Heatwaves: an invisible risk in UK policy and research

Brimicombe, C., Porter, J. J., Di Napoli, C., Pappenberger, F., Cornforth, R. ORCID: https://orcid.org/0000-0003-4379-9556, Petty, C. and Cloke, H. L. ORCID: https://orcid.org/0000-0002-1472-868X (2021) Heatwaves: an invisible risk in UK policy and research. Environmental Science & Policy, 116. pp. 1-7. ISSN 1462-9011 doi: 10.1016/j.envsci.2020.10.021 Available at https://centaur.reading.ac.uk/93835/

Environmental Science and Policy 116 (2021) 1–7

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Heatwaves: An invisible risk in UK policy and research

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ARTICLE INFO

Keywords:
Heatwave
UK
Policy
Health
Building
Risk

ABSTRACT

In 2019, a heatwave – an unusual extended period of hot weather – broke the UK's highest recorded temperature of 38.7 °C set in 2003. Of concern is that for summer 2019, this resulted in 892 excess deaths. With the intensity and frequency of UK heatwaves projected to increase, and summer temperatures predicted to be 5 °C hotter by 2070, urgent action is needed to prepare for, and adapt to, the changes now and to come. Yet it remains unclear what actions are needed and by whom. In response, a systematic literature review of UK heatwaves peer-reviewed publications, inclusive of keyword criteria (total papers returned = 183), was conducted to understand what lessons have been learnt and what needs to happen next. Our research shows that heatwaves remain largely an invisible risk in the UK. Communication over what UK residents should do, the support needed to make changes, and their capacity to enact those changes, is often lacking. In turn, there is an inherent bias where research focuses too narrowly on the health and building sectors over other critical sectors, such as agriculture. An increased amount of action and leadership is therefore necessary from the UK government to address this.

1. Introduction

In 2019, a heatwave broke the UK's highest ever recorded temperature of 38.7 °C set in 2003. Over 2 heatwaves 892 excess deaths were recorded (Public Health England, 2019). Of concern here is that the intensity, frequency, and duration of UK heatwaves are all projected to increase, and summer temperatures are predicted to be 5 °C hotter by 2070 (Lowe et al., 2018) yet the UK Government's efforts to prepare for, and adapt to, these risks has been heavily criticised for leaving the UK 'woefully unprepared' (Carrington, 2018; The Committee on Climate Change, 2017; Environmental Audit Committee, 2018; Howarth et al., 2019).

Too often the problems of heatwaves are narrowly defined as one concerned with public health alone. To date, the only tangible heatwave plan in the UK is led by the Department of Health and Social Care and is aimed primarily at healthcare service providers (Public Health England, 2018). Yet heatwaves can have other negative impacts too. For instance, they can affect 'critical national infrastructure such as transport, digital systems and water supply…' cause 'railway tracks [to buckle which] are costly to repair' and in 2010 led to economic losses of £770 million related to lost staff days (Environmental Audit Committee, 2018: 4). The risks posed by heatwaves are, importantly, not confined to a single sector but cut across different sectors in both predictable and unpredictable ways (Howarth et al., 2019). Such 'silo thinking', where an issue is only dealt with by individual sectors with little or no communication between affected sectors (c.f. Pregernig, 2014; Rogers-Hayden et al., 2011), has become politically ingrained in how the UK approaches the management of heatwaves.

In turn, the UK's research and forecasting arrangements for heatwaves are institutionally fragmented. The UK Met Office is responsible for providing meteorological and climatological data and advice to policymakers and the public nationwide. In partnership with Public

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https://doi.org/10.1016/j.envsci.2020.10.021
Received 30 March 2020; Received in revised form 17 August 2020; Accepted 23 October 2020
Available online 10 November 2020

Health England, the Met Office runs an early warning system for heatwaves from 1st June to 15th September each year (Met Office, 2020). Yet this service only covers England. Scotland, Wales and Northern Ireland receive no official warnings, and it is unclear to what extent they are covered by the National Severe Weather Warnings system (Met Office, 2020). Institutional peculiarities are found in the evidence base used to inform government policy too. As part of the UK's 2008 Climate Change Act, a risk assessment must be conducted every five years to identify which climate risks the UK faces, and therein, inform a National Adaptation Programme to tackle these risks. Whilst the first and second Climate Change Risk Assessments called for urgent action to address heatwaves (The Committee on Climate Change, 2017; DEFRA, 2018), the problem of overheating – whereby a building becomes too hot reducing comfort and productivity for those using that space – will only be addressed from 2023, too late to cover new homes built to meet the Government's housing targets of 1.5 million by 2022 (Committee on Climate Change, 2020).

