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Review Article

What evidence exists on the application of biocultural approaches within infectious disease research from low- and middle-income countries? A scoping review of the peer-reviewed literature

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ABSTRACT

There is increasing research interest in bio or socio-cultural approaches in the context of infectious disease challenges, predicated on the notion that addressing health inequities in poor and marginalised populations requires nuanced, place-based understanding of the burden and impacts of health problems and associated factors determining health status and outcomes. Yet, to date, there is no systematic synthesis of how extant studies have used a biocultural approach to characterise social vulnerability in the context of zoonoses affecting humans, especially in low-and middle-income countries (LMICs). We conducted a scoping review of the scientific literature that have applied biocultural approaches within zoonoses research from LMICs. In total 43 studies were reviewed mostly from Africa (n = 24), followed by Asia (n = 12) and Latin America (n = 1). Ebola virus disease (n = 13) was the topmost disease of research interest, with reported studies mostly led by authors affiliated to Global North higher education institutions (particularly in the USA). Overall, the review showed that place-based differences and cultural systems are important determinants of vulnerability to many reported disease hazards across LMIC settings. Biocultural approaches are not holistically considered within zoonoses research and largely inclined towards the 'cultural' (n = 38) relative to the 'biological' (n = 5) aspect that influenced place-based resource use and health decision-making. The top three biocultural categories used were: livelihood practices, beliefs and knowledge systems. Twenty-five social vulnerability indicators (categorised into 6 components) were identified of which at-risk population demography (e.g. children, % of adults), education and socioeconomic status were commonly reported. Altogether, the review highlights the untapped potential of bio-culturally-informed research in advancing granular, place-based understanding of the complex socioecological, political and cultural factors that can lead to differences in disease vulnerabilities and capacities of different populations to adapt.

1. Introduction

The increasing global concern about emerging and endemic zoonotic diseases (caused by pathogens passed between animals and humans) has prompted calls for transdisciplinary place-based approaches to better understand and address the factors determining human disease vulnerabilities and outcomes, particularly in marginalised populations across different contexts (Asaaga et al., 2023; Diez Roux, 2022; Ventura-Garcia et al., 2013). This increasing attention is partly informed by the notion that social vulnerability – a disadvantage occasioned by poor social conditions that determine the degree to which people's health and livelihoods are at risk from a disease (Adongo et al., 2016; Akem & Pemunta, 2020; Ohemeng et al., 2017)– is highly context dependent. Developing evidence-informed and socially acceptable interventions

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requires an understanding of the context-specific ecological and social processes underpinning disease emergence, spread and impacts (Asaaga et al., 2024; Grace et al., 2023). Zoonotic disease or zoonoses are directly transmitted from animals to humans via various routes of transmission (e.g. air – influenza, saliva/bites – rabies; vectors – plague, Lyme disease). Transmission often involves complex communities of vector and animal hosts, whilst human behaviour and resource use within ecosystems alters exposure to infection (Lambin et al., 2010; Vanwambeke et al., 2024). For a pathogen to spill over from a wildlife or livestock reservoir host into humans, a hierarchical series of barriers must be overcome (Burthe et al., 2020; Plowright et al., 2017; Sokolow et al., 2019). Not only must pathogens evade immune system in animal hosts and humans and the barriers to infection inside arthropod vectors, but they must also be sufficiently prevalent within host and vector populations. More-over, transmission competent animal hosts (and arthropod vector) must be sufficiently abundant, widespread and overlap seasonally and geographically in the same habitats (Hartemink et al., 2015) and activities of people must overlap with some of these habitats (Burthe et al., 2020; Lambin et al., 2010; Plowright et al., 2017).

On top of the environmental context, there are interacting social, cultural and political factors that modulate disease vulnerabilities, impacts and the capacity of affected individuals and communities to respond and adapt (Bayeh et al., 2021; Buckee et al., 2021; DeSalle, 1999; Tosam et al., 2019). This is especially true for poor and marginalised populations in many LMICs who are often characterised as most 'vulnerable' to emerging zoonotic diseases due to their proximity to environmental sources of infections, high poverty levels, livelihood organisation and poor healthcare access (Asaaga et al., 2021, 2023; Jeleff et al., 2022; Tosam et al., 2019). Yet, conventional and often coarse-scale biomedical analyses (e.g. on disease diagnostics and control) (Asaaga et al., 2023; Livington et al., 2020; Yardley et al., 2015) have largely overlooked historical, social, political and cultural factors even though epidemiological analyses have long demonstrated the importance of integrating social and environment factors to understand patterns in infection and disease (Asaaga et al., 2023; Diez Roux, 2022; Farmer, 1996). Social epidemiology studies for example explore contextual factors that underlie disease processes and disparities in health outcomes, but have often tended to focus on quantified demographic characteristics (e.g. age, gender, education, poverty) rather than sociocultural (e.g. place attachment, place dependence, wellbeing), often to the detriment of nuanced understandings of the local cultural and political context and heterogeneity in social vulnerability (Asaaga et al., 2023; Friedler, 2021; Sterling et al., 2017). A good example of this is education which is often measured as the number of years of formal schooling, which often excludes informal or non-western modes of knowledge that contribute to individuals' and households' disease risk perceptions, health-seeking behaviours and decision-making (Mburu et al., 2021; Senahad et al., 2022). To help inform health policy planning and design of contextually appropriate interventions that bolster resilience of marginalised populations, the importance of moving beyond a reductionist understanding of disease transmission and outcomes to more complex models of disease systems that incorporate the social and cultural forces driving health inequalities is critical (Asaaga et al., 2023; Diez Roux, 2022; Ouafik et al., 2022).

Biocultural approaches – that integrate biological (i.e. focus on broader ecological dynamics that intersect with human ecology) and cultural (i.e. interpretation/explanations of illness) dimensions of susceptibility to disease (Alhaji et al., 2018; van Doren, 2023) – provide a theoretical lens for unpacking the complex relationships between high disease burdens and social, political and cultural factors and the differentiated adverse health and social outcomes (Dufour, 2006; Grace et al., 2023). Whereas the term 'biocultural' has been variously defined (Brewis et al., 2020), it is commonly accepted that it encompasses the diversity of knowledge systems, livelihood practices, cultural values and places that shape the myriad of ways people interact with their local environment and the associated outcomes (Friedler, 2021; Leatherman, 1996; Worthman & Costello, 2009). Biocultural approaches have roots in a rich and evolving literature involving various natural, health and social science disciplines from the 1970s (Brewis et al., 2020; McElroy, 1990). Biocultural approaches emphasise the importance of place-based practices and resource use, knowledge systems, cultural values, beliefs and worldviews of local communities in understanding the reciprocal relationships between people and their local environments (Comberti et al., 2015; Sterling et al., 2017). As such, they offer a good window of opportunity for developing a more sophisticated and integrated understanding of the cultural context of disease vulnerabilities and adaptation critical to guide the implementation of more appropriate and socially optimal interventions, particularly among underserved populations in LMICs.

Despite the potential value of biocultural approaches in highlighting the nuanced interplay of different place-based factors (e.g. ecological hazard, livelihood practices, religio-cultural beliefs and practices), accounting for differences in patterns of human health, livelihood and well-being vulnerabilities, to date, there is no systematic and coherent synthesis of the evidence-base showing how biocultural approaches have been applied in the context of zoonotic disease systems overall. Given the evolution in the focus and usage of biocultural approaches within zoonoses research in the last few decades, we assess and synthesise how biocultural approaches are conceptualised and applied in the context of zoonotic disease systems in LMIC geographies. We ask the overarching question "what is known about biocultural approaches as applied within zoonoses research from LMICs?" This is further distilled into three key sub-questions: (1) what is the existing body of zoonoses research that has used biocultural approaches? And how is it distributed over time and space? (2) what aspects/components of biocultural approaches are important for characterising social vulnerability and/or adaptation to zoonotic disease risks? And within zoonotic disease systems in LMICs? and (3) how does the evidence provided from the use of biocultural approaches support countries in designing locally appropriate and acceptable disease management interventions?

2. Materials and methods

We followed the PRISMA-SCR guidelines (Asaaga et al., 2021; Page et al., 2021) to retrieve data from Web of Science Core Collection, Scopus, PubMed, and Google Scholar databases. These bibliographic databases were selected because of their wide scope of scientific publications and multidisciplinary content, spanning the social sciences, health and biological sciences (Asaaga et al., 2024).

