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Expert insights into the health and societal risks of a potential AMOC collapse in Europe: Focus on Germany

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Abstract

This qualitative study examines the potential health and societal impacts of an Atlantic Meridional Overturning Circulation (AMOC) collapse on European populations, with a particular focus on Germany. Through semi-structured interviews with 17 transdisciplinary experts, the research investigates how a weakening AMOC could amplify existing health risks, create new challenges and strain healthcare systems. Findings suggest that a significant slowdown of the AMOC would potentially intensify climate-related health effects, increasing pressures on emergency medicine and crisis response. Food security could also be threatened due to disruptions in agriculture and global supply chains. Beyond physical health risks, psychosocial impacts, such as trauma, stress and uncertainty, are likely to rise. The study highlights how overlapping crises could undermine social cohesion, disproportionately affect young people and foster fear-driven, anti-democratic movements, ultimately weakening collective climate action. An AMOC collapse may further challenge infrastructure resilience, including energy grids and transportation networks, as extreme weather events become more frequent and severe. The research evaluates vulnerabilities within Germany's healthcare system and its readiness to respond to these emerging risks, focusing on healthcare system resilience, infrastructure adaptation and safeguarding democratic institutions amid growing polycrises. Based on expert insights, the study proposes 15 recommendations spanning healthcare, psychosocial wellbeing, crisis prevention and climate action. Overall, the findings provide guidance for mitigating health risks and protecting affected populations while emphasising the urgent need for further research on the likelihood, timing and global consequences of an AMOC collapse, including health risks, as well as urgent climate action to safeguard the health and wellbeing of current and future generations.

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Introduction

The Atlantic Meridional Overturning Circulation (AMOC) is a critical system of ocean currents that plays a vital role in regulating Earth's climate. It transports warm water from the tropics northward in the Atlantic Ocean and cooler water southward at deeper levels [1]. This circulation helps distribute heat globally, about 50 times the total energy consumption of all humanity, and influences weather patterns across the Northern Hemisphere [1]. To put the AMOC into perspective: "It moves nearly 20 million cubic metres of water per second, almost a hundred times the Amazon flow", says Stefan Rahmstorf, a leading oceanographer and climatologist [2]. The AMOC operates through a complex mechanism. In simple terms, warm, less dense water moves northward along the ocean's surface, while colder, denser water sinks and flows southward at deeper levels. This sinking process is driven by the cooling and increased salinity of water in the North Atlantic, which makes it denser. As the cold, dense water flows southward, it gradually warms, becomes less dense and rises to the surface, completing the cycle. This system functions like a conveyor belt, circulating water, heat and nutrients across the Atlantic Ocean (Fig 1).

Recent studies have raised concerns about the potential collapse of the AMOC due to climate change [3–7]. The influx of freshwater from melting ice sheets and increased rainfall caused by global warming disrupts the delicate balance of temperature and salinity that drives the AMOC. This disruption could lead to a tipping point where the circulation system breaks down. While there is scientific consensus that the AMOC is weakening, the timeline and likelihood of reaching its tipping point remain uncertain. The Intergovernmental Panel on Climate Change (IPCC) states: "There is medium confidence that the [AMOC] will not collapse abruptly before 2100, but if it were to occur, it would very likely cause abrupt shifts in regional weather patterns and large impacts on ecosystems and human activities" [8].

However, there is growing evidence that models consistently overestimate the stability of the AMOC. Earth system data show a significant water cooling in the subpolar North Atlantic since the mid-20th century, signalling a 15% weakening of the AMOC to date [9]. Recent advances in climate modelling provide growing evidence that the AMOC may approach a tipping point within this century, with potentially severe consequences for Europe and beyond. A physics-based indicator developed from surface buoyancy fluxes over the North Atlantic has been shown to reliably signal the onset of an AMOC collapse across multiple models and forcing scenarios [3]. Applying this method, simulations suggest a possible collapse by 2063 under an intermediate emission scenario (SSP2-4.5) or by 2055 under a high-emission scenario (SSP5-8.5) [3].

Complementary, long-term projections from coupled model intercomparison project 6 (CMIP6) extending to 2300–2500 reveal that, under high – and in some cases even under intermediate or low – emission scenarios, the AMOC weakens drastically [4]. This would shut down deep-water formation in the North Atlantic and sharply reduce heat transport [4]. These processes are preceded by a mid-21st century collapse of deep convection in the Labrador, Irminger and Nordic Seas, driven by surface warming and freshening [4]. Consequences include subpolar North Atlantic and Northwest European cooling, a loss of up to 80–100% of regional ocean-atmosphere

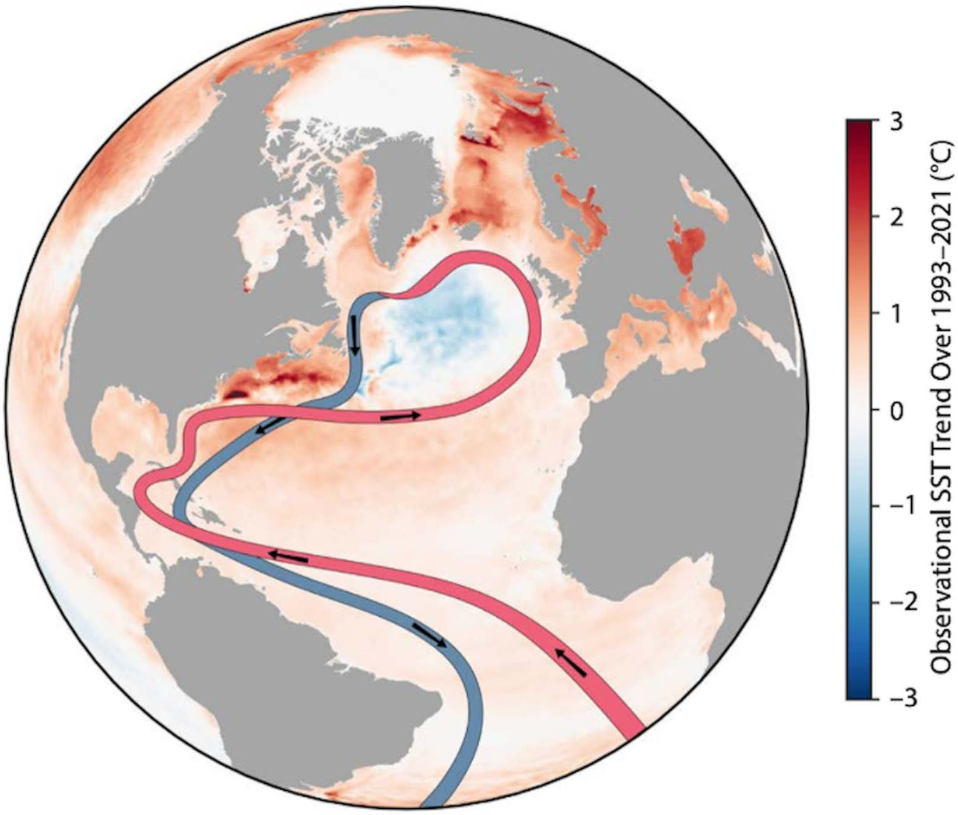

Fig 1. Schematic illustration of the AMOC. Highly simplified illustration of the AMOC against a backdrop of the sea surface temperature trend since 1993 from the Copernicus Climate Change Service. Republished under a CC BY license, with permission from Ruijian Gou.

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heat exchange and severe societal disruptions [4]. Under high-emission scenarios, 70% of model simulations result in an AMOC collapse, while intermediate-emission scenarios produce collapse in 37% of runs [4]. Even under the optimistic scenario of low emissions, 25% of models still show a collapse [4]. These findings suggest that characterising an AMOC collapse as a low-likelihood event, as has often been done over past years and decades, is misleading.

In October 2024, 44 prominent climate researchers from 15 countries issued an open letter to the Nordic Council of Ministers, warning of the potential collapse of the AMOC and calling for urgent action from policymakers [10]. Such an intervention is rather uncommon, as scientists rarely engage so directly in policymaking or issue statements of such unequivocal urgency. Surpassing 1.5 °C of global warming risks triggering multiple climate tipping elements, leading to irreversible changes in Earth systems [11]. Researchers found indications that many interactions between tipping elements in the climate system are destabilising [12]. Once triggered, these processes could amplify global warming through feedback loops, intensifying the climate crisis and posing severe risks to biodiversity, human livelihoods and the stability of the planet's climate (Fig 2).