Another challenge here is that there is no universal definition for what a 'heatwave' is. For instance, the World Meteorological Organization (2018: 4) defines a heatwaves as, 'A period of marked unusual hot weather (maximum, minimum and daily average temperature) over a region persisting at least three consecutive days during the warm period of the year based on local (station-based) climatological conditions, with thermal conditions recorded above given thresholds'. The UK Met Office, by contrast, defines a heatwave as a point 'when a location records a period of at least three consecutive days with maximum temperatures meeting or exceeding a heatwave temperature threshold' (McCarthy et al., 2019). Although subtle these definitions reveal competing criteria for what constitutes a heatwave: the uniqueness of the event itself vs. exceedance of a predetermined temperature threshold, which only adds to confusion when planning to manage the impact of heatwaves, especially when mortality rates can also increase from above average temperatures not just from a heatwave (Abeling, 2015). For this study, a heatwave will be defined as an unusual period of extended hot weather.

At present, research suggests that the problem faced by the UK in managing heatwaves is a political one (Environmental Audit Committee, 2018; Howarth et al., 2019). Either there is insufficient political appetite, patchiness in provision of forecasting services, or a lack of capacity to implement policies. Yet such reading pays little attention to what 'research' is being used to inform heatwave policy in the UK and why silo-thinking has taken root. To better understand how UK heatwave research has developed over the last twenty years, and importantly to assess what are the drivers, barriers and recommendations for future heatwave policy, a systematic literature review was conducted. This research seeks to pinpoint where the problem of inaction comes from and what could be done in response. To do this, the data and methods used to conduct the systematic literature review are explained in the next section, followed by the key findings, and a discussion of what those findings mean and why they are important.

2. Data and methods

To understand how UK heatwave research has developed over the last twenty years, and to assess the main drivers, barriers and recommendations for future policy, a systematic literature review was conducted (cf. Berrang-Ford et al., 2010; Porter et al., 2014; Porter and Birdi, 2018). Web of Science, and Scopus, two of the largest and most comprehensive publication index databases, were used to perform a keyword search for peer-reviewed research published between 1st January 2000 and 31st December 2019. Research published prior to 2000 was excluded because the UK's ten hottest years on record have happened in the last two decades and the frequency, intensity and duration of UK heatwaves have also increased since that point (McCarthy et al., 2019).

Systematic literature reviews offer an effective, transparent, accountable, and reproducible method for identifying, analysing and synthesising large amounts of published research (Ford et al., 2011). By making both the selection criteria and the analytical framework used explicit from the outset, biases can be reduced and more reliable conclusions reached. As noted earlier, the term 'heatwave' is understood and enacted differently across disciplines – hot spells, extreme weather events, severe heat – and therefore different keyword combinations were used to ensure the topic was comprehensively searched (see Supplementary Materials). In total, 33 keywords were used across 3 categories: (i) *topic*: heatwave identifying characteristics; (ii) *purpose*: policy and research domains; and (iii) *place*: countries within the United Kingdom. 183 publications were returned. After importing the publications to an MS Excel spreadsheet, inclusion and exclusion criterion were applied.

Only empirical, peer-reviewed, publications written in English and focusing on UK heatwave policy were analysed. Impact studies that only focused on modelling future mortality rates or temperature projections, for instance, and papers concerned with detection and attribution, were excluded. Publications that failed to address the main drivers, barriers, and recommendations for formulating and/or implementing UK heatwave policy, were also excluded. 52 journal articles fulfilled the inclusion criteria.