2.1. Search strategy

We collated peer-reviewed evidence to answer the review question "what is known about biocultural approaches as applied as applied within zoonoses research from LMICs?". Initial searches for published systematic reviews on the subject-matter were undertaken in Cochrane Database of Systematic Reviews (www.cochranelibrary.com) and Joana Briggs Institute (https://jbi.global/scoping-review), which yielded no relevant reviews. Afterwards, we developed an initial search string for Web of Science based on which iterations of search terms were developed for three other bibliographic databases (i.e. PubMed, Scopus and Google Scholar). Our search strategy comprised of two key stages – preliminary search and main search. The preliminary search was conducted in August 2022, and the goal was to refine the exemplar search strings developed to inform the main search (Asaaga et al., 2024). Following the preliminary search, we carried out the main search (from November 2022 to January 2023) to retrieve relevant studies in four electronic databases (Web of Science, PubMed, Scopus and Google Scholar) with the example search strings 'bio-cultural' or 'biocultural' or 'sociocultural' in title, keywords, abstract of publications. The search was conducted by author EST with guidance from author FAA. We search articles containing 'bio-cultural' or 'biocultural' or 'sociocultural'

or 'socio-cultural' and 'disease' or 'health' or 'zoonot*'or 'zoonos*' in their title, abstract or keywords (see Table S1). No timeline restriction was applied given the expected low number of citations relating to the subject matter. The search was restricted to scholarly literature published on the topic only in English language (due to language deficiency of the review team), which yielded 1984 records. We subsequently updated our search records in June 2024 (which culminated in 6 additional studies identified) prior to publication. Table 1 summarises the inclusion/exclusion criteria applied to screening relevant studies.

2.2. Review criteria and study selection

After the systematic search, different inclusion and exclusion criteria were used to select relevant studies for the review (Table 1). Only electronically available and full-text articles written in English were considered. Articles on syndemics, evolutionary medicine and psychology (based on title and abstract screening) were excluded. We also excluded commentaries, editorials, and letters due to their limited empirical engagement on application of biocultural approaches to zoonotic disease contexts. We retrieved the full-text of the remaining 77 articles. At the full-text review stage, we further excluded 26 articles as they did not focus on the geographical context of interest (i.e. LMICs). We define LMICs to constitute countries with a gross national income (GNI) per capita of $4515 or less following the World Bank LMICs classification (World Bank undated). We identified 51 studies that met our inclusion criteria, and these citations were imported to Sci-wheel online reference database (https://sciwheel.com/?lg) for the review (Table S2).

2.3. Data extraction and thematic analysis

We coded for six aspects: (i) study characteristics (study design, geographic location, study participants), (ii) biocultural and vulnerability conceptualisations, described below, (iii) study data collection (e.g. interviews, focus groups, surveys), (iv) disease context, (v) biocultural and vulnerability domains/indicators operationalised, and (vi) study relevance for disease management policy, either clearly stated or inferred. We surveyed 5 biocultural domains including livelihood practices, knowledge systems, governance/institutions, beliefs and worldviews and health-seeking behaviour and practices (see Section 3.2). For social vulnerability framing, we extracted and coded vulnerability elements/lenses (e.g. sociodemographic factors, healthcare access and infrastructure, livelihood and occupation) and indicators as reported in each study, categorised similar codes and finalised themes related to vulnerability to reported disease risks. The representativeness and accuracy of identified vulnerability components and indicators were confirmed based on authors' knowledge of commonly measured domains in the extant literature and team discussions (Asaaga et al., 2023; Dzingirai, Bukachi, et al., 2017).

Table 1
Inclusion and exclusion criteria.

Code	Inclusion	Definition
I1	Inclusion	Primarily focussed on the subject matter – biocultural studies that focus on zoonotic disease systems in low-and middle-income countries (LMICs).
I2	Inclusion	Peer-reviewed, i.e. published in scientific journals, conference or workshop proceeding
I3	Inclusion	Geographical focus on low-and middle-income countries
E1	Exclusion	Biocultural studies that do not focus on zoonotic disease systems in LMICs.
E2	Exclusion	Studies that apply syndemics, ecocultural theories and psychology without consideration of cultural factors that shape disease dynamics.
E3	Exclusion	Non-English studies.
E4	Exclusion	Not available as a full text.

2.4. Appraisal of methodology quality and risk of bias

A risk of bias assessment was not conducted which is in line with standard scoping review practice (Asaaga et al., 2024; Tricco et al., 2018).

2.5. Data synthesis

Using a thematic and content analysis approach (Braun & Clarke, 2006), we extracted information across three sub-research questions. For the first research question (what is the existing body of zoonoses research that has used biocultural approaches? and how is it distributed over time and space?), we extracted data regarding study design; location of study; sample size; age of the sample; marginalised populations (if any) studied (e.g., tribal groups, nomadic pastoralists); disease studied. For the second research question (what aspects of biocultural approaches are important for characterising vulnerability and/or adaptation to zoonotic disease risks? and within zoonotic disease systems in LMICs?), we extracted information related to how the terms 'biocultural' and/or 'vulnerability' is/are characterised, elements/dimensions of vulnerability defined and measured, adaptive strategies employed, and outcomes qualitatively measured as applicable. In addressing the third question (how does the evidence provided from the use of biocultural approaches support countries in designing locally appropriate and acceptable disease management interventions?) we extracted information on explicit mentions of evidence-based disease management (if any) and/or inferred policy relevant implications from each study recommendations/suggestions. We performed descriptive analyses (frequency and percentage) on reported diseases, biocultural and vulnerability elements and the bibliometric characterises (e.g. contributing journals, research institutions, and affiliating countries of authors).

3. Results

We present the main findings and synthesis of the biocultural studies focussing on zoonotic disease systems in LMICs. We first synthesise the literature landscape on the application of biocultural approaches, the geographical coverage and representation.

3.1. General overview of the literature landscape

The search strategy retrieved 2053 (Web of Science = 1861; PubMed = 41; Google Scholar = 82) peer-reviewed articles from three databases. After removing 176 duplicates, the titles and abstracts of the 1972 articles were screened. From the title and abstract screening, only 77 studies were included for full-text screening and 43 articles met the inclusion criteria (Fig. 1).

Of the 43 studies reviewed, most studies (n = 22) were published in the last 20 years (i.e. between 2002 and 2022) (Fig. 2A). These studies were mainly published in Social Science & Medicine (n = 22 studies) and Public Health (n = 19 studies) (Fig. 2B). Thirty-nine of the 43 included articles were open access. Approximately two-thirds of publications were empirical (n = 34 studies; Fig. 2C) and we observed that these were predominantly qualitative in design (i.e. reported on interviews, focus group discussions and textual analysis) (n = 21 studies; Fig. 2D). Fifteen studies were quantitative (mostly surveys) all of which related on knowledge, attitudes and practices (KAP) of surveyed populations. Only 7 (16 %) studies adopted a mix of qualitative and quantitative designs. Fig. 2 displays a summary characteristics of the included studies (see Fig. 3).

Regarding the geographical distribution of reviewed studies, most studies came from African countries (47.l%, n = 24 studies) and the remaining from Asia (n = 12) and Latin America (n = 1) respectively. Most studies focussed on disease contexts at the local (60 %, n = 26 studies) or national level (23 %, n = 10 studies), while 16 % (n = 7