Earth system implications of an AMOC collapse

The Global Tipping Points Report 2023 synthesises key biophysical and societal impacts following an AMOC slowdown [13] (Fig 3). A collapse of the AMOC would disrupt warm water transport from the tropics to the North Atlantic, causing significant cooling in the Northern Hemisphere and intensified warming in the Southern Hemisphere [13]. This imbalance

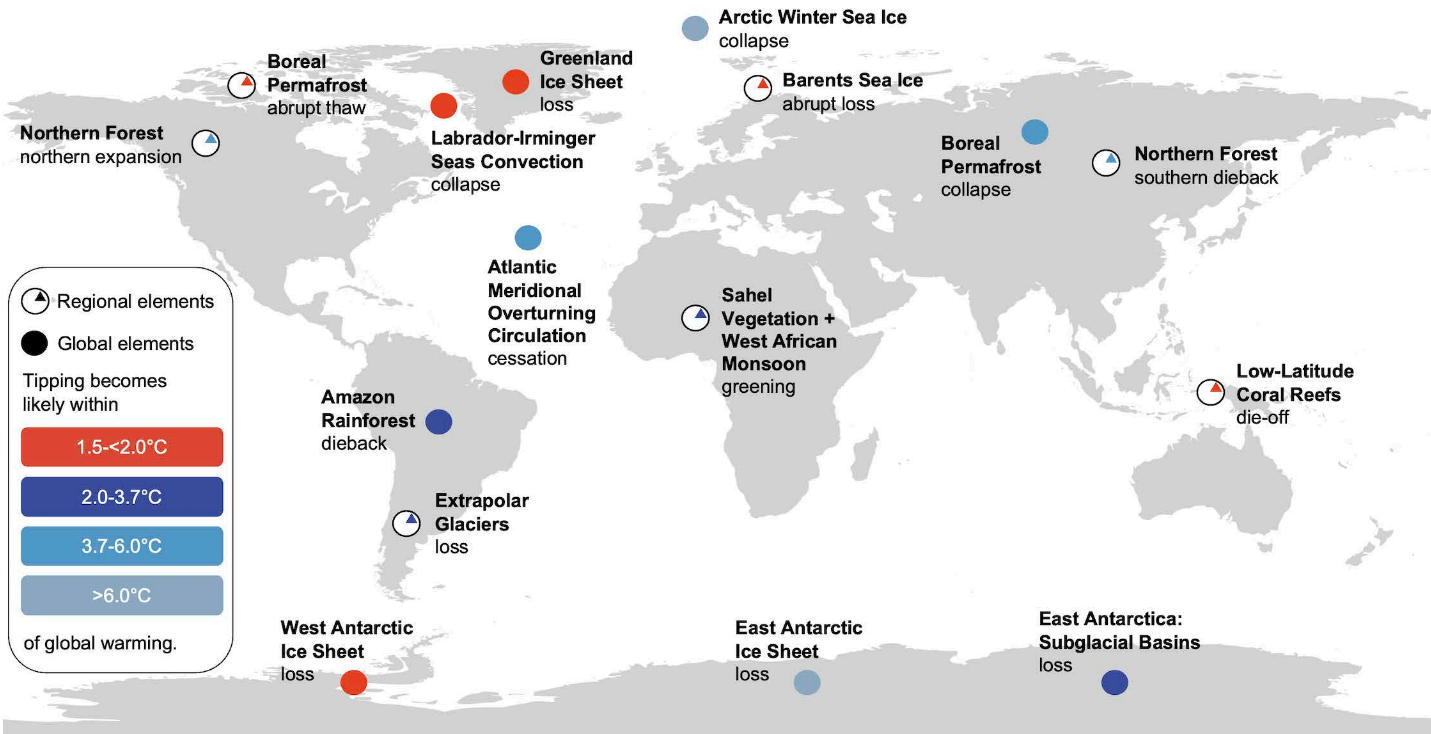

Fig 2. Climate tipping elements. The geographical distribution of global and regional tipping elements, colour-coded based on the best estimates of their temperature thresholds, beyond which these elements are likely to cross a tipping point. Credits: adapted from Potsdam Institute for Climate Impact Research; world map published under a CC BY license, with permission from Carolina Veloso Ferreira, copyright 2026.

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would heighten global temperature disparities, destabilising climates worldwide. Regions like Europe would face harsher winters, shorter growing seasons and increased energy demands [13]. Yearly temperatures in Bremen, a city in northwestern Germany, could drop by up to 10 °C, while Berlin might see a decrease of up to 5 °C (S1 Fig). In Bremen, average temperatures could drop as low as -20 °C in February, affecting it more than cities located further south in Germany (S2 Fig). Sea level rise would accelerate due to Greenland's ice melt, threatening coastal areas with flooding and erosion [13]. Europe would see more extreme weather, including storms, droughts, heavy rain and snowfall [13]. Simultaneously, the tropical rain belt would shift southward, causing regional droughts and floods, leading to agricultural and water crises [13]. Monsoon systems would weaken, desiccating regions like the Sahel, while monsoons in the Southern Hemisphere would intensify, causing devastating floods [13]. Marine ecosystems would suffer as reduced ocean circulation depletes oxygen levels and disrupts food webs [13]. The AMOC's collapse would also hinder the ocean's ability to absorb atmospheric carbon dioxide, accelerating global warming [13]. These cascading effects would likely amplify climate inequities, destabilise ecosystems and strain societal resilience.

Impacts of climate change on health in Germany

Europe is the fastest-warming continent globally, with a rate of warming second only to the Arctic [14,15]. Even without accounting for the potential collapse of climate system tipping points, projections across 854 European urban areas show that rising heat-related mortality will consistently outweigh reductions in cold-related mortality, driving a substantial net increase in temperature-related deaths, especially in the Mediterranean and Eastern Europe, unless strong mitigation and adaptation measures are implemented [16].

Fig 3. Earth system implications of an AMOC collapse. World map with simplified depiction of key implications for the Earth system following an AMOC collapse. Credits: adapted from Lenton TM, Armstrong McKay DI, Loriani S, Abrams JF, Lade SJ, Donges JF, et al. The global tipping points report 2023. University of Exeter. 2023 [Cited 2025 August 29]. Available from: https://report-2023.global-tipping-points.org/; world map published under a CC BY license, with permission from Carolina Veloso Ferreira, copyright 2026.

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The climate crisis is already significantly impacting the lives of people in Germany: The 2023 German Status Report on Climate Change and Health, published by the Robert Koch Institute, outlines current health risks in Germany associated with climate change while emphasising the role of social determinants in shaping vulnerabilities [17]. Rising temperatures result in more frequent and severe heatwaves, which increase the occurrence of heat-related illnesses and deaths, particularly among vulnerable groups [18]. During the 2003 heatwave, nearly 10,000 people in Germany died, and between 2018 and 2020, the country experienced substantial excess mortality from heat for the first time over three consecutive years, with almost 20,000 deaths [19]. According to estimates from the Robert Koch Institute, around 4,500 deaths occurred due to heat in the summer of 2022 [20], and approximately 3,200 and 3,000 deaths were reported in 2023 and 2024, respectively [21]. Beyond mortality, heat-related morbidity and productivity losses also represent substantial impacts that must be accounted for [18].

Furthermore, the frequency and intensity of extreme weather events, such as floods and storms, are rising, resulting in injuries, fatalities, long-term mental health issues, increased risks of infectious diseases due to exposure to contaminated water and respiratory health problems from mould exposure [22,23]. These events can disrupt healthcare services and infrastructure [24]. A devastating example is the Western European flood of July 2021, which heavily impacted Germany's Ahr Valley. The disaster led to over 200 deaths, left thousands of homes uninhabitable and caused widespread damage to critical infrastructure, including water and electricity supplies, bridges, sewage systems, schools and hospitals [24,25].

Climate change also alters ultraviolet (UV) radiation and annual UV exposure. Satellite data from Germany reveal an increase in peak UV exposure and total UV dose over the past decade compared to the previous three decades [26]. Prolonged UV exposure can cause immediate health effects like sunburn; over time, it increases the risk of skin cancers and eye conditions [26]. Climate change is also exacerbating air pollution, particularly ground-level ozone and particulate matter, which, in turn, increases the prevalence of respiratory and cardiovascular diseases [27].

Increased temperatures contribute to the spread of infectious diseases in Germany, as they expand the habitat range for disease vectors such as ticks, mosquitoes and rodents. This leads to a rise in diseases like Lyme disease (Germany's most common vector-borne illness), West Nile fever and *Hantavirus* [28]. Shifts in temperature and precipitation patterns also negatively impact water quality, increasing the prevalence of pathogens, for example, non-cholera *Vibrio*, *Legionella* and cyanobacteria [29]. Likewise, climate change affects food safety, raising the risk of food-borne illnesses, such as *Campylobacter* enteritis (the most frequently reported bacterial food-borne infection in Germany) and salmonellosis [30]. Changes in the spread and transmission of infectious diseases lead to higher antibiotic use, contributing to the spread of antimicrobial resistance [31].

Moreover, climate change influences the distribution and intensity of allergens, most notably pollen, worsening respiratory conditions such as asthma and allergies [32]. Changes in biodiversity, including the spread of invasive species with high allergenic potential like the common ragweed (native to North America) and the oak processionary moth (native to Southern Europe), further intensify these health issues [32]. Lastly, psychological stressors linked to climate change, including anxiety after extreme weather events, loss of livelihoods and displacement, are contributing to rising rates of mental health conditions like anxiety, depression and post-traumatic stress disorder [33].

Study rationale and research questions

An AMOC collapse could trigger significant climate changes with profound impacts on ecosystems and human health. However, the direct and indirect health effects are severely under-researched. Adaptation strategies in Europe, particularly Germany, lack an assessment of how such an event might affect vulnerable populations and strain healthcare systems. This research addresses these gaps through the following primary research question: What are the potential direct and indirect health impacts of an AMOC collapse on populations in Europe, with a focus on Germany? and three secondary research questions: (1) Which groups are most vulnerable, and what factors contribute to their vulnerability? (2) How prepared is Germany's healthcare system for these risks? (3) What strategies can mitigate the health impacts in Europe, focusing on protecting Germany's populations?

Germany was selected for its high vulnerability to AMOC-related climate impacts [34], its status as a significant greenhouse gas emitter [35] and its potential to serve as a role model in addressing climate-related risks in Europe and worldwide.