To ensure consistency, a qualitative scorecard was created to record key details about the retained journal articles including funding sources, disciplinary orientation, research focus, and methods used. This data helped to build a picture on 'what' research was being done, and in 'which' sector, so that linkages and gaps could be identified. A thematic analysis of the dataset was then performed whereby a ranking criterion was developed to differentiate between the high-quality, empirically robust, publications and the less rigorous studies using a grading system from one to five. A five-star paper used method(s) highly appropriate for the research question(s), included a large sample size (e.g. $>$ 200 survey subjects or 50 interview participants), and were critically and reflexively analysed. By contrast, a two-star paper or below was more exploratory in nature, with lower data points (e.g. $<$ 50 survey respondents or $<$10 interview participants), and the findings were more speculative (see Supplementary Materials).

20 journal articles (38.5 % of the retained search) scored three-stars or above and were analysed. Of these, different research designs were used such as quantitative (n = 7), qualitative (n = 7), and mixed methods (n = 6), and the sectors covered focused on: health (n = 8), building/infrastructure (n = 6) and behaviour/adaptation (n = 6).

3. Results

To date, the UK's most prominent heatwave policy is the 'Heatwave Plan for England' (see Supplementary Materials for full details). It covers England only, however (n = 9/20 – number of papers out of total that mentioned this policy) (Public Health England, 2018). Under the plan, responsibilities are divided between the Department of Health and Social Care, which takes the lead role in coordinating heatwaves responses across the National Health Service (NHS) and community health services, and the UK Met Office, which forecasts heatwaves and issues warnings to healthcare practitioners and Local Government (Met Office, 2020).

Our review suggests that questions remain over the effectiveness of the interventions proposed by the Heatwave Plan for England, whether these interventions are aimed at the right people, and if sufficient efforts are being made to manage heat risk in sectors beyond health Many studies praised the Heatwave Plan, for putting in place reactive measures, which are reviewed annually (Abeling, 2015; Abrahamson and Raine, 2009; Khare et al., 2015; Page et al., 2012). However, these studies also raised challenges the Heatwave Plan doesn't address, for instance, Abeling (2015: 7) suggested that the plan failed to 'consider social, environmental and technical risk dimensions', which is due to the reactive nature of the plan. Whilst Page et al. (2012) argued that the heatwave plan does not address the risks posed to mental health

patients, especially those based in the community.

Several studies (n = 3/20) also referred to the important role that national climate change policies can play such as the UK's latest Climate Change Risk Assessment, which identified heatwaves and building overheating as 'high risk' (The Committee on Climate Change, 2017), and the National Adaptation Plan, which seeks to address these risks (DEFRA, 2018). Of interest here is the Climate Change Risk Assessment considers the level of heat risk to be the same for all parts of the UK. Our review, however, found that the evidence base for heatwave research varies geographically as 94 % (n = 172/183) of the returned results for the original Scopus search focused on England, and only fraction considered Wales (n = 10/183) and Scotland (n = 1/183), with Northern Ireland absent altogether (n = 0/183).

In terms of the building sector, which is responsible for designing and building new homes, office space, schools, and other properties; there is no official Government policy and/or legislation that requires overheating to be factored into new builds. Rather 'best practice' involves following the Chartered Institution of Building Services Engineers (CIBSE) thermal comfort guidance (CIBSE, 2013, 2015, 2017). Yet two-thirds of the overheating studies reviewed suggest that upwards of 20 % UK buildings exceed the maximum thermal comfort limit for a normal UK summer, without additional extreme heat, or the projected higher summer temperatures from climate change (Baborska-Narożny et al., 2017; Vellei et al., 2017).

3.1. What are the main drivers for formulating and/or implementing UK heatwave policy?

Of the 20 papers reviewed, the main drivers that influence the formulation and/or implementation of UK heatwave policy were: (i) the occurrence of a heatwave event(s); (ii) concerns about the frequency, severity and duration of heatwaves increasing due to climate change; and (iii) growing recognition of the wide range of vulnerabilities exposed by heatwaves. The vast majority of papers (80 %, n = 16/20) found that heatwaves, such as the 2003 European heatwave, were instrumental in the development of new policies and/or plans as well as research into warning systems and coping strategies.

