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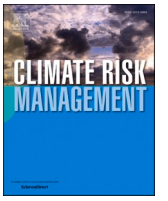

Identifying adaptation 'on the ground': Development of a UK adaptation Inventory

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ABSTRACT

Adaptation plays a crucial role in managing the unavoidable risks from climate change. The UK is considered to be at the forefront of national adaptation planning. However, the extent to which plans and programmes translate into tangible risk reducing action on the ground, as opposed to adaptive capacity building, remains less clear. Given that there is no formal database of adaptation action for the UK, despite the various needs of government to identify, assess and report on adaptation progress, including the UK national stocktake on adaptation under the UNFCCC Paris Agreement, this study outlines the development of an up-to-date and forward-looking UK Adaptation Inventory. The Inventory documents adaptation on the ground, based on national reporting to government by public and private sector organisations and a systematic review of peer-reviewed literature. The framework is centred on identifying and documenting current and planned adaptation; how it is being implemented in terms of the types of adaptation actions; and the sectors where adaptation is occurring and where gaps may remain. For the sub-set of sectors captured there is clear evidence of a wide range of cross-sectoral and sector-specific adaptation being implemented. In total, 360 examples were identified, over 80% of which have already been implemented. This comprises 134 different types of adaptation action, largely aimed at reducing vulnerability using engineered, built environment or technological mechanisms. Compared to the situation a decade earlier, this suggests that significant progress has occurred in the UK in terms of reporting and implementing adaptation, including adaptation by the private sector in climate sensitive sectors. At the broader level, the Inventory is a first step in providing a baseline assessment for the UK stocktake on adaptation; can help inform other organisations about adaptation options that are available; and provide case studies of actions in practice to help support decision-making.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC, 2018; 2014) estimate that human activities have already caused approximately 1 °C of global warming above pre-industrial levels. It is not only the human influence on the climate system that is clear, but also evidence of widespread impacts on human and natural systems, which will increase in severity in a warmer world (IPCC, 2018; 2014). The global community is demonstrating significant cooperation in terms of mitigation under the UNFCCC Paris Agreement,

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aimed at limiting global warming to well below 2 °C, preferably to 1.5 °C, compared to pre-industrial levels (UNFCCC, 2016). Nonetheless, the current Nationally Determined Contributions (NDCs) commitments under the Paris agreement are still expected to result in a warming of between 2.7 and 3.2 °C above pre-industrial levels (Gütschow et al., 2018). Given uncertainties over the level of stabilisation of greenhouse gas emissions, and lags in the climate system that mean decades of committed temperature change and centuries of committed sea-level rise from historical anthropogenic emissions alone (Oppenheimer et al., 2019), the past decade has seen an increased focus on adaptation as a risk management strategy.

However, the adaptation gap, defined as the difference between existing adaptation efforts and adaptation need (Chen et al., 2016) is in many cases widening (UNEP, 2021, Climate Change Committee, 2021). Addressing this gap is critical given adaptation will play a vital role in managing not only the unavoidable risks from future climate change, but also risks from today's climate. The Paris Agreement commits both developed and developing countries to adapt to climate change (UNFCCC, 2016). It has established a global goal on adaptation to enhance adaptive capacity, capturing progress towards commitments in the form of a Global Stocktake. The first Global Stocktake will be undertaken in 2023, and every five years thereafter, with Parties invited to report progress towards the adaptation goal (*ibid*). Tracking adaptation is considered an urgent priority critical to understand if adaptation is taking place, to support future decision-making (Berrang-Ford et al., 2021) and drive future action. As a starting point, it is essential to have a clear baseline of current adaptation against which further assessments can be carried out. For example, if identified actions are reducing vulnerability and if policy decisions and global agreements are contributing to increased adaptation investment (Ford et al., 2015). A key priority for countries, therefore, is to begin creating a national narrative of current adaptation efforts (Beauchamp and Bueno, 2021).

The aim of this study is to use the UK as a case study to analyse current and planned adaptation on the ground in the UK, to support understanding of how adaptation is being implemented in terms of the types of adaptation actions; to identify the sectors where adaptation is occurring and where gaps may remain; and begin to create a baseline of current adaptation for the UK's adaptation stocktake.