Materials and methods

Data generation

This study adopted a qualitative approach, utilising semi-structured interviews with subject matter experts to gain an in-depth understanding of the potential direct and indirect health impacts of an AMOC collapse. Expert opinion plays a crucial role in evidence-based healthcare, either complementing empirical evidence or, in the absence of scientific data, serving as the best available source of insight [36]. The flexibility of interviews allows for detailed exploration of complex topics with a relatively small sample size, centring the research on the perspectives and expertise of participants.

Participants. Studies suggest that 9–17 interviews or 4–8 focus group discussions typically reach saturation in qualitative research [37]. Although there is no universal rule for determining sample size in qualitative research, aiming for approximately 15 participants is a common approach to achieving data saturation and ensuring comprehensive data collection in expert interviews. This study used purposive sampling to recruit participants meeting the inclusion criteria (Table 1).

Potential participants were identified through professional networks and recommendations from key informants. No relationship was established before the commencement of the study. However, a professional relationship existed with three of the study participants already before the study. Initial contact was made gradually via email between late October and early November 2024, and those who responded positively were provided with an information sheet and consent form. Out of 60 people contacted, 17 accepted (Table 2), 12 declined, resulting in a response rate of 48.3%, with the remaining 31 not responding (in time).

The study participants were grouped into eight categories according to their areas of expertise (Fig 4).

Table 1. Inclusion criteria.

Inclusion criteria
Having expertise in one of the following areas: • Anaesthesiology, Intensive Care, Emergency Medicine (e.g., health impacts of heat or cold temperatures, increasing falls during colder weather) • Cardiology (e.g., impacts of heat or cold temperatures on the cardiovascular system) • Infectiology, Tropical Medicine, Toxicology (e.g., vector-borne/ water-borne/ food-borne infectious diseases, human-to-human transmittable diseases) • Allergology (allergies and climate change) • Pulmonology (air pollution and climate change) • Food (in)security due to climate change/ extreme weather events/ cold climates • Link of UV radiation with climate change • Climate change impacts on the healthcare system • Civil protection • Psychosocial health and climate change/ environmental disasters
Minimum 3 years of experience in the respective field
Current or recent involvement in the respective field

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Table 2. Overview of study participants.

Participant code	Discipline/ position	Area of work	Location
P1	Professor of Sociology	Academia	Germany
P2	Anaesthesiologist and Intensive Care Physician	Practice	Germany
P3	Anaesthesiologist and Emergency Physician	Practice	Germany
P4	Anaesthesiologist	Practice	Germany
P5	Scientist: Vector-Borne Diseases	Government agency and research institute	Germany
P6	Scientist: Highly Pathogenic Infectious Diseases	Government agency and research institute	Germany
P7	Environmental Health Researcher	Academia	The Netherlands
P8	Public Health Researcher	Academia	United Kingdom
P9	Lecturer and Sustainability Manager	Academia and practice	Germany
P10	Doctoral Researcher: Climate Extremes	Academia	Germany
P11	Civil Protection Head of Unit	Practice	Germany
P12	Public Health Researcher	Academia	The Netherlands
P13	Professor of Clinical Psychology of Childhood and Adolescence	Academia	Germany
P14	Psychological Psychotherapist	Non-governmental organisation	Germany
P15	Psychological Psychotherapist	Practice	Germany
P16	Medical Psychotherapist	Academia	Germany
P17	Medical Psychotherapist and Climate Manager	Non-governmental organisation	Germany

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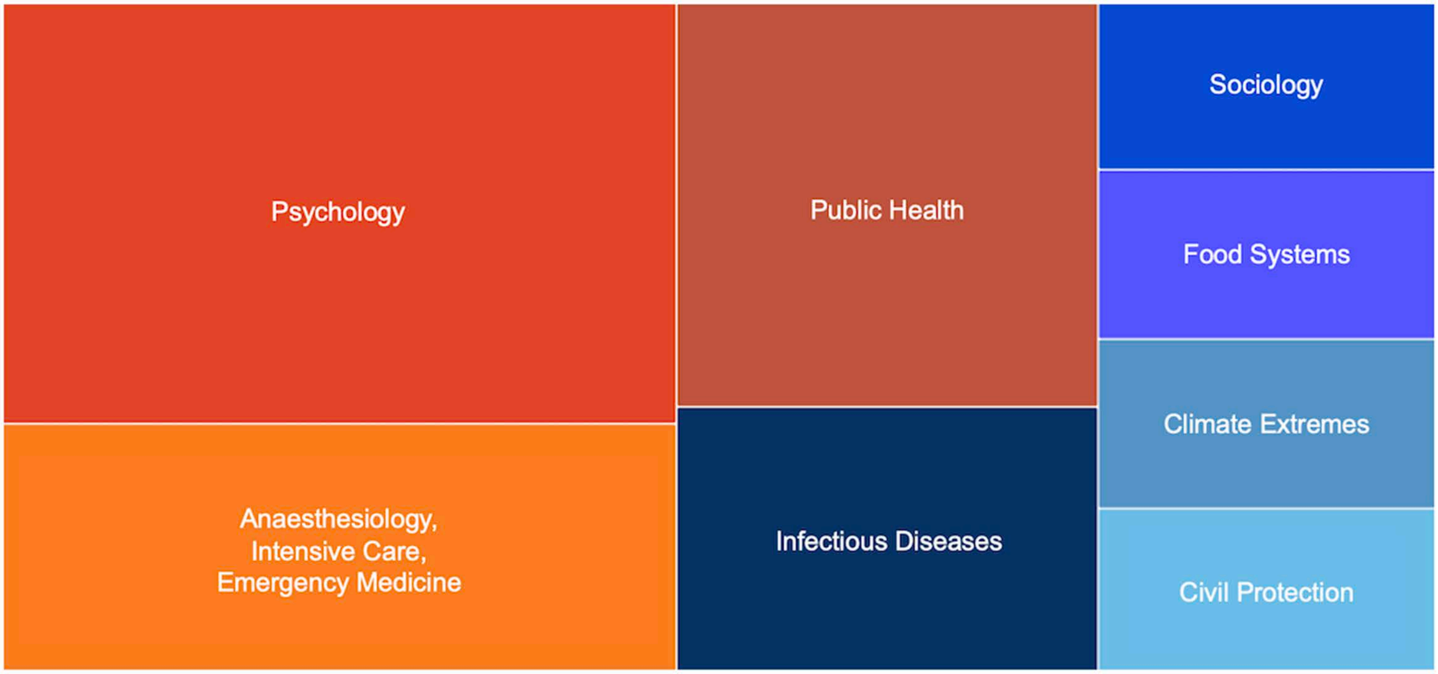

Fig 4. Tree map of study participants.

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Semi-structured interviews. JM conducted the interviews in November 2024 via video conferencing (Zoom Workplace Version 6.2.6), which lasted 30–60 minutes each. Interviews were conducted either one-on-one with the participant and researcher (n = 8), but in some cases also in groups of two (n = 3) or three (n = 1). Equal participation in group interviews was ensured through active moderation, including structured turn-taking, targeted follow-up questions to quieter participants and interventions when necessary to prevent dominant voices from steering the discussion. Conducting interviews in small groups of two to three participants fosters richer discussions, reduces the pressure on individuals and allows for the emergence of diverse perspectives through interaction. No one else was present besides the participants and the researcher. No repeat interviews were carried out.

With participants' consent, all interviews were audio-recorded and transcribed verbatim. Field notes were made during the interviews. A topic guide developed from the literature review and research questions steered a semi-structured format (S1 File). The topic guide was used to ensure consistency across interviews while allowing flexibility to follow participant-specific expertise. Given the heterogeneity of participants, follow-up questions varied accordingly. At the beginning of each interview, time was allocated to explain the AMOC, its potential implications for the Earth system and reasons for conducting the research, to ensure a shared understanding and facilitate the discussion. This procedure was communicated to participants in advance during the initial email contact. Two background interviews with AMOC experts from Utrecht University and Hamburg University were conducted prior to the commencement of the study to verify and deepen the researcher's understanding of the AMOC.

Data analysis

The interview transcripts were analysed with NVivo version 15.0.1. The analysis employed a thematic approach, integrating both deductive and inductive methodologies, using a combination of pre-selected codes based on the literature review and the topic guide, namely direct and indirect impacts on individuals' health and society, vulnerability, adaptation, challenges and recommendations, as well as codes iteratively derived from the interviews (Fig 5). This hybrid approach