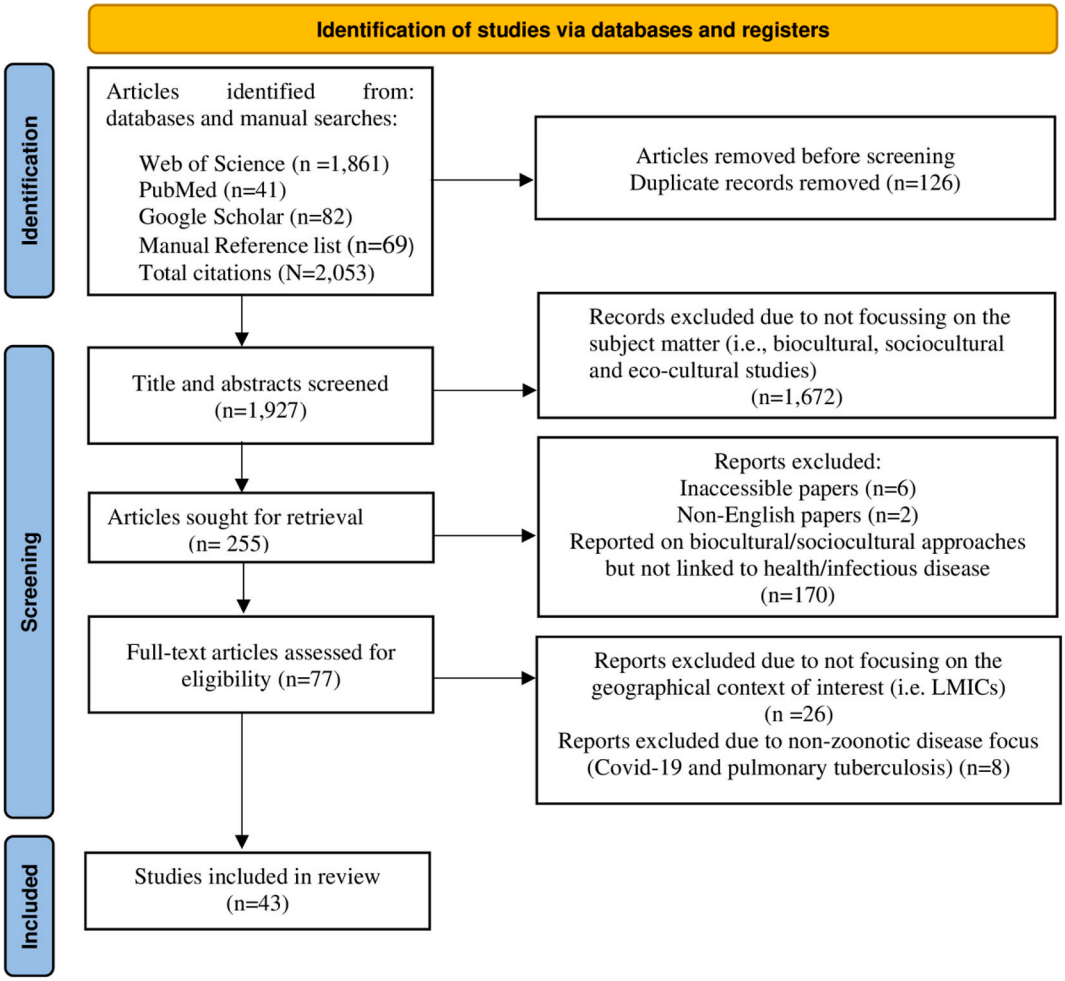

Fig. 1. Flowchart of the selection process of relevant articles. Adapted from the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) protocol by Page et al., 2021. Source: Page et al., 2021 (modified).

studies) were reported at the regional (multi-country) level. For the local or national classifications, reviewed studies were biased towards rural localities (n = 26). As Africa and Asia are characterised as hotspot regions for zoonotic disease spillover (Jones et al., 2008; Tynsong et al., 2020) this could have influenced the geographical variation in terms of reporting from biocultural studies. Over 25 of the reviewed studies had lead authors affiliated with global North higher education institutions (particularly in the USA relative to 18 papers from global South institutions).

3.1.1. *Classification of disease focus*

Of the 43 studies, 25 studies (58 %) reported on a specific pathogen or disease and the remaining 18 studies reported generally on "zoonoses" and/or "infectious diseases". Only 3 studies reported on multiple diseases (i.e. more than one disease condition) (Table 2). A word cloud analysis showed Ebola virus disease as the most frequent disease reported in the surveyed studies (n = 11 studies) followed by rabies (n = 4 studies) and lymphatic filariasis (n = 2 studies). Contrasting disease focus and publication trends showed most Ebola-related studies (n = 15 papers) were published within a 5-year period (i.e. 2014-2021) coincident with the widely reported Ebola epidemic in the West Africa subregion (in Guinea, Nigeria, Liberia and Sierra Leone) between 2014 and 2023. A summary of the topmost diseases reported in the surveyed studies is presented in Table 2.

Regarding taxonomic classification, an overwhelming majority of studies focussed on viral zoonoses (n = 22 studies) followed by bacterial (n = 2 studies) and protozoal zoonoses (n = 3 studies) respectively. Most studies focussed on viral and bacterial were from Africa (n = 24 studies) and Asia (n = 14 studies) (Fig. 4).

3.2. *What is the existing body of zoonoses research that has used biocultural approaches?*

To delineate the various ways biocultural theory has been interpreted and applied in the academic literature on zoonotic disease systems, we synthesis the evidence around three main themes: (1) 'biocultural' and 'vulnerability' definitions, (2) assessment of biocultural and social vulnerability elements utilised, and (3) scale and application of biocultural approaches. At the end of the results section, we bring together the findings of our review and set out an agenda for future research on the empirical application of biocultural frameworks in One Health research on zoonotic disease systems in LMICs.

3.2.1. *Deconstructing 'biocultural' and 'vulnerability' definitions*

Table 3 summarises the mapped studies and their application of biocultural approaches across the different LMIC geographies. Of the 43 studies reviewed, only 3 studies provided an explicit definition of biocultural, whereas the remaining 40 papers did not state a definition but can be implicitly inferred (Table 3). Goodman (Goodman and Leatherman, 1999) and Zuckerman & Martin (Zuckerman et al., 2016) for instance characterised biocultural approaches as integrative anthropological approaches that synthetically link biological and cultural processes with ecological conditions offering stimulating ways to think about the interconnectedness of social, biological and cultural systems.

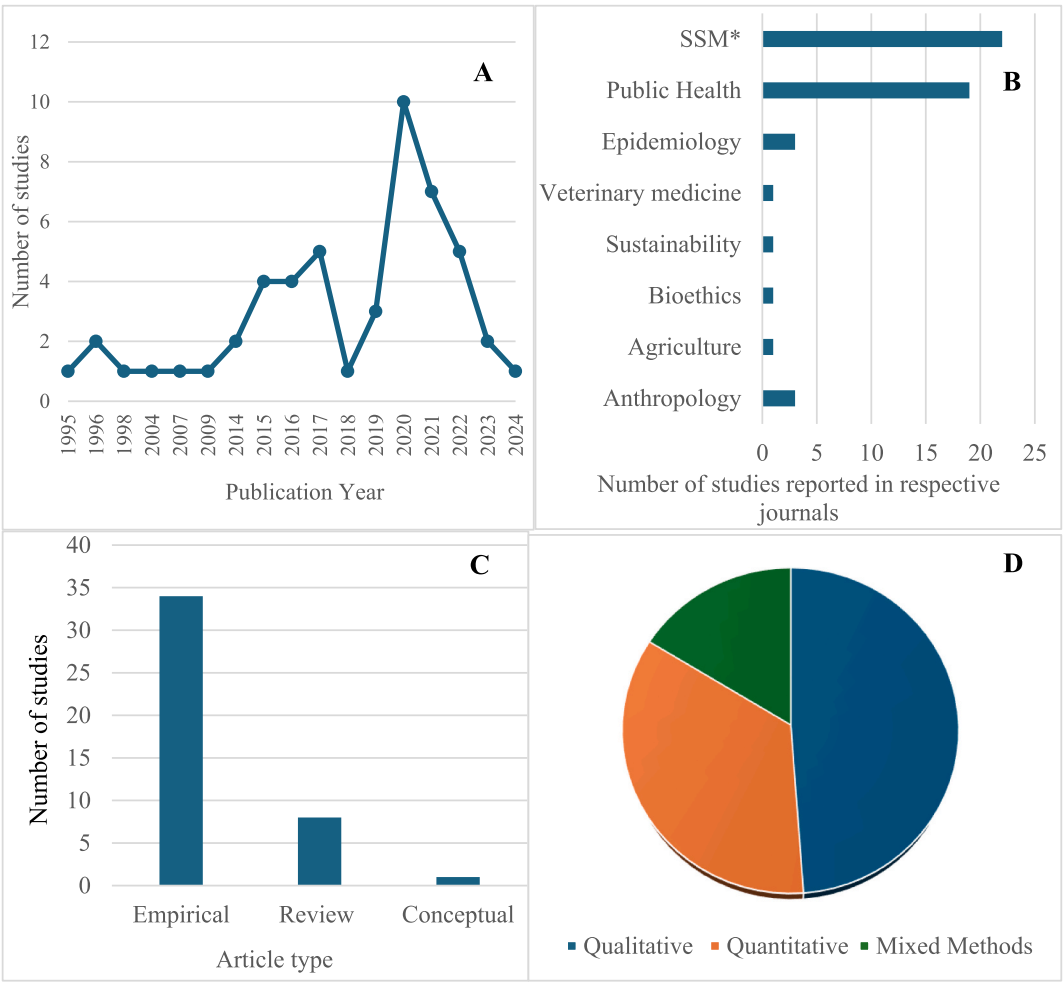

Fig. 2. Descriptive summary of included studies. (A) number of subject-relevant publications identified in the literature review between 1995 and 2024, with dotted line showing the upward trend over time. (B) Number of articles published per journal article. SSM* = Social Science & Medicine journal (C) categorisation of publications by study type. (D) Pie chart showing the number of publications by study design. Source: Authors'.

Hoke & Schell (Hoke & Schell, 2020) defined biocultural theory as using sociological constructs to understand disparities in health conditions. Worthman & Kohrt (Radhakrishna, 2023; Worthman & Kohrt, 2005) characterised biocultural research as the integration of biological and cultural perspectives to address the interplay of social, economic and political factors that shape the local experience of illness. A keyword analysis also showed rare explicit usage of the terms biocultural or sociocultural in the reviewed citations, although these have been applied as analytical/theoretical frameworks in several studies on zoonoses and infectious diseases broadly (Friedler, 2021; Rakotondrabe & Girard, 2021; van Doren, 2023; Zinsstag et al., 2009). Biocultural conceptualisation within the zoonoses research commonly highlighted the linkages between 'biological' and 'cultural' practices that shape human ecosystem use, exposure and health-seeking practices and outcomes. In this context, biocultural studies typically focussed on four (4) main domains: knowledge systems (n = 13 studies), worldviews and religio-cultural beliefs (n = 10 studies), livelihood practices (n = 16 studies) and health-seeking behaviours and practices (n = 4 studies) in characterising people-environment relationships in the context of disease exposure and vulnerability.