Nearly half of the papers (40 %, n = 8/20) agreed that the growing scientific infrastructure around heatwave forecasting, particularly in relation to climate change risk assessments and projections, was also a driving force in the formulation and implementation of UK heatwave planning. It was noted that as the frequency, severity and duration of heatwaves increase, if the UK does not adapt fully and soon key sectors, including healthcare and agriculture, could fail (The Committee on Climate Change, 2017). Indeed, the UK's 2019 climate projections suggest that the 2003 heatwave will become a normal event for UK summers by 2040 (Murphy et al., 2019).

Over a third of the papers (35 %, n = 7/20) agreed that the growing recognition of vulnerabilities exposed by heatwaves played an important role in driving UK heatwave policy and/or plans. The Intergovernmental Panel on Climate Change, for instance, defines 'vulnerability' as 'the propensity or predisposition to be adversely affected' and it 'encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt' (IPCC et al., 2013, p. 128). How vulnerability is defined depends, however, on the sector. Healthcare studies (n = 9/20) identified vulnerable groups as those above the age of 65 and/or those with pre-existing medical conditions such as respiratory diseases (Abrahamson and Raine, 2009; Page et al., 2012). Infrastructure studies (n = 6/20), by contrast, focus on vulnerable as the capacity for buildings or equipment to cope with excess temperatures such as the failure of signals for the railway network (Ferranti et al., 2016, 2018; Larcom et al., 2019).

3.2. What barriers were identified to the formation and/or implementation of UK heatwave policy?

14 barriers were identified to the formulation and/or implementation of UK heatwave policy or plans. As shown in Fig. 1, the most frequent barrier cited was the perception that heatwaves are not a risk (n = 10/20). Prior to 2003, heatwaves in the UK were fairly uncommon occurring in 1976 and 1995 (see Fig. 2). This may help clarify why, as Wolf et al. (2010: 47) explains, 'long term and anticipatory responses to heat [are] perceived as largely unnecessary because of a belief that heat waves are and will remain rather uncommon in the UK'.

A quarter of the studies (25 %, n = 5/20) also commented on how UK heatwaves are 'invisible' in comparison to other extreme meteorological events (Abeling, 2015; de Bruin et al., 2016; Ferranti et al., 2018; Murtagh et al., 2019; Taylor et al., 2014). As Murtagh et al. (2019) suggests, the visual impact and newsworthiness of flood events captures public attention far more than heatwaves, in part because newspaper coverage tends to link hot weather with barbeques and other positive outdoor pursuits as opposed to there being a risk. Indeed, Taylor et al. (2014) found that UK residents believe that floods are more likely to increase due to climate change than heatwaves. Adapting our original search in Scopus to account for floods instead of heatwaves, returned 1766 results for the keyword flood compared to 68 results for the keyword heatwave, which suggests that difference in public perceptions may also be related to a research bias in favour of flood risk studies over heatwave research.

A lack of research into different areas impacted by heatwaves was also identified by a third of the studies (35 %, n = 7/20) as a barrier. Although the 2003 European heatwave has served to generate more research in the healthcare and building sectors, other at-risk sectors including transport, energy, water and food are largely ignored. Even when research is happening the focus can be somewhat narrow. For instance, much of the research from the building sector concentrates on homes, with research on other building types such as schools and offices having to play catch up (Montazami and Nicol, 2013). In turn, behaviour studies suggest that building research rarely considers the motivation and capacity of users to tackle concerns with overheating risks or the role played by mental health and pro-environmental values (Khare et al., 2015; Murtagh et al., 2019; Page et al., 2012).