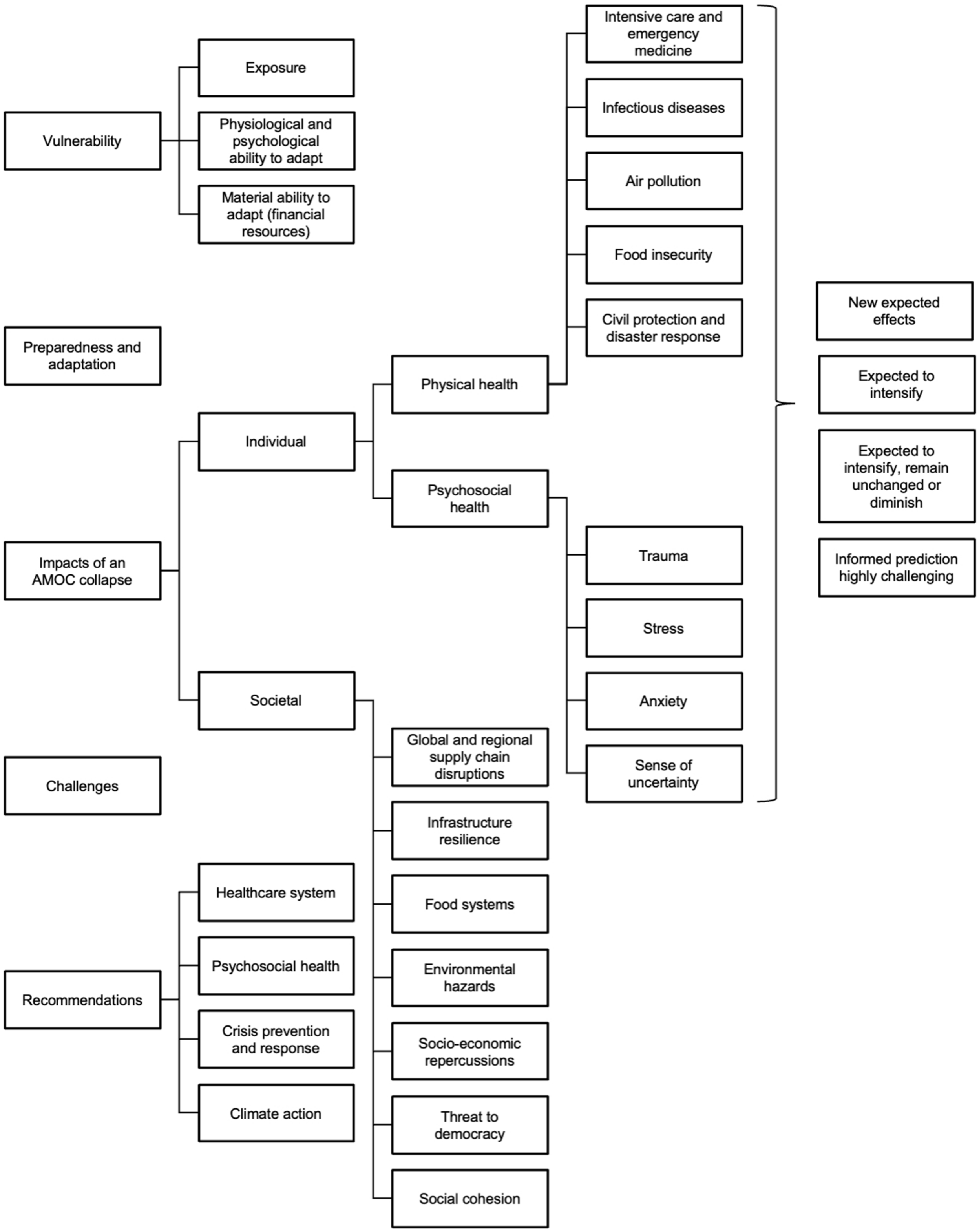

Fig 5. Coding tree.

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permitted the exploration of pre-defined themes and the flexibility to identify and incorporate novel insights that emerged directly from the data. Deductive coding ensured alignment with the study's framework and research questions, while inductive coding allowed for discovering unexpected patterns or themes that could enhance the understanding of the topic. Toward the end of data analysis, the qualitative findings were compared with existing literature and additional codes were applied to indicate whether observed climate change effects on health are expected to intensify, diminish or evolve differently. A single researcher (JM) coded and organised the data to maintain consistency in the analytical process.

A positionality statement is provided (S2 File), outlining the researcher's role in the study and offering transparency about how their experiences and perspectives may have shaped the research process and interpretation of the findings.

Reporting

This study was reported in accordance with the Consolidated Criteria for Reporting Qualitative Research (COREQ), a 32-item checklist for interviews and focus groups [38]. Direct quotations selected for reporting were returned to participants for comment and correction.

Ethical considerations

Ethical approval was not required for this study, as it did not involve collecting or using private or sensitive information. All invited participants received an information sheet detailing the study's purpose, procedures, participation requirements, data protection and confidentiality measures, as well as the contact details of the research team. An informed consent form was provided prior to the interviews, and written consent was obtained from all participants via email before the interviews were conducted. To ensure confidentiality, all data were anonymised, safeguarding the identities and privacy of the participants. The collected data is securely stored per the General Data Protection Regulation, with access strictly limited to the primary researcher.

Results

The results of this study are presented in two main sections: *Physical health risks*, which explores the following key areas: intensive care and emergency medicine, infectious diseases, air pollution, food insecurity, civil protection and disaster response, and *Psychosocial health risks*, addressing the mental and social dimensions of health impacts linked to a potential AMOC collapse.

Physical health risks

Intensive care and emergency medicine. A recurrent theme was that human health is highly sensitive to temperature variations due to narrow biological homeostasis. Even slight deviations from the normal body temperature range of 36–39 °C can lead to pathological reactions, making humans less adaptable to temperature extremes than some animal species. Interviewees highlighted that cold spells, much like heatwaves, can cause severe health problems, including circulatory disturbances, frostbite, hypothermia, cardiovascular diseases, organ failure, increased susceptibility to infections and falls leading to fractures like femoral neck injuries, resulting in high demand for trauma surgery, intensive care and emergency services. When asked about how well Germany's healthcare system is prepared in terms of cold temperatures, the participants had unanimous views:

> I'm smiling right now because I feel like I've become more familiar with heat-related illnesses. When I took my emergency doctor exam, I was even asked about a hypothermia case. Back then, I probably knew very little about heat-related illnesses. And now it has turned around over the years. However, I believe that, because hypothermia or hypothermia-related illnesses still occur in the winter months, the level of expertise is still relatively high, and it's also included in the curriculum for emergency physician training (Anaesthesiologist and Emergency Physician, P3).

> Patients with cold exposure or with cold shock, frostbite shock, if we get them, then they have to be treated professionally immediately (and it's a matter of hours) […] by specialists. I don't see us being equipped for that at all (Anaesthesiologist and Intensive Care Physician, P2).

Participants agreed that cold-related health challenges put immense pressure on healthcare infrastructure. Extreme weather events, including heavy snowfall and floods, can obstruct emergency services, delaying response times and potentially exacerbating patient outcomes. Prolonged waiting times after polytrauma pose additional challenges for both patients and emergency medical personnel, as illustrated by one interviewee:

> I can imagine, especially in the case of external injuries, polytrauma on the street, you have to wait an hour until the patient is cut out. That's also really unpleasant for the ambulance service when you're standing there waiting. And it's also really unpleasant for the patients because they naturally cool down even faster. […] Especially in the case of polytrauma at -20 °C, there's a very small chance of getting them to the hospital alive at all (Anaesthesiologist, P4).

Participants highlighted supply chain disruptions during extreme weather, intensifying healthcare stress by limiting access to critical medicines. Key challenges identified include political and systemic issues aggravating vulnerability, such as insufficient pedestrian-friendly urban planning, reliance on fossil fuels, poverty and inadequate heating. Treating cold-related conditions, like those requiring heart-lung machines, is complex and demands skilled personnel. Preparedness gaps, such as shortages of cooling clothing, dialysis machines during heatwaves and warming devices during cold spells, further hinder adaptation. The increasing healthcare demand during extreme weather events underscores the urgent need for trained personnel and better infrastructure to address these escalating challenges effectively.

Infectious diseases. Interviewees revealed that many infectious diseases are highly susceptible to climate change:

> Basically, all pathogens that are either associated with a matrix, namely water, soil and food, or are vector-borne […], are dependent on environmental conditions, including climatic conditions. That's, of course, a whole range of pathogens that play a role. There are also pathogens that would certainly be less affected, for example, pathogens that are usually transmitted from person to person (Scientist: Highly Pathogenic Infectious Diseases, P6).

According to the participants, pathogens generally thrive in warmer and humid conditions. Warmer temperatures accelerate the replication of pathogens, while colder temperatures may reduce their spread but could lead to new challenges like the spread of other invasive species or disruptions in ecosystems.

Interviewees noted that an AMOC collapse could reduce the incidence of vector-borne diseases in Germany. After outlining that mosquitoes increasingly feel at home in Europe due to rising temperatures, with growing incidences of yellow fever, the introduction of malaria via *Anopheles* and the spread of ticks such as *Hyalomma* capable of transmitting Crimean-Congo haemorrhagic fever, one of the participants reasoned:

> Conversely, one could then of course also conclude that if it were to get colder again, they [invasive species] might also disappear again, unless the vectors adapt. In my opinion, this is not to be expected, but we cannot rule it out entirely either (Scientist: Highly Pathogenic Infectious Diseases, P6).

Another participant made a similar point but added:

> Well, ticks don't really care about extreme weather because they occur in such large numbers. They are relatively resistant (Scientist: Vector-Borne Diseases, P5).

As one participant explained, the situation is quite different for rodents, which are, among other things, responsible for transmitting *Hantaviruses*:

> There are years with few rodents and years with many rodents, and this is not necessarily related to the weather, but rather follows a [population cycle]. Of course, warmer temperatures generally favour rodent populations in terms of social behaviour within the group, reproductive behaviour and so on, compared with colder temperatures. [...] Here too, one could say that, assuming there is no adaptation, which in my opinion is unlikely, there would be a decline in the rodent population. What we do not yet know is whether the pathogen would then decrease in number or instead cluster. This remains an open question that has not yet been fully researched, but one that we are investigating in principle (Scientist: Highly Pathogenic Infectious Diseases, P6).