Concerning the conceptualisation of vulnerability, only a handful of studies explicitly defined it, all of which used Adger et al.'s (Adger, 2006) seminal publication and the Intergovernmental Panel on Climate Change (IPCC) definition (IPCC Intergovernmental Panel on Climate Change, 2001). Vulnerability in this context is understood as the "propensity or predisposition to be adversely affected" encompassing three elements of risk, hazard, sensitivity/susceptibility to harm and lack of capacity to cope and adapt. Social vulnerability thus encapsulates all social and livelihood practices, structures and web of relations and hierarchies that render individuals, groups or communities unable to respond or adapt to zoonotic disease risks and associated impacts (Li et al., 2023). In operationalising vulnerability, 32 studies broadly considered institutional (including governance and institutional arrangements) and structural (including sociodemographic factors, power relationships) factors modulating vulnerability and capacity of at-risk populations to respond and adapt to reported disease risks.

Deconstructing biocultural theory as applied in the reviewed studies revealed preference for wholly 'cultural' (n = 26 studies) as against the wholly 'biological' (e.g. disease aetiology, risk factors) dimension (n = 5 studies) modulating exposure to disease risks and associated vulnerabilities. The remaining papers reported on both the 'biological' and 'cultural' domains (n = 12 studies) of place-based factors affecting exposure to disease risks and the capacity to respond (Fig. 5). Delving into the 'cultural' domain, the related studies focussed on place (i.e. place attachment, sense of place, place identity/meaning), livelihood practices (linked to risk exposure), worldviews and beliefs (i.e. underlying values and religio-cultural practices that affect health and well-being priorities and actions) and governance and institutions (i.e. formal and informal rules and norms that influence health decision-making and livelihoods at the local level) as key determinants of disease vulnerability and health-seeking practices (see Table 4, Fig. 5). Conversely, reviewed studies reporting on the 'biological' strand commonly focussed

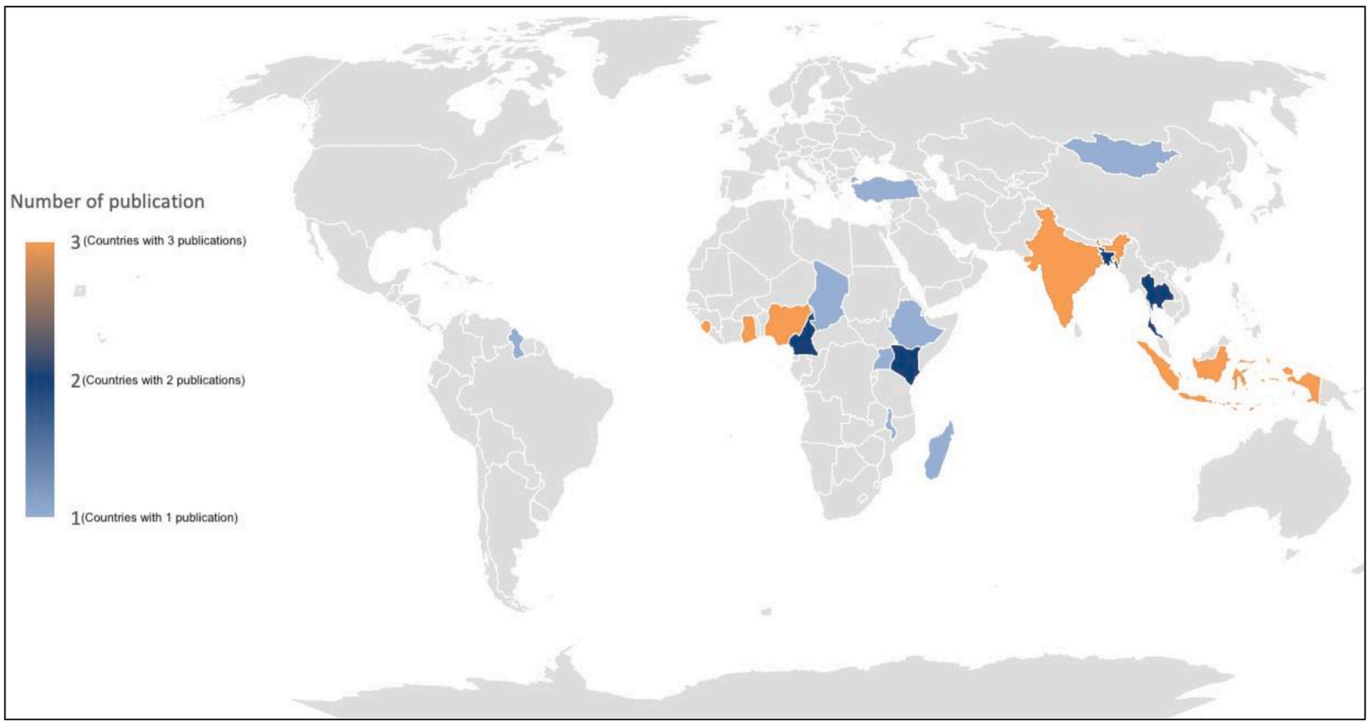

Fig. 3. Geographical distributions of publications based on data/analysis from LMIC contexts, 1995–2024. Different colours represent different numbers of papers in different geographic regions: Light blue = context with 1 relevant publication; Deep blue = contexts with 2 publications and Orange = contexts with 3 or more relevant publications reported. Source: Authors'.

Table 2
Common zoonotic diseases identified in the systematic review library, organised by the number of articles in which the disease was reported at least once, and by the related citations.

Disease category	Causative agent	Number of articles
Viral Zoonoses		
Ebola virus disease	Ebola virus	11
Rabies	Rabies virus	4
Nipah virus	Henipavirus nipahense	2
Avian Influenza	Avian influenza virus A (H5N1)	2
Kyasanur forest disease	Kyasanur Forest Disease Virus	1
Zika virus	Zika virus	1
Rift valley fever	Rift valley fever	1
Bacterial zoonoses		
Anthrax	Bacillus anthracis	1
Brucellosis	Brucella melitensis	1
Protozoal zoonoses		
Lymphatic filariasis	Lymphatic filariasis (elephantiasis)	2
Schistosomiasis	Schistosomiasis (Bilharzia)	1

on disease knowledge/awareness in terms of aetiology (e.g. causal factors and symptoms), risk factors (e.g. pathogen prevalence, hotspots), vulnerable populations (i.e. immunocompromised and other high-risk individuals– e.g. young children, the elderly and pregnant women) and disease-related impacts (e.g. cost of illness and treatment).

3.2.2. Biocultural categories and indicators used in the reviewed studies

Table 4 synthesises biocultural lenses and related indicators used within the reviewed studies to elucidate place-based factors that affect exposure to different disease hazards and adaptation. Indicators used in biocultural studies mainly captured the dynamic interplay of ecological factors and socio-cultural systems modulating people's vulnerability and/or capacity to respond to disease risks. For the governance/institutions aspect (commonly reported biocultural lens) for example, indicators often focussed on understanding how rules and norms governing land and forest access and their influence on exposure (who is at risk, when and where) to disease hazards or affected capacity of individuals and communities to respond/adapt (Table 4). Similarly, the livelihood associated indicators were commonly used as a function of how identified livelihood critical but 'risky' practices to the exposure and spread of diseases. A case in point is a case study of how local communities' traditional dietary preferences (i.e. pertaining to the consumption of rodents) amplified the risk of exposure to Ebola in West Africa (Akem & Pemunta, 2020; Zinsstag et al., 2009).

3.2.3. Summary methods used in biocultural studies within zoonoses research

Most studies adopted participatory methods (i.e. interviews (n = 17 studies) and focus groups (n = 11 studies) as the common techniques used to collate data from sampled populations. Most of the empirical studies were situated at the household (n = 12 studies) and community (n = 15 studies) levels respectively exemplifying the typical granularity and 'localness' often associated with biocultural research. A cross-tabulation of the study type and duration showed that all the empirical participatory studies were cross-sectional, largely conducted between 1 and 3 months. Only 2 empirical studies lasted more than 3 months and these studies employed 'group' participatory methods (mainly focus groups) reporting on risk perceptions, beliefs and cultural practices linked to health and health-seeking practices (21 %, n = 11 studies). A cross-section of the reviewed studies employed surveys primarily focussed on the exploration of actors' knowledge, attitudes and practice regarding disease exposure and adaptation and associated data collection was usually less than 3 months (25 %, n = 13 studies). The 8 mixed-methods studies mostly triangulated results from data collated through surveys and interviews.