The barriers outlined in this section can hinder the uptake of heatwave research in policy decision-making. A research bias in favour of floods, for instance, serves to keep heatwaves as an 'invisible' risk whilst the amount of research conducted on some sectors (e.g. healthcare, building) can skew which risks are identified and who should be responsible for dealing with them so that a form of silo thinking develops in policy debates. Indeed, the UK's latest National Adaptation Plan uses the word 'heat*' 70 times compared to 251 times for 'flood*' (DEFRA, 2018).

3.3. What solutions were proposed to improve the formulation and/or implementation of UK heatwave policy?

Just under half of the studies reviewed (40 %, n = 8/20) agreed that a key solution to managing heatwaves is through 'targeted action'. For example, where a railway signal is at-risk of failing in a heatwave, a 'targeted action' would be to replace it before this occurred (Ferranti et al., 2016, 2018). Targeted action, therefore, involves identifying, assessing, and proactively intervening in current systems to reduce, or avoid, the negative impacts associated with a heatwave. For the healthcare plan, this could involve a shift away from concentrating responsibilities in a single Government department and redistributing those responsibilities according to where heat presents a risk across Government as a whole (Oven et al., 2012).

Another main solution discussed was how to better communicate heat risks using different strategies, across different geographical scales, and aimed at different actors. This was identified through 3 separate

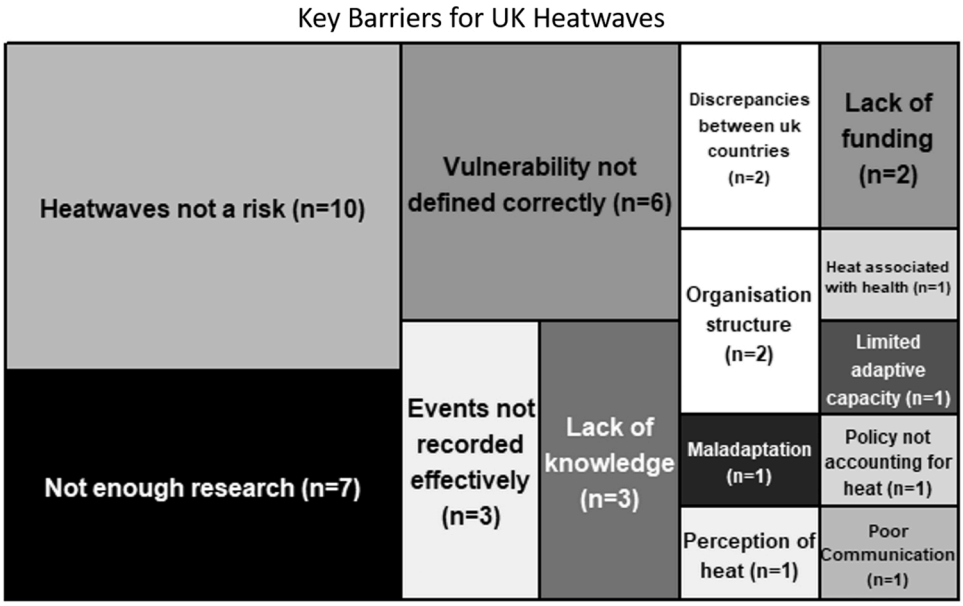

Fig. 1. Treemap visualisation of all 14 barriers identified in the dataset. The different size boxes represent the level of agreement within the dataset.