However, the methodological process by which countries will define, track or measure various components of adaptation, such as its adequacy and effectiveness, in a manner that can be aggregated and compared across different contexts and sectors is still unclear and challenging (Kato and Ellis, 2016, Christiansen et al., 2020, Dilling et al., 2019, Craft and Fisher, 2018, Berrang-Ford et al., 2019). One barrier is that there is no specific or universally accepted definition of adaptation (Biagini et al., 2014, Tompkins et al., 2018, Berrang-Ford et al., 2019, Ford et al., 2013). The IPCC (2014, pg.5) define adaptation as: "The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects". At a broad level, adaptation can be characterised by timing, reflecting proactive or reactive adaptation; the degree of spontaneity, reflecting planned or autonomous adaptation; or its resource dimension, capturing hard and soft interventions (Power et al., 2020, Smit et al., 2000).

Given the diverse range of adaptation actions available to different stakeholders, sectors, communities and individuals, there are numerous detailed and/or context specific typologies of adaptation (e.g. see Tompkins et al., 2010, Berrang-Ford et al., 2011, UKCIP, 2018, Power et al., 2020, Smit et al., 2000, Biagini et al., 2014, Grüneis et al., 2018). The IPCC (2014)(IPCC, 2014a) categorise adaptation actions into ten categories that are more broadly defined by their Structural and/or Physical, Social or Institutional mechanism or form. Tompkins et al., (2018) highlight the merits of focusing on the objectives of adaptation by categorising actions into sub-categories of reducing socio-economic vulnerability; disaster risk reduction; or building social-ecological resilience. Power et al., (2020) identify a typology based on the behavioural objectives, covering hazard reduction and avoidance; vulnerability reduction; preparing to respond; coping during a crisis; and preparing for recovery. This is aligned with the concept of risk defined by the IPCC (2014) as "the interaction of vulnerability (of the affected system), its exposure over time (to the hazard), as well as the (climate-related) hazard and the likelihood of its occurrence".

Empirical evidence also highlights how, across typologies, adaptation can be viewed in terms of whether the objective is to build adaptive capacity or to deliver adaptation action. The former increases the ability of systems, institutions, or individuals to adjust to potential changes. For example, by undertaking research; knowledge exchange and raising awareness through education and training schemes; creating a supportive institutional environment through legislation; or developing appropriate strategies and plans. In contrast, the latter transforms adaptive capacity into practical action 'on the ground' (Tompkins et al., 2010, UKCIP, 2018), for example through building flood defences, flood proofing buildings or relocating buildings.

There is growing evidence that national and sub-national government and a range of sectors across the world are embedding adaptation into some planning processes and adapting to climate variability and change (UNEP, 2021). In many instances the challenges and experience of adaptation are not new, given the historical need of human systems to manage and cope with natural climatic variability (Berrang-Ford et al., 2011). The extent to which these plans capture current and future risks, however, and the success of such planning in terms of transforming adaptive capacity into action on the ground, is less clear (Preston et al., 2011, Lorenz et al., 2019, Ford and Berrang-Ford, 2016, IPCC, 2014).

The IPCC highlight the challenges faced by governments in moving from national or local adaptation planning and policy making to implementation. Few assessments of adaptation focus on the practical process of implementation and the outcomes of adaptation actions, key components that the global adaptation stocktake aims to track, versus those discussing concepts, strategies, and plans themselves (Mimura et al., 2014, Berrang-Ford et al., 2021). Further barriers include that existing adaptation assessment frameworks are often not designed to be consistent or transferable across regions, sectors, and governments but tend to be highly case specific (Berrang-Ford et al., 2019); there can be a disconnect in timescale between adaptation implementation and subsequent assessments needed to inform policy (Ford et al., 2013); and climate adaptation can intersect different policy spheres, such as those related to development or disaster risk management (Lesnikowski et al., 2017).