3.2.4. Social vulnerability elements and indicators reported in the reviewed studies

Overall, 6 aspects and 25 relevant indicators affecting social vulnerability to reported diseases were identified from the reviewed studies. The most cited elements of social vulnerability to reported

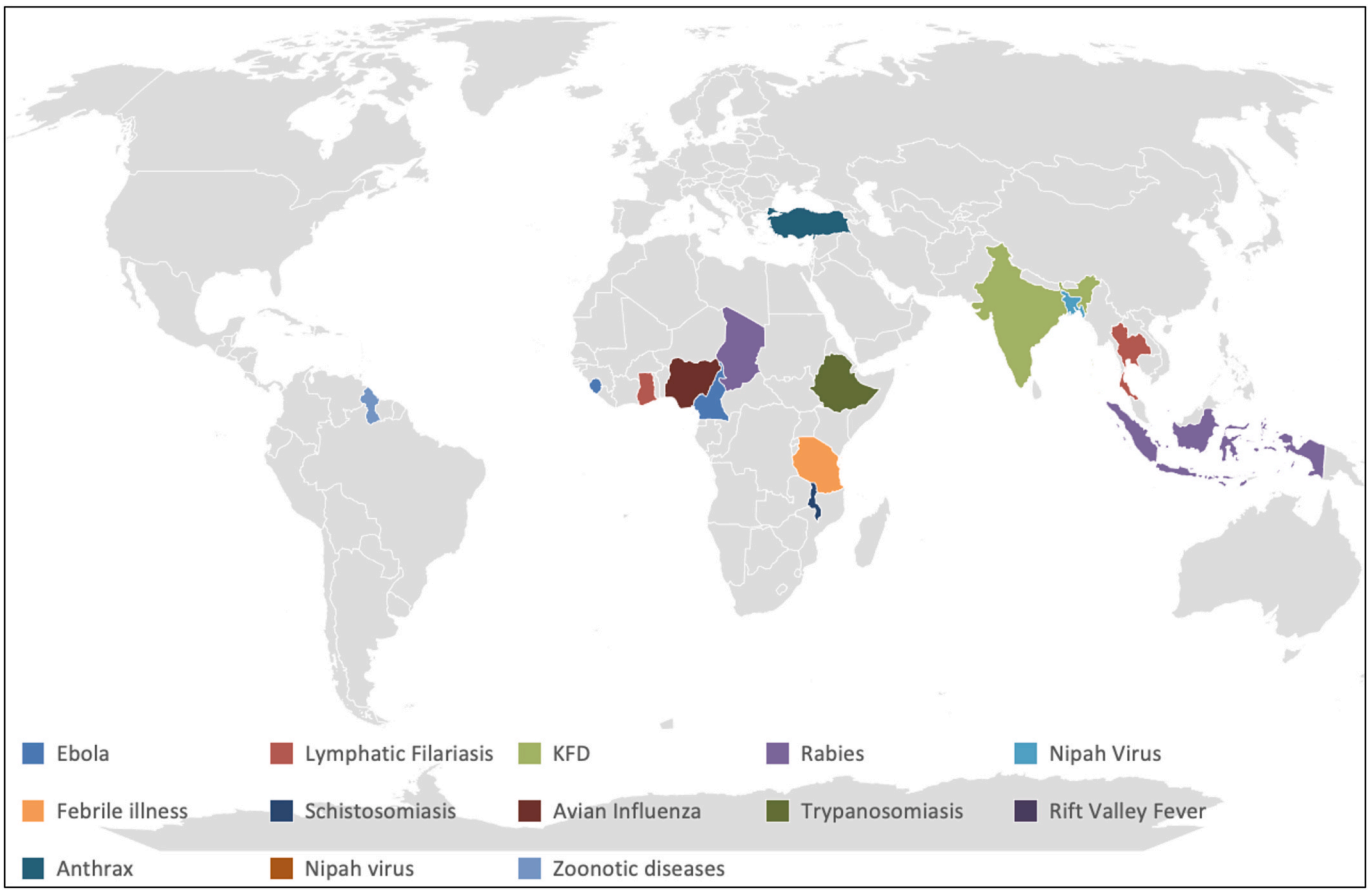

Fig. 4. Overview of disease distribution by region as reported in the surveyed literature. KFD= Kyasanur Forest Disease. Source data: Map base layer is from the OpenStreetMap. This dataset is available under a CCO 1.0 Universal (CC0 1.0) Public Domain Dedication license (https://creativecommons.org/publicdomain/zero/1.0/), and any copy of or work based on this dataset requires the following attribution: This dataset is based on the dataset produced by the OpenStreetMap Foundation (https://osmfoundation.org/). Source: Authors'.

Table 3
Exemplar definitions of biocultural in the reviewed studies.

Biocultural definitions used	Related citations
An integrative anthropological approach that synthetically links biological, demographic and cultural processes with ecological conditions offering stimulating ways to think about the interconnectedness of social, biological and cultural systems.	Goodman & Leatherman 1999; (Ulijaszek, 2013), Zuckerman & Martin, 2016
The integration of biological and cultural methods and perspectives to answer anthropological questions.	Sindhu Radhakrishna 2020
Biocultural research includes a range of methods and research areas from employing sociological constructs to understand disparities in health conditions and examining the impact of social practices on child nutrition and development to using human biology methods and biological theory to interpret social inequalities.	(Hruschka, Lende, & Worthman, 2005); Hoke & Schell, 2020
Addresses the interplay between social, economic and political forces that shape the local experience of illness	Worthman & Kohrt, 2005

disease risks were sociodemographic factors (n = 50 studies); place and culture (n = 48 studies); disease knowledge/awareness (n = 45 studies); health-seeking practices (n = 38 studies); livelihood and occupation (n = 33 studies); and healthcare access and infrastructure (n = 15 studies) (Figs. 6 and 7). Of the sociodemographic indicators identified, age, gender, education, poverty, affected social and occupational groups and mortality were the most common indicators, suggestive of a general predisposition towards easily quantifiable metrics/variables in social vulnerability assessments. Figs. 6 and 7 typify the respective elements and indicators of social vulnerability reported in the reviewed literature.

3.3. How does the biocultural research evidence support countries in designing locally appropriate and acceptable disease management interventions?

Although explicit mention of biocultural studies supporting evidence-based disease management policy and/or interventions were lacking, several policy relevant implications can be inferred as displayed in Table 5. The policy contributions of relevant biocultural literature can be synthesised into two inter-related themes for analytical clarity: (1) social differentiation in affected communities' vulnerability and adaptation to emerging disease risks, and (2) place-based determinants of community vulnerability and adaptation.

3.3.1. Social differentiation in disease vulnerability and adaptation

The review highlights marked social differentiation along occupational, ethnicity and cultural lines in terms of vulnerable populations to zoonotic disease outbreaks and impacts. Risk perceptions and understandings of vulnerability and/or capacity to implement adaptive actions are not only influenced by physical environmental features but also culturally constructed landscapes and the context of place (Table 5). This highlights the limits of conventional vulnerability assessments (often predicated on a narrow range of quantitative metrics) in

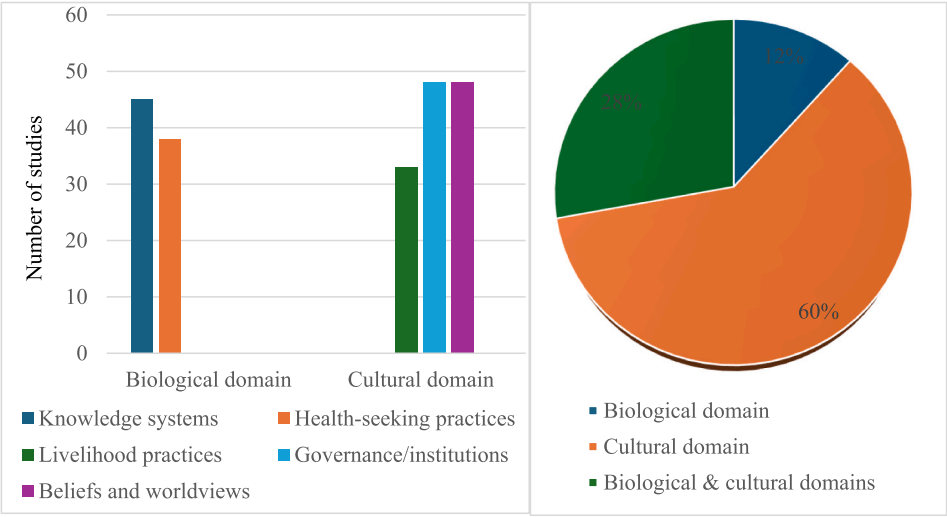

Fig. 5. Number of studies according to biocultural domains/lens investigated. Source: Authors'.

Table 4
Synthesis of biocultural lenses applied in the context of zoonotic disease threats.