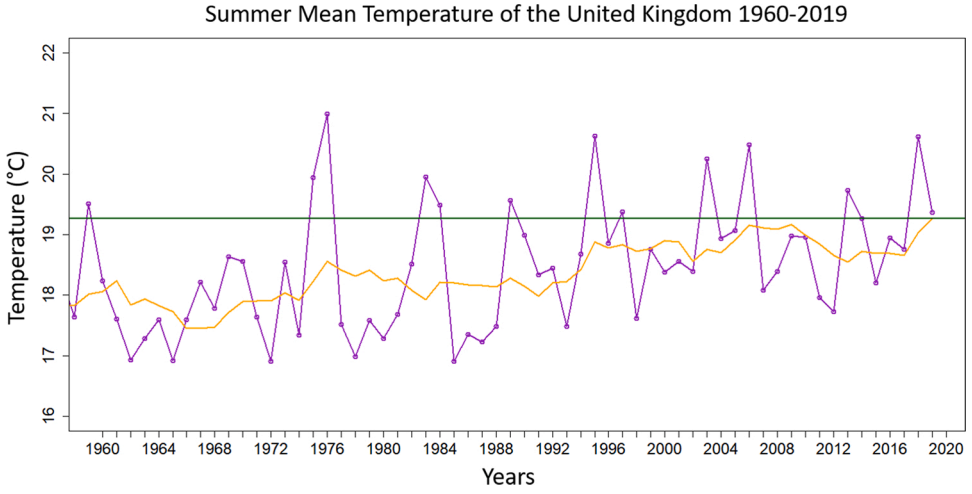

Fig. 2. Summer Mean Temperature for the UK 1960-2019. The purple line represents the trend of the summer mean temperatures from 1960 to 2019; the orange line depicts a smoothed rolling mean line of the summer mean temperatures; and the green line shows the 90th Percentile of summer mean temperatures from 1960 to 2019, purple values above this line indicate heatwaves (Met Office, 2018).

themes/scales: nationwide engagement with the population (n = 4/20), community-based engagement (n = 4/20) and the use of media (n = 3/20). Most communication solutions were proposed by research participants who were surveyed or interviewed through the studies. Abrahamson et al. (2008), for instance, reported that respondents suggested heatwaves should be incorporated in television or radio storylines, as a creative way to present the risk to a large proportion of the population. Whilst others have called on the Met Office to give heatwaves names similar to winter storms to help persuade the media, and by extension the public, of the serious risks heatwaves pose (Ward, 2019).

Furthermore, the papers reviewed agreed that more research could hold the answer to identify which sectors are at-risk, where targeted action is needed, and provide a richer and more robust evidence base to inform policymaking. One concern raised is that the UK's National Adaptation Plan seeks to empower the public to make decisions in their own interest to reduce their exposure to heat risks (Abeling, 2015; DEFRA, 2018). Yet the studies analysed suggest that the evidence base for heatwaves lacks sufficient depth to be able to inform policy on how to help people improve their adaptive capacity, drill down into the important role that social networks play in building up their resilience (Abrahamson et al., 2008; Wolf et al., 2010); or how the difference between a tenant and homeowner can limit adaptive capacities. More research was called for to better understand what solutions can be offered, and if these solutions are context specific (Baborska-Narożny et al., 2017; Murtagh et al., 2019).

4. Discussion

A major challenge faced by nation-states as well as international bodies over how best to manage heatwaves relates to a lack of evidence and inconsistencies within the evidence base that is available (e.g. geographical, sectoral). In the UK, silo thinking has taken root in the policy arena as the healthcare sector and building/infrastructure sector have been proactive in developing policies, plans and guidance, whilst other at-risk sectors are largely ignored. In turn, the research community has produced evidence to support these policy domains but again largely

ignored the challenges faced by other sectors and an imbalance between heatwave and flood risk research has emerged. As a result, UK policy and research on heatwaves have worked together to produce this 'invisible risk'.

4.1. Why are there discrepancies in the reporting and analysis of extreme weather events?

Arguably the imbalance in research between floods and heatwaves is borne out of a legacy, where triggering events motivate research and policy changes, which historically has favoured the higher frequency of flood events in the UK (Met Office, 2019). With more research written about UK flooding than heatwaves, an 'availability effect' has developed. That is, the importance of something is directly related to how prevalent it is and/or how it is perceived (Khare et al., 2015). Media reporting of extreme weather events has contributed to the 'availability effect' by framing floods as a risk, and heatwaves as an opportunity (Wolf et al., 2010).

