulated by the interaction between climatic, environmental, social and behavioral factors. The development cycle of mosquitoes is highly linked to favorable conditions, such as the water availability for their early stages, and is usually impacted by the amount of rainfall. At the same time, the characteristics of the landscape and land cover play a crucial role in providing suitable habitats and essential elements for the survival of adult mosquitoes, including breeding and resting sites in both wild and urban areas, and the presence of vertebrate hosts as a blood source for female mosquitoes (Carlos *et al*., 2019; Francisco *et al*., 2020).

4. Mosquitoes and Other Vectors in the Amazon Ecosystem

Despite the relevance of arthropods as pathogen vectors, these organisms have other ecosystem roles, generally little known. Some species of mosquitoes, for example, act as pollinators, predators and prey, contributing with services to the ecosystem, as components of biodiversity (Figure 3) (Bhattacharya *et al*., 2016).

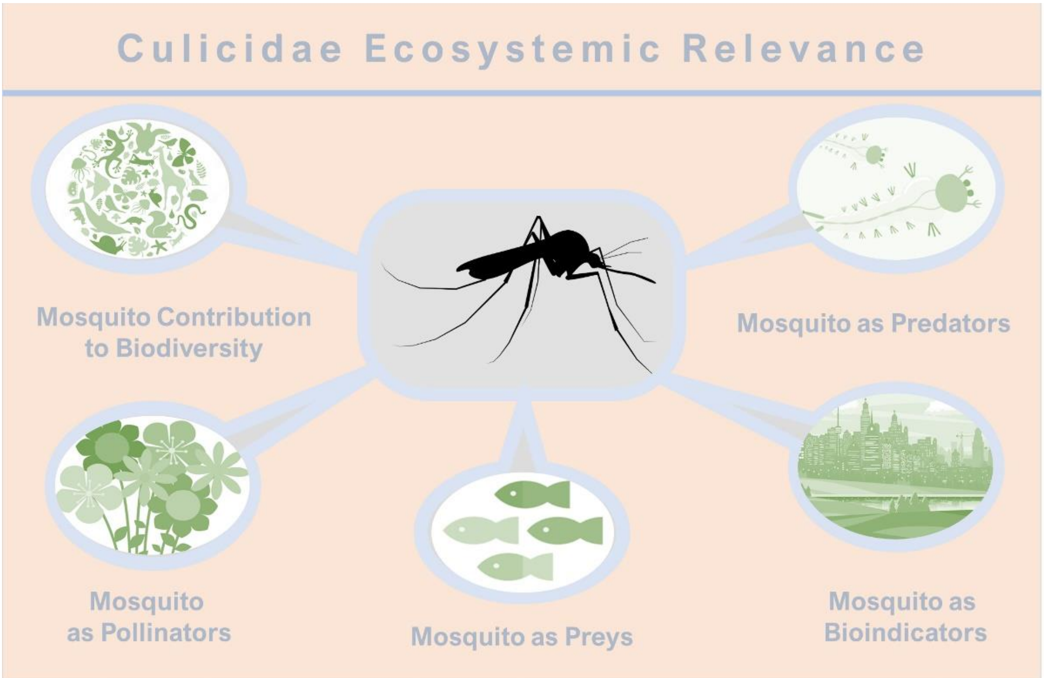

Figure 3. Ecological importance of mosquitoes (Culicidae) based on Bhattacharya *et al*., (2016).

In order to illustrate species of mosquitoes that hold significant ecosystemic importance, *Aedes communis*, *Culex pipiens*, *Culiseta annulata*, *Culex tarsalis*, *Anopheles annulipes*, and *Culiseta incidens* have been found participating in pollination systems. Mosquito larvae are an important food source for many vertebrates and invertebrates. One well-known predator of immature mosquitoes is the fish species *Gambusia affinis*, also called the "mosquito fish" (Bhattacharya *et al*., 2016; Kumawat *et al*., 2024).