Biocultural category	Description	No. of studies[a]	Biocultural indicators used within studies	Focal zoonoses reported in reviewed studies
Livelihood practices	Actions individuals and/or groups take to meet their needs and fulfil their wellbeing aspirations.	27	• Practices that lead to exposure and spread of disease both within housing and settlements and in the landscape. • Routes of exposure (hunting, preparation, and consumption of small mammals). • Traditional dietary preferences that could lead to exposure.	• Brucellosis • Ebola • Kyasanur Forest Disease • Nipah virus • Rabies
Knowledge systems	Different knowledge sources (scientific and indigenous/ traditional knowledge) that underpin individuals/groups interaction with local environments and their health decision-making.	39	• Risk perception, beliefs and practices that influence exposure and spread of disease. • Knowledge/awareness of infection pathways within local environments.	• Brucellosis • Lymphatic filariasis • Rabies • Ebola
Governance/ institutions	Formal and informal rules and norms that determine resource access (including access to health services), use and decision-making in traditional and socio-ecological landscapes.	42	• Differentiated exposure due to differential resource, information or health system access (who, when and where is at risk). • People-ecosystem interactions and exposure to disease-causing pathogen circulating in wildlife. • Structural factors (e.g. weak governance, resource-use restrictions) influencing exposure frequency and specific risk hotspots.	• Ebola • Ebola • Rift valley fever • Zika virus
Beliefs and worldviews	Values that shape individuals' and groups' perceptions of their relationships with their environment and decision-making with respect to livelihoods, health and wellbeing.	42	• Perceived reasons for disease outbreaks (e.g. supernatural causes – witchcraft, sorcery). • Cultural beliefs and culturally sanctioned practices that lead to exposure and spread of disease (e.g. burial practices/ceremonies, drinking water from dead bodies). • Stigma that could lead to mal-adaptative practices	• Ebola • Lymphatic filariasis • Rabies • Schistosomiasis • Nipah virus • Zika virus
Health-seeking behaviours and practices	Actions that individuals and/or groups take to try and meet their health needs and priorities.	32	• Perceptions, beliefs and experiences that influence access and utilisation of (formal and informal) health infrastructure and services. • Risk perception, beliefs and practices that influence health decision-making (e.g. traditional medicine patronage and usage for zoonotic illnesses).	• Brucellosis • Ebola • Kyasanur Forest Disease • Lymphatic filariasis • Rabies • Rift valley fever

[a] Most studies reported on more than one biocultural domain.

identifying most vulnerable groups and designing culturally appropriate targeting of interventions. For interventions to be context-appropriate and acceptable, heterogeneities in community vulnerability and agency (e.g. the trade-offs between critical livelihood activities and exposure to disease risks) should be duly recognised and accounted for in health policy planning and decision-making processes.

3.3.2. *Place-based determinants of community and vulnerability adaptation*

Given the importance of the concepts of rurality (i.e. whether or not people reside in rural locations) and everyday practices (linked to livelihoods and welfare) in shaping socio-spatial differences in disease exposure and vulnerability (Alhaji et al., 2018; Wolfe et al., 2004), it follows that predetermined, quantitative-derived variables and indicators of social vulnerability alone may be insufficient in capturing the contextual nuances about place-based relationships determining vulnerability and adaptation outcomes (Table 5). In this respect, questions of equity, social differentiation and legacies of land-use and management and how these interact to entrench health inequities and

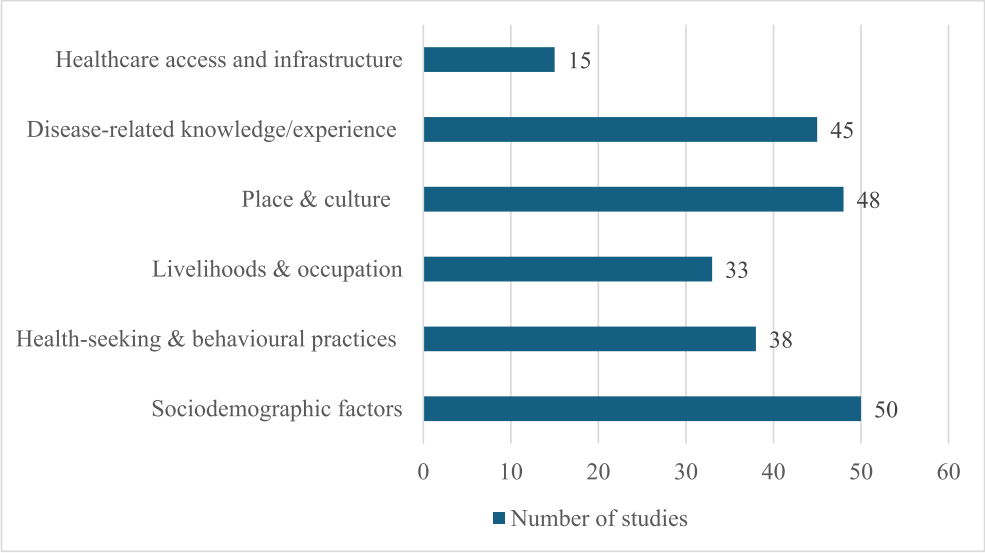

Fig. 6. Distribution of reviewed aspects of social vulnerability as reported in the biocultural literature. Source: Authors'.

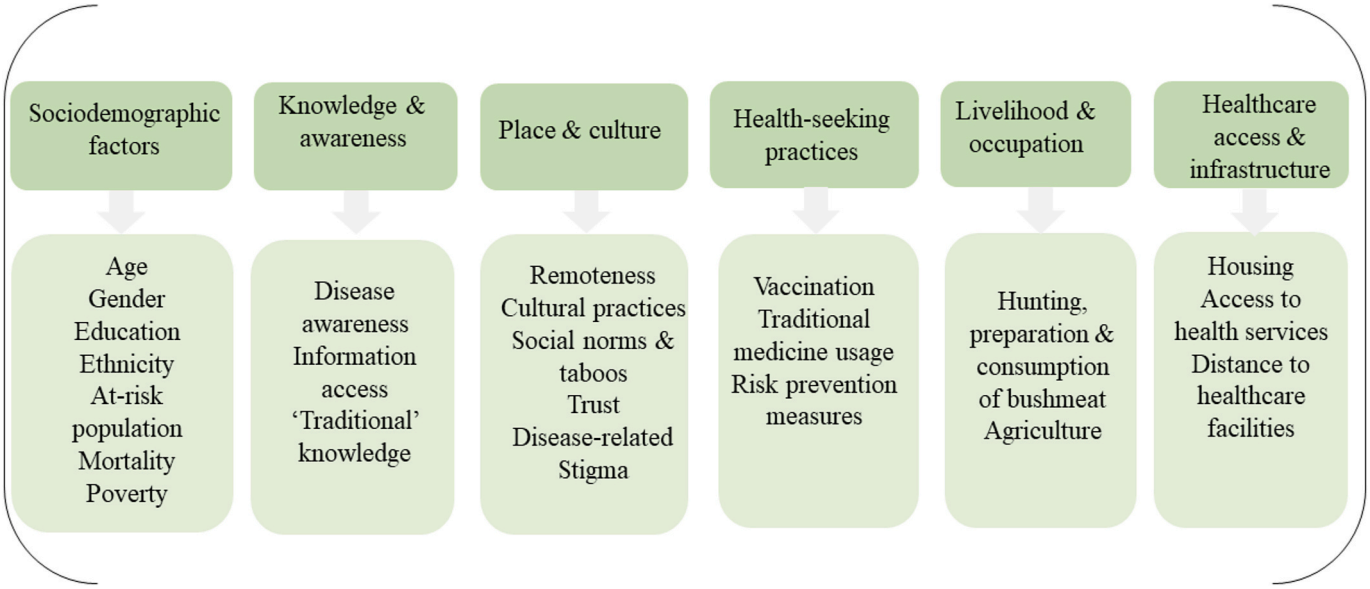

Fig. 7. Summary of social vulnerability variables and indicators as reported in the reviewed studies. Dark green = social vulnerability dimensions identified; and light green = specific indicators of social vulnerability reported in the reviewed studies. Source: Authors'.

vulnerabilities must be central in local disease policy and management considerations.

4. Discussion

There is a call for transdisciplinary research to better understand human disease spillover and place-based differences in vulnerabilities considering the vastly complex mix of environmental, social and cultural influences (Akem & Pemunta, 2020; Dillon & Ocho, 2024; Ohemeng et al., 2017). Socio-ecological factors that modulate exposure and vulnerability to disease hazards are complicated and often very system and location dependent. Currently, variation in biocultural or socio-cultural parameters are seldom considered in zoonoses research (Radhakrishna, 2023; Senahad et al., 2022). For effective and culturally acceptable interventions, several scholars (Dzingirai, Bett, et al., 2017; Widyastuti et al., 2015) have underscored the importance of multiple empirical case studies of factors affecting exposure, vulnerability and adaptive capacity at local scales. In this regard, biocultural approaches have the potential to highlight often overlooked 'place-based' and cultural dimensions critical to addressing seemingly intractable disease challenges and development of locally relevant interventions (Asaaga et al., 2021; Sterling et al., 2017). This is especially true in LMIC geographies (with disproportionately high burden of zoonotic diseases and health infrastructural disparities) where (top-down) interventions have at best been sub-optimal and at worst exacerbated pre-existing vulnerabilities of certain sub-populations (Asaaga et al., 2021, 2024). Thus, bio-culturally-informed research is needed to increase the resilience/adaptation of affected communities and mitigate the further exacerbation of the multi-factorial impacts of disease outbreaks and health inequality (Li et al., 2023).