Of interest here, is that discrepancies between extreme weather events is not unique to the UK. In 2017, the European Environment Agency released its report on 'Climate Change Adaptation and Disaster Risk Reduction'. A keyword search of the document for 'flood*' and 'heat*', returned 446 and 186 mentions respectively (European Environment Agency, 2017). Despite the European Union funding research projects on extreme heat, an imbalance exists in which extreme weather events are given top billing. At the international level, reports by the OECD (Organisation for Economic Co-operation and Development) and the WMO (World Meteorological Organisation), on Climate Change Adaptation and services the word 'flood*' appears at least twice as often as the word 'heat*' (GFCS, 2016; OECD, 2018). Yet for health and climate change reports by WHO (World Health Organisation), 'heat*' does appear more frequently than 'flood*', but suggests that extreme heat remains an 'invisible risk' outside of the health sector (WHO, 2019; 2018).

4.2. Are heatwaves an 'invisible risk'?

Our review shows that, outside of a select few policy domains, yes heatwaves remain an 'invisible risk' in the UK. However, a growing body of literature is seeking to change this by broadening the scope of research into other at-risk sectors. The grey literature may offer a template for the research community to follow here. The Joseph Rowntree Foundation, for instance, has commissioned several studies on heat risks that capture the experiences of practitioners and stakeholders working and living in exposed sectors, and found that the Heatwave Plan for England is too reactive in that it focuses on coping rather than building adaptive capacity within communities (Benzie et al., 2011). Likewise, the UK's second Climate Change Risk Assessment brought together insights from researchers and practitioners to review how heat risk had been discussed across different sectors, with the findings aimed at policymakers across the full breadth of Government (The Committee on Climate Change, 2017). Such efforts reveal how the profile of heat risks can be increased via more interdisciplinary and collaborative projects, and why future research should focus on mining the grey literature to see how to accelerate the changes it calls for in both policy and research too.

4.3. Why is defining heat-related vulnerability key?

Vulnerability was a central theme throughout the reviewed papers. Heatwaves events served to reveal where social inequalities exist in the capacity of people, buildings/infrastructure, and sectors to respond effectively. Yet it is important to remember that vulnerability is not static but dynamic. Different studies, and different sectors, conceptualised and enacted the discourse on vulnerability differently. Whereas for healthcare professionals 'vulnerability' concerns the ability of 'people' to adapt and respond, for building/infrastructure researchers 'vulnerability' concerns the 'physical apparatus' that allows everyday life to function (Curtis et al., 2017; Larcom et al., 2019; Murtagh et al., 2019; Page et al., 2012; Wolf and McGregor, 2013). One solution made in the review was that the Health and Social Care Act 2012 could be updated to include consideration for climate change, and particularly heat risk, as this would help mainstream the need to address vulnerabilities across all policy areas in Government (Rauken et al., 2015). This has also been highlighted in the grey literature (see Benzie et al., 2011; Royal Society et al., 2014).

4.4. What action is needed on overheating in buildings and at work?

To date, the vast majority of the research into building overheating has focused on homes. Despite research suggesting that up to 20 % of homes currently experience overheating problems during an average UK summer, new houses built in line with Government housing plans do not have to factor overheating into their designs (Peacock et al., 2010; Wilson and Barton, 2018). Moreover, the UK Government's own research has already found that new homes do overheat, but no policy action has been taken (MHCLG, 2019). New legislation on building standards is needed as 'best practice' guidance is not working (CIBSE, 2013, 2015; 2017).

It is also surprising the main research has been on homes given that – outside of a global pandemic – people come into contact with a wide variety of building types in their everyday lives. A growing body of literature is seeking to addresses the problem of overheating in other buildings such as hospitals, schools and offices (The Committee on Climate Change, 2017; Montazami and Nicol, 2013). But there is currently no 'maximum' safe working temperature under the UK's Workplace (Health, Safety and Welfare) Regulations 1992, despite there being a 'minimum' safe working temperature. This needs to be urgently addressed as exposure to extreme heat can be a contributory factor to a range of health conditions (Glaser et al., 2016) as well as impact upon productivity.