Some genera of mosquitoes also have predator species, including *Toxorhynchites*, *Armigeres*, *Megarhinus*, *Eretmapodites*, *Lutzia*, and *Psorophora*. Among these, *Toxorhynchites* is the most widely recognized genus in both tropical and temperate regions (Bhattacharya *et al*., 2016; Kumawat *et al*., 2024). These insects are commonly known as "elephant mosquitoes" or "mosquito eaters," and the females do not feed on blood, instead mainly feeding on nectar sources. Due to the predatory habits of larvae, these organisms pose great potential for biological control mainly those of public health concern, such as larvae of *Aedes aegypti*, *Aedes albopictus*, and *Culex quinquefasciatus* (Sukupayo *et al*., 2024).

Mosquitoes can also be used as bioindicators since some species have specific requirements regarding the habitats and resources they exploit. In the southeastern Brazil, *Anopheles* (*Kerteszia*) *cruzii*, *Ochlerotatus* (*Ochlerotatus*) *scapularis*, *Haemagogus* spp., and some species of Mansoniini have been demonstrated as bioindicators to monitor the status of forest degradation (Dorvillé, 1996). As components of global biodiversity, these dipterans contribute around 3,618 known and valid species, listed on the "Mosquito Taxonomic Inventory" website. The family comprises two subfamilies, Culicinae and Anophelinae, and 113 genera (Harbach, 2024), and the current body of knowledge suggests that there are still numerous species awaiting discovery, particularly in tropical forests (Foster; Walker, 2019).

5. FIOCRUZ initiatives at the Brazilian Amazon

In the Brazilian Amazon, FIOCRUZ is engaged in various initiatives through several research groups and Laboratories of Entomology at Fiocruz Rondônia and Fiocruz Amazonas. These initiatives focus on studying the ecoepidemiology of vectors, pathogens, and hosts, with a specific emphasis on mosquitoes, sandflies, biting midges, black flies, triatomines, and ticks. The research groups are dedicated to the production, dissemination, and sharing of knowledge concerning: (i) biology of arthropod vectors and pathogens; (ii) and the molecular interactions between them; (iii) identification of pathogens using molecular techniques; (iv) taxonomic and molecular identification of vectors and parasites; (v) temporal and spatial distribution patterns; (vi) alternative tools for surveillance, prevention and vector control, with an emphasis on Citizen Surveillance; (vii) animal health and frontier surveillance. Furthermore, our mission encompasses the training of human resources and the strengthening of entomological research in the northern Brazilian Amazon (see Figure 4), ultimately striving to support a One Health approach.

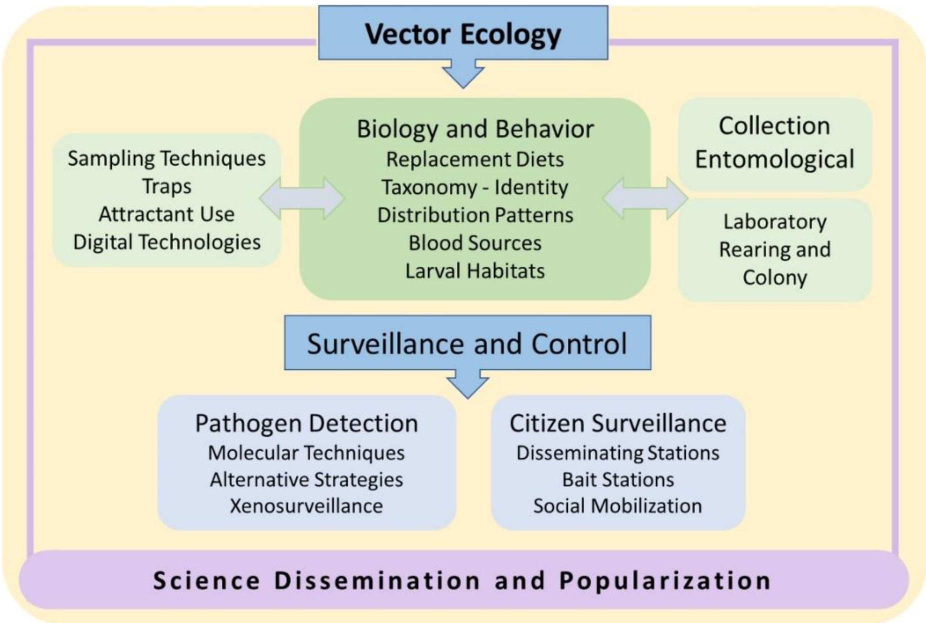

Figure 4. Schematic representation of the research focus and activities developed by the Entomology Teams at Fiocruz Rondônia and Fiocruz Amazonas, Brazil.