Synthesising a body of 43 studies, the present review assessed the current state of the literature on the use of biocultural approaches in the context of zoonoses research from LMICs. While bio-culturally-informed zoonoses research has expanded since 2015, the field is still nascent

Table 5
Exemplar themes synthesised from biocultural constructs applied to zoonotic disease systems in the reviewed studies.

Biocultural domains	Definitions	Exemplar themes synthesised from reviewed studies	How insights can be used to improve disease management
Livelihood practices	Actions individuals and/or groups take to meet their needs and fulfil their wellbeing aspirations.	Homogenous characterisation of at-risk occupational groups not meaningful in prioritisation of interventions at the local level. Relative contribution of livelihood activities beneficial for community resilience and preservation of traditional and cultural values (e.g. traditional dietary preferences and ritual ceremonies).	Accounting for the relative contribution of critical but 'risky' livelihood activities (e.g. bushmeat hunting) to household/community welfare and preservation of customary practices necessary in developing locally relevant interventions as well as proper targeting of most vulnerable groups.
Knowledge systems	Different knowledge sources (scientific and indigenous/traditional knowledge) that underpin individuals/groups interaction with local environments and their health decision-making.	Nuanced knowledge and experiences of disease risk factors, symptoms and preventive measures can inform interventions to bolster long-term community resilience. Local communities can self-innovate solutions based on local traditional knowledge to place-based challenges. Acknowledging the validity of 'other' knowledge systems a critical setup for adaptation planning and decision-making.	Inclusion of local traditional knowledge in community-based interventions can increase local ownership and optimise uptake of risk prevention/adaptation measures. Better contextualisation of disease risk communication and general health information to needs of different at-risk groups.
Governance/institutions	Formal and informal rules and norms that determine resource access, use and decision-making in traditional cultural landscapes.	Top-down poorly targeted public health measures in country contexts can entrench or worsen pre-existing vulnerabilities Uneven healthcare access and information asymmetries can modulate vulnerability patterns and capacity to adapt to disease risks Gender inequities and power relations linked to resource-use and healthcare access shape individual and community agency to adapt.	Better understanding of place-based and socio-cultural heterogeneities relating to community vulnerability/resilience and access to local healthcare systems. Questions of equity, social differentiation and legacies of land-use and management must be central in local policy considerations.
Beliefs and worldviews	Values that shape individuals' and groups' perceptions of their relationships with their environment and decision-making with respect to livelihoods, health and wellbeing.	Traditional belief systems and religio-cultural practices contain taboos for livelihoods and health-seeking practices (e.g. disease associated stigma). Cultural beliefs and norms place different gendered expectations regarding livelihood and health decision-making. Shifting cultural beliefs and religious syncretism contributes to the erosion or increase in patronage of alternative types of medicine and/or interventions. Sense of place and place attachment critical determinants in overall social organisation and health decision-making.	Co-production and participatory based approaches needed to inform ethical and sensitive community engagement and implementation of interventions. Adaptation enhancing and undermining components situated in an intricate web of socio-cultural relations and systems – (e.g. patronage of traditional healers associated with primitive faith expressions).
Health-seeking behaviours and practices	Actions that individuals and/or groups take to try and meet their health needs and priorities.	Health-seeking behaviours and practices changing largely influenced by religio-cultural practices and contemporary trends.	Need for open-mindedness to other forms of medicine rather than prescriptive western medicine.

exemplified by marked variation in publications across LMIC geographies. Of the 43 studies identified, over two-thirds were from West Africa (i.e. Ghana, Nigeria Guinea and Sierra Leone) alone mostly in rural contexts. The predominance of rural locations in research efforts is somewhat telling of the notion that poor and rural populations in LMICs bear the disproportionate brunt of endemic and neglected zoonoses globally, due to their proximity to sources of disease risks and poor access to formal healthcare infrastructure (Asaaga et al., 2023; Grace et al., 2023). It could also be that the links between spillover and human activities in agricultural or agro-forest ecosystems are more pronounced/detectable in rural than urban environments. There is also a marked difference across the focal diseases studied. Most biocultural studies reported on epidemic or pandemic diseases like Ebola (suggestive of a research topic bias) probably because of the massive risk posed by human-to-human transmission and the risk of 'large-scale' pandemics in the event disease gets to highly populated areas. Nevertheless there are other diseases (e.g. Kyasanur Forest Disease, Nipah virus and Lymphatic Filariasis) whose burdens and impacts are under-estimated and important to understand too and where biocultural approaches are needed (Asaaga et al., 2021). As West Africa is the topmost regional foci for published biocultural research, the intense research focus on Ebola virus disease, a classical priority disease in the sub-region (whose origin dates back to 1976) is not surprising. Indeed, the establishment of the Ebola Response Anthropology Platform (https://www.ebola-anthropology.net/) focussed on the co-design of locally appropriate and socially informed outbreak response from the 2013–2015 Ebola outbreaks may have spurred the increased research interest in the application of

biocultural frameworks. The limited evidence may reflect limited resource investment and underscores the need for concerted research focus on such endemic and neglected disease threats to shore up the evidence base for improved interventions.

The review shows an uneven geographical representation in publication authorship in favour of North American institutions (particularly in the USA) and the need for targeted research partnering with institutes and stakeholders within LMIC regions. The fact that 42 % of the reviewed studies were funded by North America and Europe based funding agencies may have occasioned the bias in publication efforts. While acknowledging the subjectivities and/or contentions associated with the spatial characterisation of the knowledge production economy (Christopher et al., 2021; Tiwari et al., 2019), our findings highlight marked differences between institutions involved in biocultural-related research in the global North and the specific geographies commonly prioritised for the study of infectious diseases in the global South (Ryan et al., 2020, 2023). The relative dearth of contributions from the Global South could be further indicative of limited research collaborations and resources (e.g. research funding, institutional support etc.) to spur research efforts. With critical global health equity scholarship (Abimbola et al., 2024) cautioning against an overly 'external' gaze narrative, the review highlights the urgent need for a further 'decolonising' approach and deeper equitable engagement with 'in-country' research partners, including vulnerable communities, in researching and reporting about their contexts.

Overall, biocultural approaches and indicators used lacked uniformity across research contexts due to differences in conceptualisation across reviewed studies. Most studies focussed on the cultural aspects (e.g. cultural values, beliefs and practices) relative to the 'biological' strand (e.g. disease aetiology) that influences place-based resource-use and health decision-making. While the focus on place-based cultural factors is critical, there is a sense in which a grounded exploration of other equally important biological determinants (e.g. health statuses of sub-populations, ecological hazard) in biocultural studies could afford additional explanation to any observed spatial and in-group heterogeneities in vulnerability patterns. The lack of standard definitions of the 'biocultural' concept (which emanated from the field of anthropology), and related indicators (Radhakrishna, 2023; van Doren, 2023), may have driven the somewhat 'scholarly interest' around the cultural as opposed to the biological dimension. Besides, the fact that the zoonoses literature is replete with biomedical and/or eco-epidemiological studies may have spurred the increasing focus of bio-culturally-informed studies on exploring the immaterial 'cultural' and place-based factors that modulate disease risks and associated vulnerabilities to fill a critical knowledge gap. The above observation also finds expression in the widespread notion that biocultural approaches are witnessed as a "conceptual bridge" that can provide insights into human-nature interactions, particularly the cultural expressions of the interplay of power and inequality in shaping patterns of vulnerabilities and outcomes across different socio-spatial contexts (Hirons et al., 2018; Sterling et al., 2017). Indeed, delving into cultural dimension of the bio-cultural, beliefs and worldview, livelihood practices and knowledge systems were the common variables investigated aligning with prior studies highlighting the primacy of contextual factors in understanding the social and place-based differentiation associated with disease vulnerabilities (Asaaga et al., 2023; Dzingirai, Bukachi, et al., 2017).

As shown in this review, place-based differences and cultural systems are important determinants of social vulnerability and adaptation to zoonotic disease risks. Echoing the limits of wholly quantitatively derived variables and/or indicators of social vulnerability (e.g. age, gender and socioeconomic status), extant biocultural studies point to the importance of context-informed indicators/metrics to better capture often under-explored place-based relationships in better understanding the social and cultural drivers of disease risks. While it is difficult to compare studies given the marked differences in study designs, the limited quantitative and/or mixed methods studies (see section 3.1) somewhat attest to the frequent challenges biocultural researchers grapple with in terms of defining appropriate 'fine scale' quantitative metrics that better capture situated social and cultural determinants shaping disease dynamics at the local level. Indeed, the fact that such cultural attributes (which affect adaptive capacity (Johnson et al., 2022) are often intangible and challenging to measure (Paige et al., 2014; Shishehgar et al., 2017)), may have informed the inclination of extant studies towards qualitative techniques in characterising social and cultural factors affecting vulnerability and adaptive capacity. If this inference is true, then it is not surprising that vulnerability assessments often rely on easily quantifiable indicators in the attempt to capture social and cultural risk factors (at the local level) amenable to broad comparisons and generalisation across different contexts. Investigating granular, place-based disease dynamics calls for longitudinal ethnographically oriented studies due to the long-time lags in socio-political transitions, e.g. land use, affecting disease dynamics and vulnerability extant studies, as evidenced above, are often short term and cross-sectional perhaps reflective of the current research funding landscape. This highlights the need for greater inter/transdisciplinary exchange that could bridge 'modern' scientific and 'local' knowledge systems to interrogate differentiation in at-risk communities' vulnerabilities and promote adaptation to environmentally mediated risks especially in culturally pluralistic contexts.