Consequently, defining, identifying, and documenting climate related adaptation poses many challenges (Ford et al., 2015). Adaptation databases suitable to inform the Global Stocktake remain rare (Tompkins et al., 2018, Ford and Berrang-Ford, 2016, de Bruin et al., 2009), as does more detailed information on the type of adaptation actions being implemented on the ground (Jude et al., 2017).

However, national reporting of adaptation can help governments to identify and assess progress in this area (Defra, 2011), as underscored by the need to report on progress as part of the Paris Agreement. The UK is considered to be at the forefront of adaptation planning (Lesnikowski et al., 2020). It provides one of the earliest examples of a strategic national legal framework for climate change action in the form of the Climate Change Act 2008 (Averchenkova et al., 2021). In addition to mitigation, the Act contains several components on adaptation including a continuous 5-year cycle of adaptation planning, beginning with a Climate Change Risk Assessment (CCRA), which informs the National Adaptation Programme (NAP) aimed at responding to key risks. Another aspect of the Act is the Adaptation Reporting Power (ARP), which enables the Secretary of State to ask key organisations with climate-sensitive services and infrastructure, such as water companies, to report the steps and actions planned to adapt to identified current and/or future climate change (Street et al., 2017, Committee on Climate Change, 2017a). A primary aim of the ARP is to ensure that these organisations are systematically assessing present and future climate risks and providing evidence on the level of preparedness and adaptation actions (Defra, 2011). Two reporting rounds were completed in 2011 and 2015, with a third in progress with reports now being published in 2022. Despite its many achievements, however, over a decade after the adoption of the Act there is still concern that adaptation is receiving less attention and progressing more slowly than mitigation, and there is inertia in translation of the broader adaptation planning and reporting under the Act into tangible risk reduction on the ground (Fankhauser et al., 2018). Recent evidence from the UK Climate Change Committee affirms this, by concluding that adaptation action has failed to keep pace with climate risk resulting in a widening adaptation gap (Climate Change Committee, 2021).

Evidence of this inertia has also been highlighted in academic reviews. Preston et al. (2011) reviewed local, regional and national adaptation strategies from the UK, United States, and Australia prior to December 2008, and found that capacity building was dominant (72%) compared to options that specified delivering adaptation actions on the ground. At the sectoral level, Tompkins et al., (2010) developed an inventory of adaptation in the UK by reviewing academic peer-reviewed papers, government and company reports, trade documents, media reports and UK Climate Impacts Programme (UKCIP) reports. Six sectors were analysed: water supply; flood management; construction; agriculture and forestry; biodiversity and conservation; and transport; providing a snapshot of adaptation in 2005. Although 300 adaptation actions were identified, most related to building adaptive capacity. Just twelve related to the implementation of adaptation actions. In addition, Porter et al., (2014) note that in the UK, like other developed countries, academic research predominantly focuses on adaptation by public and private organisations, overlooking the role of individuals and households.

These limited examples of documented adaptation on the ground in the UK are also reflected in other national-, European- and global-scale reviews. Given the growing importance and emphasis now placed on adaptation, including the forthcoming Global Stocktake, there is a pressing need to systematically document adaptation on the ground in the UK versus aspirations and theory (Tompkins et al., 2018). In this study, this is achieved through the development of an up-to-date and forward-looking UK Adaptation Inventory (henceforth referred to as the Inventory), made available as an online, searchable database. The Inventory framework has been designed to collate key information on each identified example of adaptation. The Inventory has been populated based on (1) a critical review of the second round ARP reports submitted by public and private sector organisations; and (2) a systematic review of peer-reviewed literature.

As well as providing an insight into what is happening on the ground in the UK, and synthesising information into a baseline assessment of adaptation for the UK stocktake, the Inventory provides a resource to build on, allowing policymakers and adaptation practitioners to learn from existing knowledge and practical case studies. Providing more in-depth information about actual adaptation actions that are technically, economically, and politically feasible, as evidenced through their implementation elsewhere, could enable policymakers and other organisations to make better informed choices about the different adaptation actions that are available (de Bruin et al., 2009, Tompkins et al., 2018). Such information can also support the communication of lessons learned and examples of best practice (Kato and Ellis, 2016, Biagini et al., 2014).