5. AI as a tool to research Medical Entomology and One Health studies

The Research Rabbit (https://www.researchrabbit.ai) is a free online platform to search and visualize literature reviews, create alerts for recent published papers, and collaborative works and used to conduct a mini review, based on thirty selected articles (Table 1) from those suggested in the PubMed and Semantic Scholar databases from 2000 to

2024, as a starting point for scientific literature research. “Medical Entomology” and “One Health” were the keywords applied in the search.

The thirty articles were published between 2000 and 2024 and represented the main subjects in the Medical Entomology and One Health research or reviews. Research Rabbit also found 2,193 similar articles during the AI screening. An imagery resource produces a network graphic, showing the connection between the 30 selected articles and a set of 50 similar articles (Figure 5).

Table 1. List of 30 articles manually selected (2000-2024) in Research Rabbit as a starting point for searching of similar literature on Medical Entomology and One Health.

Authors	Year	Keywords*	DOI
Islam *et al.*	2024	Ectoparasite, Helminth, protozoa, Commensal rodents, Qatar, One Health.	10.1016/j.onehlt.2024.100708
Laroche and Weeks	2023	Rickettsia, Bacteria, Vector-borne diseases, Zoonotic pathogens.	10.1111/mve.12646
de la Fuente *et al.*	2023	Tick, Tick-Borne Diseases, Environment, Surveillance, Epidemics, Vaccine.	10.3390/pathogens12101258
Cuthbert *et al.*	2023	Anthropogenic Activities, Biological Invasion, Biodiversity Homogenization, Climate Change, Global Trade, Public Health, Mosquitoes, Ticks.	10.1186/s13071-023-05887-x
de Freitas Milagres *et al.*	2023	One Health; Citizen Science; Environment; Epidemiology; Global Changes; Sand Flies.	10.1016/j.pt.2023.06.008
Soghigian *et al.*	2023	Phylogenomics, Host shift, Mosquitoes, Mammals.	10.1038/s41467-023-41764-y
Walsh *et al.*	2023	Japanese encephalitis, Vector-borne disease, Animal health, Wildlife-livestock interface, Arbovirus, Disease ecology, Landscape epidemiology.	10.1016/j.onehlt.2023.100566
Johnson *et al.*	2022	Tick, Surveillance, Pathogens, Citizen Science, Animal Health.	10.3390/ijerph19105833
Walsh *et al.*	2022a	Japanese Encephalitis, Infection Ecology, Landscape Epidemiology, Vector-Borne Disease, Wildlife-Livestock-Human Interface.	10.1111/tbed.14656
Walsh *et al.*	2022b	Zoonosis, vector-borne disease, landscape epidemiology, wildlife–livestock–human interface, Japanese encephalitis.	10.1093/ije/dyac050
Eassa and Abd El-Wahab	2022	Egypt, Preparedness, Vector-borne diseases.	10.4103/0972-9062.321759
Pham *et al.*	2022	Japanese Encephalitis Virus, Flavivirus, Laboratory Diagnosis, Serology, Zoonosis.	10.1016/j.pathol.2022.07.001
Kurucz *et al.*	2022	FTA™ cards, Kunjin virus, Flaviviruses, Mosquitoes, Saltwater Crocodile, Sentinel Chickens, Surveillance, Virus Isolation.	10.3390/v14061342
Yang *et al.*	2022	Vector competence, Immune response, *Aedes aegypti*, Ebinur Lake virus.	10.1371/journal.pntd.0010642
Lippi *et al.*	2021	Geospatial, Maps, Prevalence Species Distribution Modeling, Tick-Borne Diseases.	10.1093/jme/tjab086
Charles *et al.*	2021	Ticks, Tick-Borne Diseases, Central America, Caribbean, One Health.	10.3390/pathogens10101273
Islam *et al.*	2021	Rodents, Ectoparasites, Fleas, Lice, Mites, Ticks, Middle East, Systematic Review, Meta-Analysis.	10.3390/pathogens10020139
Olsthoorn *et al.*	2021	Lyme borreliosis, Anaplasmosis, Hard tick-borne relapsing fever, Tick-borne diseases, One Health, Cross-sectional study	10.1186/s13071-021-04946-5