4.1. Directions for future biocultural research on zoonotic disease systems in culturally pluralistic contexts

We argue that there is the pressing need to account for biocultural factors to better understand underlying inequities that entrench or exacerbate vulnerability to disease risks across different socio-ecological contexts. Future biocultural studies could expand research focus on social vulnerability assessment (covering a multiplex of qualitative and quantitative indicators – e.g. gender, occupation, ethnicity, nature-dependent livelihood) across different local and/or regional contexts to provide nuanced and yet generalisable insights on the distribution and patterning of disease risks and associated vulnerabilities. Other than blanket description of 'vulnerable or at-risk populations', our review highlights the importance of specifying and expanding the cohort of demographic characteristics of sampled groups to capture meaningful variability and heterogeneity that may exist within and across sub-populations. This approach may help better inform the contextualisation and targeting of local disease management policy in many LMIC geographies which is often broad-based or generic with the risk of underrepresentation or missing altogether some key high-risk groups – e.g. nomadic pastoralists, hard-to-reach forest dwelling groups. In the case of Kyasanur forest disease (KFD) in south India for example, there is an overemphasis on forest-based communities and their nature-dependent livelihoods as driving exposure to KFD-associated risks resulting in blunt interventions such as forest-bans that can be harmful for human livelihoods and wellbeing (Asaaga et al., 2021, 2023). Yet burgeoning evidence on the social and ecological risk factors points to a broader risk across forest and non-forest land-based activities and land use legacies modulating risk and differentiated vulnerability in traditional cultural landscapes (Asaaga et al., 2023; Friedler, 2021; Radhakrishna, 2023; Vanwambeke et al., 2024). The evidence base entails an underrepresentation of key at-risk social groups (including 'risk indifferent' individuals who do not engage in forest-based activities and perceive the risk of KFD exposure to be restricted to forests) within an intervention policy (Asaaga et al., 2023).

Gendered differentiation in resource-use, healthcare access and decision-making was conspicuously missing in the reviewed studies despite the primacy of place-based vulnerability assessments. Perhaps the sparseness of extant datasets covering nuanced gendered categories/demographics (e.g. single-headed vs female-headed households) could have occasioned the seeming lack of attention to gendered dynamics in the reviewed studies. The limited evidence on gendered dynamics can be

problematic as it risks masking or overlooking otherwise 'invisible' challenges and/or entrenching pre-existing vulnerabilities experienced by certain sub-groups (e.g. young women, single parent or female-headed households). It is imperative for future studies to carefully consider and reflect on data sources to better capture nuanced information (beyond binary conception of gender) on 'other' minorities. Likewise, the homogenous labelling of 'smallholders' (without disaggregation into functionally distinct sub-classes – e.g. landholding versus landless groups) limits the scope of collating information on differential exposure patterns and temporalities. Moreover, the over-representation of cross-sectional studies though informative (in terms of affording snapshot insights), is broadly limiting in informing long-term programmatic interventions (requiring longitudinal studies that account for changes in disease-related experiences and impacts overtime) at the local level. Furthermore, the dearth of cross-context studies limits the scope of generalisability and 'extrapolated' understanding of disease dynamics and vulnerability patterns at both the micro and meso scales for wider health policy and intervention planning. This latter observation derives from the notion that while disease risks are locally manifested their associated impacts are spatially far-reaching and differentially experienced (Asaaga et al., 2023; Zuckerman et al., 2016). In any event, such multi-case study investigations could provide the evidence needed to operationalise and evaluate different health/disease intervention options in terms of their relative social acceptance, cost effectiveness and outcomes across different socio-spatial contexts. As evidenced above, the limited foci in the sampled populations studies (i.e. mostly rural sub-populations) across the different LMIC contexts is suggestive of the need to expand the cohort of 'at-risk' demographic groups studied to better understand the heterogeneities that might exist in disease experiences, vulnerabilities and agency within a biocultural conceptualisation. The above observation also finds expression in the observation that there is often marked differentiation in at-risk sub--populations and the associated social determinants of health and experiences (Dzingirai, Bukachi, et al., 2017; Gyapong et al., 1996; Oduyemi et al., 2016). Future biocultural research in this direction should reflect this variability and be more inclusive, drawing samples and co-developing research priorities with other 'hard-to reach' or 'marginalised' populations that are traditionally under or not represented in extant zoonoses scholarship. Likewise, the unique everyday activities and experiences of indigenous or marginalised populations (e.g. nomadic pastoralists) were largely absent from the studies included in this review, which highlights an important avenue for future research considering these populations have been identified as disproportionately affected/impacted by zoonotic diseases and their multi-factorial impacts (Barnes et al., 2020; Kusumaningrum et al., 2022). In any event, the traditional livelihood patterns, social organisation and health-seeking practices of these cohorts of at-risk populations underscores the importance of spatial, place-based understanding of the social epidemiology and contours of vulnerability to emerging and endemic disease risks across different socio-ecological, economic and political contexts.

4.2. Study limitations

The study is not without limitations. First, we acknowledge that biocultural studies published before the 1980s are less likely to be available in electronic format and we may have missed this in the scope of the literature reviewed. Second, our review included articles written only in English and grey literature was not searched which meant relevant non-English peer-reviewed and non-scientific papers were not covered. Third, normative descriptions of study methods presented limited detail on how methodological issues were addressed. For instance, limited discussion regarding the reflectivity and positionality of researchers (i.e. background and contextual experience) affected the issues examined, including participants' recruitment methodology, findings and conclusions. Finally, the quality of the studies was not assessed given the focus on mapping the biocultural evidence base. Nevertheless, a form of quality control was the delimitation of the review scope to only include peer-reviewed publications.

5. Conclusion

This review provides a synthesis of the evidence base on the application of biocultural approaches to zoonotic disease systems in the LMIC context. The review underscores the relevance of bio-culturally informed research in yielding nuanced understanding of place-based differences in the multi-factorial disease impacts and associated vulnerabilities and accounting for these in local disease management policy across different socio-spatial and political contexts. There is strong evidence across studied LMIC contexts that culturally rooted beliefs and sanctioned practices impact health decision-making and that at-risk sub-populations have heterogenous agency to adapt to disease challenges and capitalise on available health system interventions. The review also identified potential avenues of future bioculturally-informed research on socio-spatial disease risks and associated vulnerabilities in culturally pluralistic LMIC geographies. It further emphasises the need for more longitudinal 'cross-cultural' studies on place-based drivers of community vulnerability and/or resilience to emerging disease risks for contextually and evidence informed interventions. Although the strength of biocultural studies resides in their granularity and contextuality, there is also a sense in which some degree of methodological 'standardisation' particularly in deriving bio-culturally-derived indicators for quantitative-oriented vulnerability assessments (often with large sample sizes) could afford broad comparative insights across socio-spatial contexts. That said, we acknowledge that the proposed methodological 'standardisation' and the elucidation of context-specific factors modulating disease risk and prevalence are somewhat in tension with one another. Usage of mixed methods approaches (that leverage qualitative and quantitative data collection methods) could offer some analytical latitude in the derivation of semi-quantitative indictors/metrics (amenable to broad scale comparisons) and, at the same time, exploration of context-specific drivers thereby addressing any potential tensions. The review adds to our theoretical and practical understanding of potential and limits of the application of biocultural approaches to health research, particularly zoonotic disease systems across different LMIC contexts.

CRediT authorship contribution statement

Emmanuel S. Tomude: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Bethan V. Purse:** Writing – review & editing, Project administration, Funding acquisition, Conceptualization. **Sarah J. Burthe:** Writing – review & editing, Funding acquisition, Conceptualization. **Juliette C. Young:** Writing – review & editing, Funding acquisition, Conceptualization. **Festus A. Asaaga:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Data availability

The datasets used and/or analysed for the study are included as metadata in the supplementary information section.

Declaration of generative AI and AI-assisted technologies

Authors declare that no generative AI or AI-assisted technologies were used in any part of the manuscript.

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Declaration of competing interest

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

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssaho.2025.101709.

Abbreviations

LMICs	Low-and Middle-Income countries
KFD	Kyasanur forest disease
USA	United States of America
SSA	Sub-Saharan Africa
SSM	Social Science & Medicine

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