The complex interplay between climate, vectors and pathogens creates uncertainty in predicting disease risks post-AMOC collapse. One participant explained that climate shifts may disrupt biodiversity, increasing risks of zoonotic and novel diseases. Urbanisation and habitat changes could disrupt the animal-human boundary, raising the likelihood of emerging pathogens. The more disruptions to the biosphere and human activities, the higher the likelihood of mutations that lead to new pathogens like the coronavirus SARS-CoV-2:

> For a novel disease to make that jump, it's never guaranteed, because you're essentially looking for that one mutation. It's very much the Swiss cheese problem: the mutation has to be there, and the disruption has to be there. But the more of these disruptions you introduce at once, the more likely it becomes that the right mutation will occur, in the right virus, in the right animal, at the right place, under the right conditions, for what could become the 'new COVID' (Environmental Health Researcher, P7).

Cold temperatures might reduce human-animal interactions, but most participants agreed on the complex link between temperature and human-to-human infectious diseases. While cold weather does not directly increase transmission, it promotes urban crowding and weakens immune systems, creating conditions for respiratory infections like influenza or the common cold. Interviewees also noted that climate-induced migration to cooler northern regions and consequent increasing urban density could further strain public health:

> We see some implications of climate migration already, right? Especially from the South to the North, where it's getting hotter. So, it's probably reasonable to expect that that would continue. It would be reasonable to expect that the current health implications of increasing urban density would continue, assuming a linear trend. If more people move into cities to be warm, you have more urban density, more urban crowding, so that may have potential implications for infectious diseases, which I guess makes sense. If it's getting colder, then you're going to have longer cold and flu periods. If climate migration is increasing, people going from uncomfortably hot to liveable cold, that does have the potential for increasing the spread of infectious diseases (Environmental Health Researcher, P7).

Additionally, resilient pathogens like *Cryptosporidium*, which survive extreme conditions, could persist despite cooler climates, posing risks during floods. According to participants, water-borne pathogens, including non-cholera *Vibrio*, *Legionella*, cyanobacteria and *Cryptosporidium*, present significant threats after extreme weather disrupts sanitation systems. They further noted that food-borne illnesses, such as salmonellosis and *Campylobacter* enteritis, remain a concern during warmer periods due to their effects on food safety. Moreover, toxin-producing species like *Ambrosia* (common ragweed) or pests like the oak processionary moth produce toxins exacerbated by warmer temperatures. Climate shifts may alter the prevalence of these organisms, influencing exposure risks. Additionally, the climate-induced proliferation of certain species could lead to higher concentrations of harmful toxins in ecosystems, impacting both human and animal health.

Participants stressed that health professionals need more education and to stay ahead of emerging species and diseases, and that health communication is key. A delay in recognising new species or pathogens could complicate managing risks:

> When it comes to insects in particular, I don't think [the German healthcare system] is well prepared, because the diseases that are already here are not even [all] known yet [by practitioners], and if new diseases come along now... (Scientist: Vector-Borne Diseases, P5).
>
> I think that, in principle, we have a good healthcare system, but, of course, there also need to be tools and information channels in place to prepare doctors who practise medicine for such scenarios, so that they are aware of pathogens that have been relatively rare until now and can have them diagnosed if necessary (Scientist: Highly Pathogenic Infectious Diseases, P6).

You can only find what you know about (Scientist: Vector-Borne Diseases, P5).

Air pollution. The participants highlighted that air pollution is currently the leading environmental risk factor for death and disability, and many of the factors driving climate change impact air quality:

> Many of the determinants of air quality are also determinants of climate or drivers of climate change. So, when we're looking at the major drivers or determinants of air quality, we're looking primarily at things related to fossil fuel burning (Environmental Health Researcher, P7).

Participants pointed out that extreme weather conditions exacerbate air pollution: heat waves can lead to higher ozone concentrations, while cooler temperatures increase particulate matter levels:

> It always feels a bit contradictory to say, but if it's too hot, that's bad for air quality – and if it's too cold, that's also bad (Environmental Health Researcher, P7).

Energy use for heating and transport adds to pollution. According to one interviewee, storms can clear pollutants but elevate allergens like pollen, while wildfires cause severe pollution spikes, harming vulnerable populations. Emergency responses also temporarily increase pollution through rescue vehicles and generators.

One participant highlighted vegetation's vital role in filtering pollutants, warning that temperature drops could impair its effectiveness. Intensified agriculture from an AMOC collapse might worsen air quality via increased nitrogen emissions.

One interviewee stressed that air pollution affects all regions but hits vulnerable populations hardest. While measures like heating, ventilation and air conditioning filters can improve indoor air quality, their high cost raises concerns about accessibility and worsening health inequities. On one hand, participants emphasised co-benefits between climate action and air quality improvements:

> […] there are always these beautiful co-benefits between climate and air pollution. Very seldom is it a zero-sum game – mitigation and adaptation strategies typically, though not always, work well together (Environmental Health Researcher, P7).

On the other hand, they acknowledged that meteorological conditions like stagnant air trapping pollutants could worsen pollution:

> While we can't control natural phenomena, adequate regulation can help limit their effect. If we can adequately control air quality, then the uncontrollable effect of natural phenomena can be mitigated to some extent (Environmental Health Researcher, P7).

This underscores the need for robust implementation and sustained political will to drive effective adaptation strategies.

Food insecurity. Participants highlighted significant concerns about food security in the face of climate change and disruptions to the AMOC. They noted worries about producing crops, such as maize and wheat:

> Large parts of Germany may become unsuitable for certain types of crops, or at least for many staple crops grown already (Doctoral Researcher: Climate Extremes, P10).

Being more climate-sensitive, maize may struggle with changing conditions, while wheat shows greater adaptability. Globally, colder, drier climates could disrupt agriculture and food supply chains. Livestock faces challenges with feed availability and colder temperatures, forcing shifts to alternative species and energy-intensive indoor heating:

> One is obviously the impact on crops and land. But food security also includes animals and livestock, which could also be impacted. For example, if it's much colder, certain animals may not be able to be raised as easily in certain areas (Doctoral Researcher: Climate Extremes, P10).

Interviewees highlighted that extreme weather and temperature shifts could amplify biodiversity loss and threaten pollinators, further destabilising food production:

> A change in temperature and weather extremes will impact biodiversity and pollinators. So it can be that pollinators have to change their range, and I don't know. Bees don't live in the Northern Hemisphere because it's too cold, and in addition to the land not being available for agriculture, you might have issues with pollination, which also impacts food security (Lecturer and Sustainability Manager, P9).

Water stress and its implications on agriculture, livestock and fruit plantations were also underscored:

> If you look at the other planetary boundaries, water resources could become an issue as well. My understanding is that a change in the AMOC could make Europe hotter at first and then lead to cooling. So, there would be changes in temperature and in the amount of rainfall, and the water supply for agriculture could also become an issue (Lecturer and Sustainability Manager, P9).
>
> With an AMOC collapse, precipitation all over Europe is expected to decrease – except in certain parts in certain seasons – but I think by large, there's a decrease which is projected […] so that would obviously lead to more water stress, which would have to be compensated by, I guess, more education or more technology (Doctoral Researcher: Climate Extremes, P10).

Marine ecosystems and fisheries are expected to face severe disruptions, compounding food security challenges:

> Another impact will be on marine life. […] The ocean – all that we get out of the ocean nowadays (Lecturer and Sustainability Manager, P9).

Participants also expressed concern about the nutritional and health impacts of these changes. A diminished availability of fruits, vegetables and other vital food groups could lead to malnutrition and a decline in diet quality, diversity and safety:

> The diet would probably change in the quantity, the quality, the diversity and maybe also in the safety of the food. This will impact, for sure, the nutritional status of people. And the nutritional status then influences the health outcomes (Lecturer and Sustainability Manager, P9).

Participants discussed socio-economic effects, noting that some farmers may leave agriculture, causing relocation and mental health challenges. The global food system's interdependence worsens these issues, with risks of instability if production chains falter or reliance on imports persists. Food sovereignty, ensuring reliable local production, was emphasised as a key policy focus. Participants identified small-scale farmers as particularly vulnerable to climate disruptions like an AMOC collapse, as they often lack the resources to adapt. However, regenerative agriculture and agroforestry were seen as effective ways to mitigate impacts by promoting crop and ecosystem diversity, which enhances resilience to climate stressors.

Furthermore, discussions emphasised the interconnected nature of vulnerabilities, with conflict emerging as a primary driver of hunger. Participants explained that when multiple stressors converge, the risk of food insecurity intensifies:

> Countries globally suffer the most if they have more than one impact driver. So, if you have climate extremes and economic downturns, for example, at the same time, there's a higher risk of hunger in the country (Lecturer and Sustainability Manager, P9).

This increased vulnerability disproportionately affects resource-limited communities. Participants noted that farmers, due to their dependence on environmental conditions, are often more aware of climate change, which could serve as a foundation for adaptive strategies if supported with adequate resources. Participants highlighted the need for agricultural adaptation to climate change and disruptions like an AMOC collapse, including changes in crop selection and planting times. While chemical and technical solutions, such as artificial intelligence, can help maintain productivity, their high cost limits access for small-scale farmers. The discussions also touched on the societal shifts required, such as changes in dietary habits. Europe, they noted, is currently in a privileged position where traditional foods dominate and there is limited openness to alternatives like insects. Though a planetary health diet could support adaptation, participants noted resistance to such changes.