2. Method: Constructing the UK adaptation Inventory

The current version of the Inventory uses two key methods to search for examples, advocated by Tompkins et al., (2018). First, examples of adaptation are identified based on a systematic review of academic literature (Section 2.1). Second, examples of adaptation are identified from grey literature, representative of the inventory approach outlined in Tompkins et al., (2010). In both Sections 2.1 and 2.2 the methodology is focused on examples of delivering adaptation action on the ground. The definition of adaptation action on the ground used here is in line with the broader definition of adaptation from the IPCC (2014, pg5), focused on actions that reflect "a process of adjustment to actual or expected climate and its effects". The key identifier in this study, however, is actions that reflect a tangible and physical change in response that delivers adaptation action as opposed to building adaptive capacity (UKCIP, 2018). This firstly addresses criticism that previous methods of reporting adaptation have focused on intentions to act rather than actual action, for example through the inclusion of broader policies and programs as adaptation (Tompkins et al., 2018, Berrang-Ford et al., 2011). A second benefit of this method is that it explicitly highlights where there has been a transition from planning to practice, the type of adaptation action adopted, and by whom.

2.1. Systematic review of peer-reviewed literature

Systematic review allows the user to identify, analyse, and synthesise large amounts of literature in a practical and transparent manner (Porter et al., 2014, Berrang-Ford et al., 2015, Biesbroek et al., 2013). A growing number of studies have used systematic review to reframe questions on climate change adaptation, at the sub-national, national, and global level, moving from those focused on how human systems might or could adapt in theory to questions of if and how adaptation is taking place in reality, the speed of action, sectors or organisations involved, and barriers to adaptation (Berrang-Ford et al., 2011, Lesnikowski et al., 2020, Ford et al., 2011, Porter et al., 2014, Biesbroek et al., 2013, Lorenz et al., 2019).

The framework used here follows that of Berrang-Ford et al. (2011) to guide the document selection and analysis. First, a keyword search of the ISI Web of Science database was conducted, using the terms *climat*, chang*, adapt** plus locational terms such as the

Table 1
Overview of the UK Adaptation Inventory framework (see Table SM2.1 for full description of criteria).

		Description	Examples
1	Climate-related hazard/event	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources (IPCC, 2014, 2018).	Extreme rainfall; increasing temperature.
2	Climate-related compound hazard/event	As above, where reports have listed two or more concurrent or successive hazards.	Flooding; drought
3	Risk	Risk refers to the potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services, and infrastructure. Risk results from the interaction of vulnerability, its exposure over time, as well as the hazard and the likelihood of its occurrence (IPCC, 2014, 2018).	Heat Stress; damage to infrastructure.
4	Name of Reporting Organisation	This could be the name of a private sector organisation, a NGO, or government/government department etc. Where possible specific examples from the peer-reviewed literature have been classified based on the name of the reporting organisation cited in the paper. Where this is not provided, the entry is classed as 'peer reviewed paper'.	Natural England; Environment Agency.
5	Sector	Name of sector the reporting organisation belongs to. This reflects the terminology used by the ARP to group the reporting organisations.	Road and Rail; Electricity Transmitters
6	Sector Type	Defines if the sector is 'Public', 'Private', 'Other', or 'Individual', expanded from the classification of Tompkins et al., (2009), and as reported by organisations themselves.	Public – corporation; Private.
7	Geographical Location (NUTS1 region)	Broad geographical location/s the Organisations cover - Categorised using NUTS1 statistical regions for consistency (Eurostat, 2018)	East of England; South East England.
8	Geographical Location (further details)	Further detail of the organisation's geographical extent, or where provided specific details of location/s where adaptation implemented.	The Midlands; Lizard point.
9	Adaptation action	The type of adaptation action.	Property-level flood protection; Water metering.
10	Further details on adaptation action	Provides further details on the example of adaptation action recorded, as provided by the reporting organisation/peer-reviewed literature.	
11	What is being adapted/where is adaptation action being applied?	This provides an indication of the level at which adaptation action is being applied.	Infrastructure; properties; operations.
12	Expected outcome/benefit of the adaptation option	What does the organisation aim to achieve by implementing the adaptation option? As detailed by the reporting organisation/within peer-reviewed literature.	Reduce flood risk; Increase resilience of water supply.
13	Status of the adaptation option	If the adaptation action has been implemented, is planned, or a potential option that may be used in the future.	Implemented, Planned.
14	Further details on timescale of option	Where reported further details on the timescale of the adaptation option.	Planned for 2020–2025.
15	Typology of Adaptation Option – Mechanism	Adaptation is categorised by mechanism into one of three general categories: structural/physical, social, or institutional, and one of ten sub-categories (Mimura et al., 2014, Table 14.1).	Structural/Physical (Engineered and built environment); Structural/Physical (Technological)
16	Typology of Adaptation Option – Objective	Adaptation is categorised by behavioural objective into one of five categories: hazard reduction and avoidance; vulnerability reduction; preparing to respond; coping during a crisis; and preparing for recovery (Power et al., 2020).	Hazard reduction and avoidance; Vulnerability reduction
17	Challenges / Barriers to adaptation	Details any specific challenges and/or barriers to action that are reported.	Additional cost; dependent on the flexibility of local planning regulations
18	Was adaptation reactive?	Whilst extremely difficult to separate out if actions are anticipatory or reactive, where actions were clearly described as reactive following e.g. an extreme weather event, this has been recorded.	
19	Reference	Link to source material.	
20	Type of literature	If the literature is based on peer-reviewed papers or ARP reports.	ARP 2nd Round