Authors	Year	Keywords*	DOI
Stenseth, N. C.	2020	Human plague, Hosts, Vectors, Environment, Diagnostic tools, Surveillance, One Health.	10.1371/journal.pntd.0008251
Dente *et al.*	2020	Preparedness, Arboviruses, One Health, Multisectoral Risk Assessment.	10.1155/2020/4832360
Mushi, V.	2020	COVID-19, SARS-CoV-2, One health approach, Adoption and benefits.	10.1186/s41182-020-00257-0
Yang *et al.*	2022	Vector competence, Immune response, *Aedes aegypti*, Ebinur Lake virus.	10.1371/journal.pntd.0010642
Lippi *et al.*	2021	Geospatial, Maps, Prevalence Species Distribution Modeling, Tick-Borne Diseases.	10.1093/jme/tjab086
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Stenseth, N. C.	2020	Human plague, Hosts, Vectors, Environment, Diagnostic tools, Surveillance, One Health.	10.1371/journal.pntd.0008251
Dente *et al.*	2020	Preparedness, Arboviruses, One Health, Multisectoral Risk Assessment.	10.1155/2020/4832360
Mushi, V.	2020	COVID-19, SARS-CoV-2, One health approach, Adoption and benefits.	10.1186/s41182-020-00257-0
Jourdain *et al.*	2019	Entomological Surveillance, Mediterranean Area, Arboviruses, One Health strategy.	10.1371/journal.pntd.0007314
Laroche *et al.*	2017	Bedbugs, Fleas, Lice, Mosquitoes, Ticks.	10.1093/cid/cix463
Hansford *et al.*	2017	Brown dog tick, Importation, Pet travel, *Rhipicephalus sanguineus*, Risk, Ticks.	10.1136/vr.104061
Tulloch *et al.*	2017	Companion Animals, Great Britain, Electronic Health Records, One Health, Surveillance, Ticks.	10.1017/s0950268817000826
Escadafal *et al.*	2016	Medilabsecure, Laboratory Network, Euro-Mediterranean Area, One Health, Arboviruses, Zika Virus, *Aedes* Mosquito, Preparedness, Capacity-Building, Risk Assessment.	10.1186/s12889-016-3831-1

Van den Hurk *et al.*	2016	*Aedes albopictus*, Invasive mosquito, Arbovirus transmission, Australia, Ecology, Control.	10.1016/j.onehlt.2016.02.001
Braks *et al.*	2014	Disease Burden, Emerging Diseases, One Health, Surveillance, Threat, Vector-Borne Diseases.	10.3389/fpubh.2014.00280
Powell and Tabachnick	2013	*Aedes aegypti*, History Biogeography, Domestication, Arboviruses.	10.1590/0074-0276130395
Aultman *et al.*	2000	Arthropod Vectors, Experimental Design, Risk Management, Benefits, Field Research.	10.1126/science.288.5475.2321

* Keywords have been manually retrieved from article abstract or its title.

As seen in table 1, the articles deal predominantly with arthropods - ticks and mosquitoes mostly - and part of them describes the One Heath strategy for disease surveillance and control. Global and regional changes in the environment (deforestation, urbanization, for example) and in the climatic/weather components (temperature, rainfall, humidity, and seasonality), human and animal (wildlife, livestock, domestic) interactions, anthropogenic activities, biological invasions, and global trade emerge as the main key factors in studies on the transmission dynamics of arthropod-borne diseases (Table 1). Mosquito and tick populations naturally respond to seasonal cycles of temperature and rainfall, and their geographic distribution is linked to landscape characteristics, and such changes could culminate in its spatial redistribution and amplify the range of vector-borne diseases (Souza and Weaver 2024).