4.5. Is there a geography to UK heatwave research?

Yes, not only does a discrepancy exist in the amount of heatwave research conducted in different regions of the UK but this discrepancy is also mirrored in the formulation and/or implementation of official Government policies and plans (Khare et al., 2015). England is the only region of the UK that has a heatwave plan, and it focuses only on health (Met Office, 2020). Despite the UK's latest climate projections showing that heatwave will increase in frequency, severity and duration across all UK regions, the level of research and policy development does not follow these concerns. No research met our criteria for heatwaves policy and management in Northern Ireland. This is concerning because without an evidential base for policy at best the urgency of the problem will remain low and at worst it will remain an 'invisible risk'.

This result may be related to legacy as heatwave events have historically been rare in the UK and institutional fragmentation introduced through devolution – where each country controls how they are governed and the policy they prioritise – has impeded centralised planning and action This is important because heatwaves do not observe administrative boundaries: they are borderless. Yet the creation of the Heatwave Health Plan for England speaks to this inconsistency as only some sectors, and some places, prepare for and adapt to heat risks. Historically heatwaves spread across wide areas, for example the European Heatwave in 2003, and the Russian Heatwave in 2010. But it is key that all guidance on heat is developed to avoid patchiness in provision and response (e.g. WMO and WHO, 2015).

5. Conclusion

Despite scholars highlighting the importance of planning for, and

adapting to, the impacts of heatwaves in the UK (Environmental Audit Committee, 2018; Howarth et al., 2019; Public Health England, 2014), our research shows that the evidence base available to decision-makers is limited. Where evidence does exist, it is accompanied by a research bias. That is, the vast majority of studies focus on health risks or infrastructure. Other at-risk sectors, such as transport, energy, water and food, which are just as important to the functioning of our everyday lives receive considerably less attention. Risks posed by heatwaves are rarely limited to a single sector but cut across different sectors in both predictable and unpredictable ways. Efforts to formulate, and in turn, implement heatwave policies can encounter problems as Government departments have different mandates, priorities, and influence, and as a result, institutional responsibilities become fragmented and/or deferred (Environmental Audit Committee, 2018).

Our research also found that the heatwave evidence base varies geographically. Nearly all the studies focus on England, with Scotland and Wales receiving only a small amount of attention and Northern Ireland ignored altogether. Likewise, the official Government policy and/or plan for managing heatwaves focuses on just England. Yet heatwaves do not observe administrative boundaries. Without a rich, robust and diverse evidence base, the risk of maladaptation and poor coping strategies could increase on a regional basis. A major concern, therefore, is that heatwaves become an 'invisible risk' for policymakers. A lack of evidence, and inconsistencies within that evidence base, can serve to deprioritise the seriousness of heatwave risks and the urgency of policy action. For instance, 892 excess deaths were attributed to the UK's 2019 heatwaves whereas 11 deaths were ascribed to floods in the same year yet the evidence base and managerial resources for heatwaves is tiny in comparison to flood risk.

Unless the problem of 'silo thinking' in the way in which Government policy is formulated and/or implemented is urgently addressed, and the research community broadens the scope of studies to consider other at-risk sectors, the connections between those sectors, and actively seeks to fill gaps in the knowledge base between regions, then heatwaves will remain at worst an 'invisible risk' amongst policymakers or at best a niche debate between healthcare and building professionals. Answers on how to tackle these challenges may already exist but require more interdisciplinary thinking and commitment. Future research should focus on bringing insights from practitioners, local communities, and the grey literature together with scholarly research to provide a fully rounded picture on heatwave research so that policymakers can be better informed and supported when making decisions.

CRediT authorship contribution statement

Chloe Brimicombe: Conceptualization, Formal analysis, Investigation, Resources, Writing - original draft, Visualization. **James J. Porter:** Conceptualization, Methodology, Validation, Writing - review & editing. **Claudia Di Napoli:** Resources, Writing - review & editing. **Florian Pappenberger:** Writing - review & editing. **Rosalind Cornforth:** Writing - review & editing. **Celia Petty:** Writing - review & editing. **Hannah L. Cloke:** Supervision, Writing - review & editing.

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.

Acknowledgement

Chloe Brimicombe, wants to thank the SCENARIO DTP, ECMWF and the University of Reading for their continued support. All the authors, thank the reviewers for their invaluable advice.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.envsci.2020.10.021.

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