Civil protection and disaster response. The interviews revealed that a collapse of the AMOC would severely strain healthcare systems, civil protection and disaster response services. They highlighted that hospitals, clinics, emergency services and voluntary structures would face overwhelming demands, leading to disruptions in care delivery standards, particularly in rural areas:

> Whether we can maintain standards of care – and keep health impacts from becoming severe – depends on how much we are willing to invest. At a certain point, given the magnitude of climate change, we will have to ask ourselves: to what extent will we even be able to adapt (Civil Protection Head of Unit, P11)?

Interviewees pointed to increased mortality rates in winter due to frostbite, hypothermia and related accidents, exacerbated by logistical bottlenecks and limited access to care. Participants also pointed out that infrastructure, including power, logistics, roads and buildings, would be significantly affected. Power outages, inaccessible roads and damaged sewage treatment plants were identified as critical risks, along with potential environmental hazards like oil spills and water contamination. Vulnerable populations, such as individuals reliant on medical equipment or mobility assistance, were emphasised as needing specialised evacuation plans. One participant commented:

> The biggest challenge is managing the immediate effects. How can we respond effectively in such situations? What proactive measures can we take? Thus, we need to think about preparedness and preventive action: Who will be affected, how, when and where? How can we warn specific patient groups? For instance, if a cold spell or heatwave is approaching or severe weather, like flooding, is expected, we need robust warning systems. This could include sirens, app-based alerts or self-broadcasting systems. And of course, when the crisis hits – whether it's prolonged heat, cold, storms or flooding – you move into the response phase of the Disaster Management Cycle with targeted action plans for the most vulnerable population groups (Public Health Researcher, P12).

Furthermore, one interviewee highlighted reduced access to education and work as long-term consequences. Improvements in disaster management were emphasised, including better prevention, early warning systems, structural resilience and accessible infrastructure. Post-disaster recovery should focus on high-quality rebuilding to prevent recurring vulnerabilities. Energy-efficient, insulated housing with reliable heating and cooling systems was also suggested to mitigate risks, though it requires significant investment.

Participants pointed to significant challenges in addressing the impacts of a potential AMOC collapse on healthcare and civil protection systems. They questioned the long-term feasibility of adaptation, noting that current civil protection frameworks are unprepared for large-scale or prolonged crises. Key issues included insufficient (human and material) resources, outdated concepts, poor coordination and reliance on vulnerable digital systems. Integrated emergency plans connecting hospitals and the healthcare system were seen as essential but lacking. While regional crises may be manageable, large-scale events expose the fragmented nature of disaster management. The European Civil Protection Mechanism was referred to as a good practice example.

Identifying those most at risk: Physical health. Most participants identified similar risk groups across various AMOC-related health impacts. Populations most at risk for physical health threats include the elderly (especially those living alone), newborns and young children, people with pre-existing health conditions (for example, cardiovascular disease, diabetes or respiratory conditions), those on certain medications, people with a drug or alcohol addiction and those who are immunocompromised. These groups are particularly vulnerable to extreme heat, cold or other severe weather events as their bodies struggle to regulate temperature or recover from stress. Additionally, individuals with mobility impairments or disability, those living in poverty and people experiencing homelessness are at higher risk due to limited access to shelter, healthcare and resources during extreme conditions. The ageing population further contributes to the number of at-risk individuals. Lastly, according to the interviewees, some people face higher risks due to exposure. This includes outdoor workers, those who spend significant time outside in nature, pet owners and healthcare workers. Given the variety of challenges these groups face, the importance of preparing and protecting vulnerable populations in the context of AMOC-related disruptions becomes critical.

Psychosocial health risks

Trauma, stress and anxiety in a changing climate. The interviews revealed that psychological and societal consequences anticipated from an AMOC collapse are extensive and multifaceted. A prominent concern raised by participants was the significant mental health burden triggered by extreme weather events: climate-related disasters can lead to post-traumatic stress disorder, while the somatic impacts, ranging from direct fatalities to a rise in illness, further intensify psychological distress. Participants also highlighted that higher temperatures are linked to increased aggression and suicide rates. In Germany, infrastructure significantly influences these outcomes, as homes are well-insulated for cold climates but are not designed to cope with extreme heat. While low temperatures are not directly linked to specific psychological conditions, they can still impact mental health: constant cold, difficulty staying warm or an increase in infections can weigh heavily on a person's psyche.

While acknowledging that climate anxiety and grief are valid responses, the participants warned that as the impacts intensify, many could experience functional limitations that border on mental illness. Chronic stress, physical ailments and sleep disturbances could become common, exacerbated by the ongoing pressures of environmental change. This could lead to a tipping point where survival instincts take over, pushing personal issues into the background. Ultimately, the participants envision climate change leading to deep psychological trauma, especially as people begin to focus more on immediate, personal crises rather than the broader existential threat. Low mental health literacy further exacerbates these issues, leaving many unprepared for the psychological toll of climate change.

Facing uncertainty. According to participants, crises typically have a clear endpoint – an event occurs, recovery follows, and life moves on. That is not the case with persistent challenges like climate change. This creates a constant state of uncertainty, which becomes psychologically significant when people are unable to cope with it:

> It's not surprising that with so many concurrent and global crises, coping with these crises becomes increasingly difficult and mental health strain rises (Professor of Clinical Psychology of Childhood and Adolescence, P13).

For some, this uncertainty leads to anxiety disorders, while others may respond by denying the problem or succumbing to panic, essentially ignoring the reality of the situation. Some interviewees suggested that it might be time to stop framing climate change as a crisis and instead accept it as a new reality – a world shaped by vast, interconnected global challenges. According to them, denial is not helpful, as acknowledging the full scope of the problem is the first step toward addressing it:

> Is the concept of crisis still appropriate? Or should we just say we have a new reality? We have a reality in which there are immense global challenges (Professor of Clinical Psychology of Childhood and Adolescence, P13).

The participants envision a continuum leading to a state of crisis marked by increasing disasters, declining standards of living and a gradual loss of hope. This would result in heightened anxiety, depression and possibly even more extreme outcomes, such as collective suicide or violence.

Additionally, participants emphasised the psychological stress of economic insecurity, noting that uncertainty around basic needs like food, energy and housing can cause profound distress. Those with financial stability, strong social networks and good mental health are better equipped to cope. Interviewees also noted that strengthening these resources and building support systems are critical. Participants highlighted the need to challenge the positive bias of thinking, 'This won't affect me', by fostering realistic assessments of danger and promoting collective action. According to them, open communication about life's uncertainties is essential, but the slow, diluted responses of democratic systems to crises pose significant challenges.

Societal impacts and link to democracy. Interviews indicated significant socio-economic repercussions associated with poor mental health. High unemployment or early retirement can lead to a loss of workforce, tax revenue and social security contributions. They stressed the need for a mentally healthy population for society to function. Yet, participants emphasised the rise in polycrises, where multiple crises overlap. Young people, in particular, feel like they live in a perpetually insecure world where the end feels near. Ignoring these issues risks strengthening anti-democratic movements, which often thrive on uncertainty and fear:

> […] we are seeing a strengthening of the anti-democratic fringes in politics, which is probably also driven by the many crises. You can't really say which specific crisis is responsible, but these multiple crises may definitely play into their hands (Professor of Clinical Psychology of Childhood and Adolescence, P13).

> In theory, I can actually understand anti-democratic tendencies. Not because I consider that a good form of government myself, but because democracy is very slow to respond to these constant crises. And of course, our healthcare system is part of that as well (Professor of Clinical Psychology of Childhood and Adolescence, P13).

One participant described their views on a potential societal collapse:

> It's even possible that, through a different kind of crisis, namely the weakening of democracy and the rise of right-wing movements, we are forced to rethink the transformation of social orders in a completely new way. No one really knows, for example, what might happen in four years after another potential four-year Trump presidency in the United States, or whether democratic institutions will continue to function as they do now. So, alongside the possibility of a collapse [of society], another scenario could emerge: our democracies might gradually shift into regimes that constantly operate under a state of emergency and, in some ways, become quasi-fascist. This wouldn't be a breakdown of order per se, but rather the emergence of a different, authoritarian form of order (Professor of Sociology, P1).

Societal resilience depends on collective mental health. One participant shared their fears:

To be honest, I can hardly imagine any other way that doesn't lead to the collapse of social structures. And I find that very frightening (Psychological Psychotherapist, P15).

The potential breakdown of mental health infrastructure was also a significant concern, with the possibility that care systems could deteriorate, leaving many without support. Participants suggested that as anxiety becomes more pervasive, people may become emotionally numb or hardened, unable to cope with the ongoing stress. Interviewees feared this could lead to social segmentation and a diminished sense of collective coherence, where societal unity erodes in the face of continuous uncertainty:

So I would think that social segmentation processes are increasing dramatically, that the sense of coherence in societies is decreasing dramatically, that people are very focussed on their own group, their own family, etcetera, rather than something like humanity that goes beyond their own group, and that they feel that there's no longer much going on and that it's becoming unbearable for the people who continue to do it (Psychological Psychotherapist, P14).

[…] unless they are in extreme mortal danger, in which case they will probably stick together again because then it won't matter, but there are ongoing segmentation processes beforehand, which then have an impact on mental health (Psychological Psychotherapist, P14).