Some articles dealing with non-vector transmitted diseases were included as a starting point, as the One Health approach to other pathogens such as SARS-CoV-2, can be useful in finding solutions and overcoming the challenges posed by VBDs. In this way, the Research Rabbit tool proved to be effective in prospecting articles relevant to the review of the subject, but without limiting the scientific horizons.

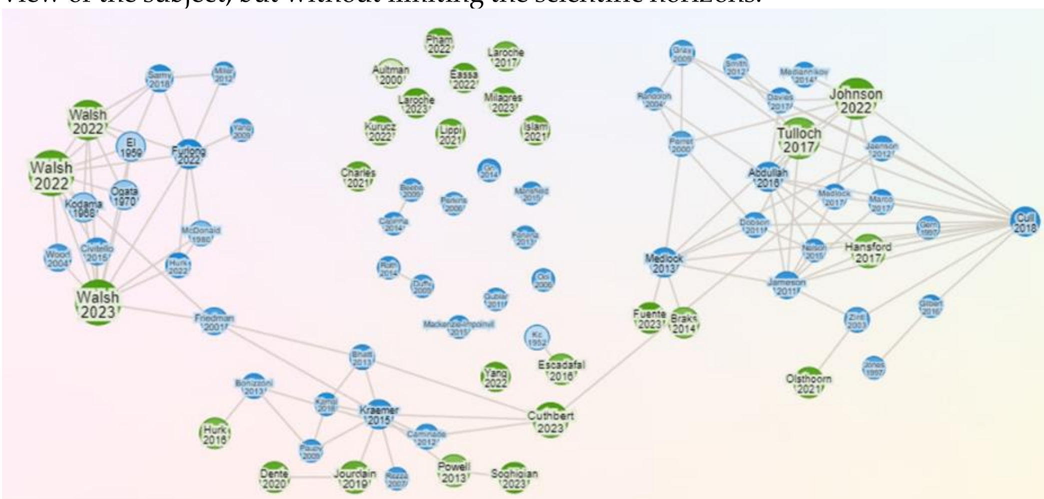

Figure 5. Network diagram showing the connection between the 30 selected articles and 50 similar articles screened by the Research Rabbit tool. Green circles depicted selected articles after keyword search, and blue circles represent the related similar articles. Inside the circles, the last name of main author and publication year. The larger the circle, the greater the citation number.

Therefore, the effects of deforestation and urbanization, of extreme temperature and rainfall indices on these organisms must be anticipated in the planning for preparedness, capacity-building, and risk assessment of disease transmission. When considering the One Health context, these studies converge (Figure 5) by proposing vector monitoring and control based on research networks, intersectoral integration, and citizen science, as well as, the need for integration in the animal health, environment, and pest management, community involvement, diffusion strategies, farming biosecurity, multiscale interventions, transdisciplinary efforts, and adequacy of policies.

Author Contributions: Conceptualization, G.R.J.; writing - original draft preparation, G.R.J., A.C.A.M., F.G.F.R., M.S.S., C.M.R.V., F.A.C.P. and J.F.M.; supervision and funding acquisition, G.R.J.; writing—review editing, G.R.J., A.C.A.M., F.G.F.R., M.S.S., C.M.R.V., F.A.C.P. and J.F.M. All authors have read and agreed to the published version of the manuscript.

Funding: This work was funded by the MCTI/CNPq/CAPES/FAPERO-INCT EpiAmO - National Institute of Science and Technology of Epidemiology of the Western Amazon, grant #465657/2014-1. This research was also funded by the Fiocruz Rondônia Research Excellence Program—PROEP (VPGDI-008-FIO-21-2-21) and Edital Capes 13/2020 – PDPG Amazônia Legal. ACAM and FGFR are PhD fellows from Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil - CAPES (grants #88887.624113/2021-00, #88887.61393/2021-00, Finance Code 001).

Data Availability: Data from mini-review will be made available on request.

Acknowledgements: We thank the anonymous reviewers for their valuable comments, which helped us to improve the manuscript.

Conflicts of interest: The authors declare that there is no conflict of interest.

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