United Kingdom, or *UK*. Following Porter et al., (2014) two subsequent searches were then conducted to account for the different terminology that may be used in place of climate 'change', covering *climat*, variab*, adapt** and *climat*, extreme*, adapt** (see SM1 Tables SM1.1-SM1.3 for further details). The searches covered the time period 1st January 2010 to 30th September 2020, providing an overview of adaptation action, reflected in peer-reviewed literature, over the past decade.

The results of the searches were combined, and duplicate entries removed, resulting in the identification of 763 papers. The papers were exported to Endnote, with the paper titles and abstracts reviewed and categorised for inclusion or exclusion based on the criteria outlined in Berrang-Ford et al. (2011). For inclusion, the paper title and/or abstract needed to explicitly indicate that previous or currently practiced adaptation is reported, mentioned, assessed, or discussed in the paper. The criteria differed from that of Berrang-Ford et al. (2011) in that options deemed as building adaptive capacity, such as improving the knowledge base, communication, etc., were also excluded. Only examples where the adaptive action was set in place on the ground or planned for implementation were included. Where the above criteria could not be directly ascertained from the abstract alone, a full review of the paper was carried out. Papers marked for inclusion were read in full and details of the adaptation options cited included in the Inventory (see Section 2.3).

2.2. Review of second round ARP reports

Two ARP rounds have been conducted from 2010 to 2012 and 2013–2016, with the third ongoing (2019–2021) (Street and Jude, 2019, Committee on Climate Change, 2017a). During the first round 91 organisations were requested to submit adaptation plans, whilst 13 were invited to report voluntarily. The second round reporting was voluntary, reflecting a more light-touch review of progress on actions to date and the inclusion of new adaptation actions (Committee on Climate Change, 2017a). The Inventory currently reflects the more recent second round reports only. In total 59 reports were submitted representing 88 organisations (some submitted joint reports). Each of the 59 reports were read and details of adaptation actions reported included in the Inventory (see Section 2.3). The approach has similarities to *inter alia* the inventory-based approaches of Tompkins et al., (2010) and de Bruin et al., (2009), in that it is focused on identifying sector specific adaptation actions in grey literature and recording details in a predefined template shaped around core questions.

Mimura et al., (2014) note that in many cases adaptation practices have been embedded in existing policies, and are not necessarily framed as climate adaptation actions, making these examples harder to identify in searches. Likewise, Tompkins et al., (2010; 2009) found it difficult to judge which actions identified in the grey literature could be classified as climate change adaptations, and of these, which were planned in response to climate change as opposed to other drivers. For example, measures by water companies to reduce demand-side pressures driven by increasing population aim to reduce the strain on the water supply system. In parallel they help reduce vulnerability that may arise due to climate-related pressures, given trends towards warmer, drier conditions and more likelihood of droughts (Committee on Climate Change, 2017b). The focus on the second round ARP reports helps overcome some of these identification challenges, given reporting organisations have explicitly identified climate risks, which may well occur in parallel with other drivers, and articulated how they plan to adapt to these specific risks.