Interviews revealed concerns about our lack of preparedness, both in terms of human capacity and expertise. There is a shortage of psychotherapists, leaving many without the support they need. Even when therapists are available, many lack sufficient knowledge about climate-related stress and its psychological impact, limiting their ability to assist those affected. This gap in support, coupled with the repression of climate realities, could lead to capable individuals withdrawing from potential solutions. Moreover, the uncertainty and emotional strain could push people towards 'strong' leaders, making them vulnerable to false narratives:

I think that, as long as possible, a large part of the population will try to suppress it and will distance themselves even further. And that is where the big risk lies. The more people suppress, the more insecure they feel, the more likely they are to look for strong leaders. Then the risk is high that they follow people who tell them things that aren't true at all. […] Like populists around the world that are active in politics now, and also historically – people with a big presence who can speak well, who promise, 'No, no, it won't be that bad.' People listen to them, but they have deeply inhumane ideas. Psychologically, I think this is understandable, but it is a major concern that we fall into this kind of denial (Medical Psychotherapist and Climate Manager, P17).

Throughout the interviews, the societal impacts of a potential AMOC collapse were discussed extensively. One participant reflected on their perspective, illustrating why this study extended slightly beyond direct health impacts:

It used to be different some time ago. Back then, it was more the case that the health impacts were what scared me the most. But I actually believe that what we will probably feel much more acutely are the societal impacts of all this (Medical Psychotherapist, P16).

Identifying those most at risk: Psychosocial health. The majority of participants agreed that psychological vulnerability to crises stems from the interplay of life stages, biological factors and external stressors. Childhood and adolescence are particularly critical, with 50% of mental illnesses developing by age 14 and 75% by 18. Yet, young people also possess remarkable resilience, as adaptable brains can better manage change when raised in stable, secure environments. Early access to supportive relationships and basic needs is vital for reducing fears and fostering resilience against future trauma. Experts identified pregnancy, early parenthood, menopause and retirement as other vulnerable life stages due to hormonal changes, social transitions and external pressures. Non-normative events, like migration and significant social changes, also heighten psychological distress, while homelessness, pre-existing mental illness and living in regions heavily impacted by environmental change further increase risks.

One participant linked societal impacts to a cascading wave, where the most vulnerable – financially, socially or psychologically – are hit first, followed by middle and higher socio-economic classes. Interviewees agreed that vulnerability is shaped by crisis circumstances, particularly the availability of social support and the strength of collective resilience. Privileged groups with financial and psychosocial resources may initially insulate themselves or relocate, but even middle-upper classes face risks over time. Those with the least resources remain the most exposed, often already grappling with existential challenges.

Recommendations from experts

Table 3 below summarises 15 key recommendations from experts, highlighting actionable strategies to address the health impacts of climate change, strengthen resilience and enhance preparedness for potential crises. These recommendations represent a synthesis of suggestions provided both prompted and, in some cases, not prompted, by all participants and are organised into four thematic areas: (1) the healthcare system, (2) psychosocial health, (3) crisis prevention and response and (4) climate action.

Table 3. Key recommendations from the interviews.

Area	Recommendation	
Healthcare system	1	Health in All Policies: Ensure health considerations are embedded across various sectors and policies, enhancing cross-sectoral collaboration for improved outcomes.
	2	Adopt holistic healthcare: Promote an integrated approach to health that links physical and psychosocial wellbeing while addressing broader determinants such as urban planning, architecture and transportation.
	3	Build climate-resilient healthcare systems: Integrate ‘temperature medicine’ and mental health literacy into educational systems and professional training programmes to equip future generations with essential skills. Draw lessons from best practices to ensure quality care during climate-related events.
	4	Improve disease warning systems: Establish effective warning chains and improve traceability for faster responses to infectious disease outbreaks, ensuring clear and actionable guidance for the public and healthcare providers.
	5	Enhance infectious disease education: Focus on educating children through hands-on activities such as gathering ticks together, to raise awareness about vector-borne diseases. Engaging parents and educators through information sessions can amplify prevention efforts.
Psychosocial health	6	Prioritise mental health prevention: Implement initiatives focusing on mental health in schools, communities and other early intervention spaces to foster resilience and wellbeing.
	7	Reimagine psychotherapy and support collective formats: Use group workshops and collaborative initiatives to foster mutual support and resilience. Media can be powerful tools to raise awareness and motivate action. Move away from rigid therapy models, embracing more flexible approaches such as group therapy, to efficiently serve a wider range of individuals.
	8	Expand psychosocial emergency care training: Include psychosocial care as part of first aid courses to better respond to both physical and emotional needs during emergencies.
Crisis prevention and response	9	Invest in structural prevention: Implement preventive measures to avoid construction in flood-prone areas, safeguard critical infrastructure and mitigate the environmental impact of climate events, including the prevention of epidemics, through targeted investments in crisis preparedness.
	10	Develop resilience in crises: Focus on fostering social skills, especially solidarity and ensuring practical disaster preparedness, such as basic medical knowledge and emergency response training, to enhance psychological wellbeing during crises.
	11	Encourage participation in emergency planning: Involve communities in creating emergency plans to help individuals feel empowered and reduce distress during crises. Offer training courses and scenario-based exercises to better prepare for emergencies.
	12	Strengthen civil protection and disaster response: Support volunteer-based civil protection services and expand cross-border cooperation in disaster response, ensuring equal opportunities for all volunteers (‘Helfergleichstellung’).

(Continued)

Table 3. (Continued)

Area	Recommendation	
	13	Strengthen post-emergency care: Build robust relocation structures and emergency plans for extreme weather events, ensuring adequate preparation for climate impacts and post-disaster recovery.
	14	Leverage technology in crisis response: Integrate innovative technologies such as drones, to enhance crisis management by delivering essentials, surveying affected areas and prioritising aid distribution.
Climate action	15	Mitigate climate change. Examples: • Transition to sustainable heating solutions: Prioritise sustainable, non-polluting heating methods, focusing on renewable energy sources and phasing out gas and wood-burning stoves, which contribute to air pollution and pose health risks. • Promote a planetary health diet: Shift towards sustainable agricultural practices and dietary changes that benefit human and planetary health.

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Discussion

Interviews highlight the significant uncertainties regarding the health impacts of an AMOC collapse, emphasising the complexity of predicting and mitigating these risks. The health effects of climate change persist and are projected to intensify. Specific impacts, such as those related to heat, cold and psychosocial health, are well established, but areas like infectious diseases, particularly vector-borne illnesses, remain uncertain. No assumptions were made about UV radiation. Participants stressed the importance of crisis prevention and response and the cascading effects on global trade and food systems, which pose significant risks to health and socio-economic stability. Fig 6 illustrates the study's findings by synthesising the interview data with the existing literature. The slowdown of the AMOC could intensify existing climate-related health effects, alter some or introduce entirely new health challenges.

Germany's lack of preparedness emerged as a key concern, emphasising the need to strengthen infrastructure and promote cross-sectoral collaboration to address these complex challenges. Global events, including the Coronavirus disease 2019 pandemic, the rise of populism and right-wing politics, democratic backsliding, the war in Ukraine and recent climate-driven disasters like the 2021 Ahr Valley floods and the 2024 floods in Valencia, Spain, have exposed the vulnerabilities of systems intended to protect public health and societal resilience [39–41]. Participants highlighted the erosion of social cohesion and democracy as significant risks, given their critical role in fostering trust, collaboration and effective governance during crises.

A key takeaway was the importance of accurate and transparent communication about tipping points, like the AMOC collapse, to mobilise action and foster public understanding. Encouragingly, recent research indicates that achieving net-zero emissions by 2100 and implementing stringent emission reductions this decade could significantly reduce the long-term risks of tipping points and promote planetary stability [42]. This underscores the critical window of opportunity for decisive climate action to safeguard health, infrastructure and democratic systems in the face of growing uncertainties.

Interesting observations

Interestingly, nearly all participants expressed initial hesitancy about taking part in the interviews, often citing a lack of knowledge about the AMOC. This reflects a broader pattern: while an increasing number of health professionals are engaging with climate-related issues, they rarely address climate tipping points. This gap is concerning, as research at the intersection of climate science, social science and public health is urgently needed to better understand the potential societal, health and wellbeing impacts of an AMOC collapse. From my experience, health professionals are increasingly willing to engage with climate science and are becoming more active at these interfaces. Non-governmental organisations, such as the UK Health Alliance on Climate Change and the German Alliance on Climate Change and Health (KLUG), are actively working to mobilise the health profession on climate-related issues. By contrast, climate scientists seldom initiate contact with public health researchers. Although there is growing work on the fiscal, economic and policy dimensions of