2.3. The UK adaptation Inventory framework

The Inventory framework has been developed to collate key information on each identified example of adaptation action, following a clear structure and set of definitions (Table 1). The initial template of Tompkins et al., (2010; 2009) was used as a starting point. Whilst this was focused on a systematic categorisation of adaptation occurring in the UK it has been modified here to capture more detail on the specific adaptation actions that are being implemented, by who and where, as well as the specific climate hazard and risks that the actions respond to. The framework also reflects the framing of information in the adaptation action tables used by many organisations in the ARP reports (Defra, 2018).

Furthermore, adaptation actions are categorised using two complimentary typologies to provide a broader picture of the types of actions that are being implemented by different sectors across the UK. Adaptation actions are categorised based on (1) the behavioural objective, defined in Power et al., (2020); and (2) based on their mechanism, defined by the IPCC (Mimura et al., 2014, Table 14.1), which aims to consider the diversity of adaptation actions for different sectors and stakeholders (see Table 1 and SM2.1 for detailed criteria).

2.4. Online UK adaptation Inventory, version 1

The information documented has been made available as an online searchable database accessible at: https://www.nismod.ac.uk/openclim/adaptation_inventory. The online database allows users to dynamically explore and filter entries based on different search criteria e.g. sector, climate related hazard/event and/or risk, as well as with their own keywords, while also providing access to the more detailed metadata for each recorded adaptation type. Users can also export any search result set as a PDF document, or a comma separated file for use off-line.

3. Results

3.1. Systematic review

The systematic review identified 764 papers for review, with 21 papers marked for inclusion (See SM1 for full list of the included

papers and Figure SM1.4 for a breakdown of the inclusion and exclusion of papers). This represents ~ 3% of total papers identified, a similar proportion as found in other systematic reviews e.g. 5% in Berrang-Ford et al. (2011), 4% in Porter et al. (2014)) and 2% in Ford et al. (2011). Results cannot be directly compared across studies due to differences in geographical coverage, time-periods considered, and inclusion criteria. However, review of the nine UK-based papers identified in Berrang-Ford et al. (2011) and Ford et al. (2011) between 2006 and 2009, found just three reflected adaptation action on the ground. In the study by Porter et al. (2014), seven of the individual/household level adaptation papers identified between 2006 and 2012 reflected adaptation action on the ground.

Alongside the findings from this review, this suggests that over a decade since the introduction of the UK Climate Change Act there is still an extremely limited, albeit ongoing and slightly increasing, incidence of academic reporting of adaptation action on the ground (Fig. 1). This finding is in line with Berrang-Ford et al., (2021) who demonstrate that at the global level, while there is a vast and ever-growing number of peer-reviewed studies on climate change adaptation, relatively few studies document evidence of implemented adaptation action. Furthermore, there are large regional disparities, with far fewer articles focused on implemented adaptation in Europe (most commonly related to health and urban systems), compared to articles identified in North America, Africa and Asia.

Of the 21 papers that reported adaptation action on the ground, they predominantly focused on specific case studies or reflected the use of survey or interview data focused on the analysis of past extreme weather events. Examples demonstrated both reactive and anticipatory adaptation, covering a range of different sectors and a myriad of climate related risks such as coastal erosion, heat stress and fluvial flooding. In total 64 adaptation actions were identified and added to the Inventory.

The above findings also highlight the importance of incorporating government reporting (in this case the second round ARP reports) and hence grey literature sources in general, from which most evidence is documented in the Inventory (Section 3.2).

3.2. Review of second round ARP reports

Of the 59 second round ARP reports reviewed, 46 (78%) documented examples of adaptation action on the ground, although the level of detail reported, and style of presentation varied considerably across the reports. In total 296 adaptation options were identified and added to the Inventory, a significant increase from the 12 examples of implemented change identified in Tompkins et al. (2010).