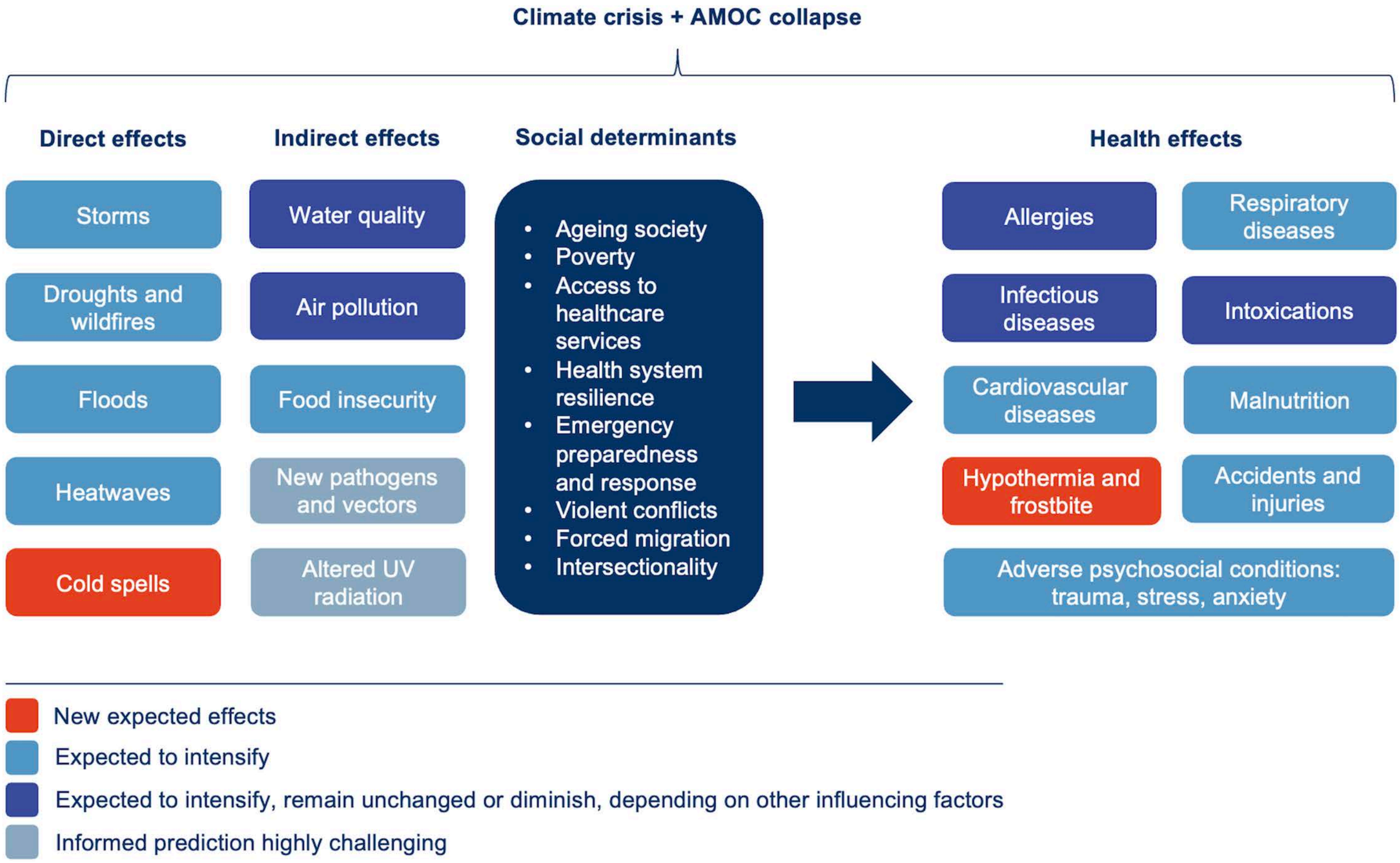

Fig 6. Potential health impacts of an AMOC collapse.

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tipping points, health implications remain largely overlooked. I also observed this dynamic at the Global Tipping Points Conference 2025 in Exeter, where I presented the findings of this study. When directly asked, many climate researchers acknowledged the importance of health impacts yet admitted they had not previously considered them. To address this critical blind spot, greater transdisciplinary research is needed, bridging the natural and social sciences to capture the full scope of risks associated with a potential AMOC collapse.

Policy gaps and responses to systemic climate threats

At the national level, the 2025 German National Interdisciplinary Climate Risk Assessment highlights the AMOC as a critical climate tipping element [34]. Its weakening or collapse could trigger extreme winter cold and intensified storms in Europe, with potentially catastrophic consequences for social, political, economic and technical systems in the coming decades [34]. While an AMOC tipping point and potential collapse by the mid-21st century cannot be ruled out, current health projections for Europe assume an unchanged AMOC [34]. Under this assumption, northern regions, including Germany, may benefit from reduced cold-related mortality, whereas southern Europe faces sharply rising heat-related mortality [34]. The report also emphasises that the risk of an AMOC collapse amplifies global security concerns and is increasingly discussed in the context of geoengineering strategies such as aerosol injection, which remain highly uncertain and politically contentious [34].

At the European level, the first European Climate Risk Assessment, published in 2024, acknowledges climate tipping points and notes that "many climate impact assessments rely largely on extrapolations of historical data and trends. As a result, they perform poorly in accounting for non-linear climate change and tipping points and largely neglect the compounding and cascading nature of climate risks" [14]. While this report considers cascading impacts and risks, it does not specifically address the AMOC. A new European Climate Risk Assessment is scheduled for publication in 2028, which may potentially fill this gap.

Despite growing scientific evidence on the likelihood and potential impacts of tipping points, such as an AMOC collapse, current climate adaptation strategies largely fail to account for these high-impact risks. Both the German Strategy for Adaptation to Climate Change and the European Union Adaptation Strategy focus on gradual climatic changes and extreme weather events, without explicitly integrating the possibility of abrupt, nonlinear shifts in the Earth system [43,44]. This omission is concerning, as tipping point dynamics could fundamentally alter climatic baselines and amplify vulnerabilities beyond the scope of existing preparedness frameworks. By focusing primarily on incremental risks, these strategies may underestimate systemic threats, leaving societies ill-prepared for cascading crises. Addressing this gap requires a forward-looking approach that explicitly incorporates low- and medium-likelihood but high-impact events, ensuring that adaptation policies remain robust under a wider range of plausible futures.

Looking ahead, the European Commission is developing a new integrated framework for European climate resilience and risk management, intended to support Member States in preventing and preparing for the growing impacts of climate change. This balanced policy package is expected to be adopted in the second half of 2026, but it remains to be seen whether it will adequately address the risks posed by potential climate tipping point collapses, including those associated with the AMOC.

What this study adds

This study advances the understanding of the health implications of an AMOC collapse by bridging climate science and public health, offering a nuanced perspective on the potential direct and indirect health impacts. By highlighting vulnerable populations and evaluating health system preparedness, it underscores the importance of equity in addressing climate tipping elements. The research contributes to building societal resilience by outlining actionable insights that support sustainable and inclusive adaptation strategies and proposing 15 key recommendations spanning healthcare systems, psychosocial health, crisis prevention and response and climate action. The study's transdisciplinary approach ensures that the findings resonate across sectors, fostering a holistic response to one of the most critical challenges of our time. The study's findings contributed to the development of a guide, 'How to AMOC', https://charm-eu.eu/wp-content/uploads/2025/06/250625_NEW-AMOC-Guide-ENG.pdf, designed to inform the public about the AMOC and its health impacts while providing recommendations for adaptation strategies and effective communication.

Generalisability and limitations

This study is subject to several limitations that may affect its generalisability. The uncertainty in climate models, particularly regarding the timing, probability and specific impacts of an AMOC collapse, makes it challenging to predict health-related consequences accurately. Additionally, the complexity of linking large-scale climate phenomena to specific health outcomes requires the integration of diverse and reliable datasets, which are not presently available. The focus on Europe, particularly Germany, may limit the broader applicability of the findings, potentially overlooking global health impacts and interdependencies that influence local outcomes. Moreover, the transdisciplinary nature of the study, involving expert opinion across various disciplines and sectors, can present challenges, which may limit the depth or coherence of the findings. These limitations must be considered when interpreting the results and applying them to other contexts or regions.

Recommendations for research, policy and practice

First, research should focus on refining climate models to reduce uncertainties linked to an AMOC collapse. Second, more comprehensive research is needed to model the specific health and societal consequences of rapid temperature changes and extreme weather events. Third, policymakers should prioritise the development of robust adaptation strategies, including improving infrastructure resilience in coastal cities like Bremen and Hamburg. Finally, public health practices should be enhanced to prepare for potential climate refugees and to address the health challenges associated with colder winters and more severe storms. Integrating these efforts into existing climate change mitigation plans is crucial, recognising that preventing an AMOC collapse through aggressive carbon reduction is paramount, as adaptation to such a severe climate catastrophe may not be viable.

Conclusion

This research highlights the profound and multifaceted health and societal challenges an AMOC collapse poses, emphasising vulnerabilities in Germany's healthcare system, food security and crisis response. Cold temperatures, extreme weather events and ecosystem disruptions could strain emergency services, intensify or moderate infectious disease risks and impair psychosocial health. Structural inequities, resource shortages and insufficient preparedness further compound these risks. Addressing these challenges requires proactive adaptation strategies, including strengthening healthcare infrastructure, enhancing disaster response systems and fostering sustainable practices in agriculture and energy. Effective communication about climate tipping elements is critical to drive public awareness and policy action. While focused on Germany, this study underscores the interconnectedness of climate, health and societal resilience, offering insights to inform broader global efforts to mitigate and adapt to climate-related risks.

Supporting information

S1 Fig. Yearly temperature difference in AMOC collapse scenario. Based on the Community Earth System Model by van Westen RM, Kliphuis M, Dijkstra HA. Physics-based early warning signal shows that AMOC is on tipping course. Sci Adv. 2024;10. https://doi.org/10.1126/sciadv.adk1189.
(TIF)

S2 Fig. Monthly temperature trend in AMOC collapse scenario. Based on the Community Earth System Model by van Westen RM, Kliphuis M, Dijkstra HA. Physics-based early warning signal shows that AMOC is on tipping course. Sci Adv. 2024;10. https://doi.org/10.1126/sciadv.adk1189.
(TIF)

S1 File. Topic guide.
(PDF)

S2 File. Positionality statement.
(PDF)

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