While the 13 excluded reports did not contain specific evidence of adaptation action on the ground, they did include evidence of building adaptive capacity. For example, through ongoing engagement and communication activities; knowledge exchange; and building their evidence base through risk assessments. Some of these reports did identify lists of potential adaptation actions, but did not provide specific details as to if, where, and when such options would be implemented.

Five of the excluded reports reflected new reporting organisations. They may be at an earlier phase of their adaptation planning, reflecting differences in the maturity and capacity of reporting organisations in terms of their consideration of climate risks and adaptation (Street et al., 2017, Committee on Climate Change, 2017a). The types of adaptive activity considered will also reflect the role of the reporting organisation (a description of the organisations in the Inventory and their remit are included in Table SM2.2). For example, Natural England are the government's adviser for the natural environment in England. While they reported some specific examples of adaptation action on the ground, including involvement in habitat restoration schemes, other actions reflected their broader remit to enable the private sector and civil society to protect, enhance and manage the natural environment (e.g., the provision of land management advice to support adaptation actions by other land users)(Natural England, 2015).

3.3. Summary of findings from the UK adaptation Inventory

In total, the Inventory recorded 360 examples of adaptation on the ground, from 67 reports and academic papers. The following sectors were included: road and rail; water companies; electricity generation; electricity distribution; electronic communications; gas transporters; road network operators; rail operators; airport operators; port operators; lighthouse authorities; public bodies[1]; land/environment; housing; agriculture; livestock; SMEs and other[2].

Figure 2 illustrates the number of adaptation actions recorded in the Inventory per sector, highlighting that the majority of actions (81%) are reported as already being implemented, suggesting significant progress in the past decade when compared to earlier reviews (Tompkins et al., 2010). Water companies, port operators, airport operators, and 'other' also indicated additional adaptation action planned for implementation in the future. Some water companies, port operators and lighthouse authorities also highlighted specific actions on the ground that could have potential in the future, although they were not currently scheduled for implementation, such as a new pier, raised flood defences, desalination and increased water tariffs, suggesting these options were being considered for the future if higher risk levels were realised.

The private sector accounts for 74% of actions included in the Inventory, compared to 16% for the public sector. This is in contrast to findings by Tompkins et al., (2010) and Lorenz et al., (2019) who highlighted the dominance of the public sector in engaging with adaptation in the UK (albeit also considering adaptive capacity building). Results presented here will reflect the sectoral bias of the second round ARP reports and coverage of sectors in peer-reviewed literature, as well as the focus on action on the ground.

To further interpret the trends in Fig. 2, Fig. 3a highlights how reporting varies across sectors, with public bodies, water companies, airport operators and port operators represented by the largest number of reports/academic papers (55%). These four sectors

[1] Comprising the Lake District National Park; Peak District National Park; Environment Agency; Maritime and Coastguard Authority; Somerset Rivers Authority; Natural England; and the Forestry Commission. See Table SM2.2 for further details.

[2] Seafish, who work with the UK seafood industry to promote good quality, sustainable seafood. See Table SM2.2 for further details.

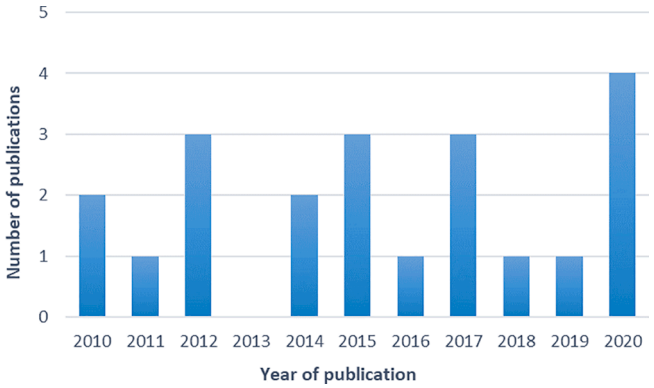

Fig. 1. The number of peer-reviewed journal publications identified that included examples of adaptation action on the ground, by year of publication.

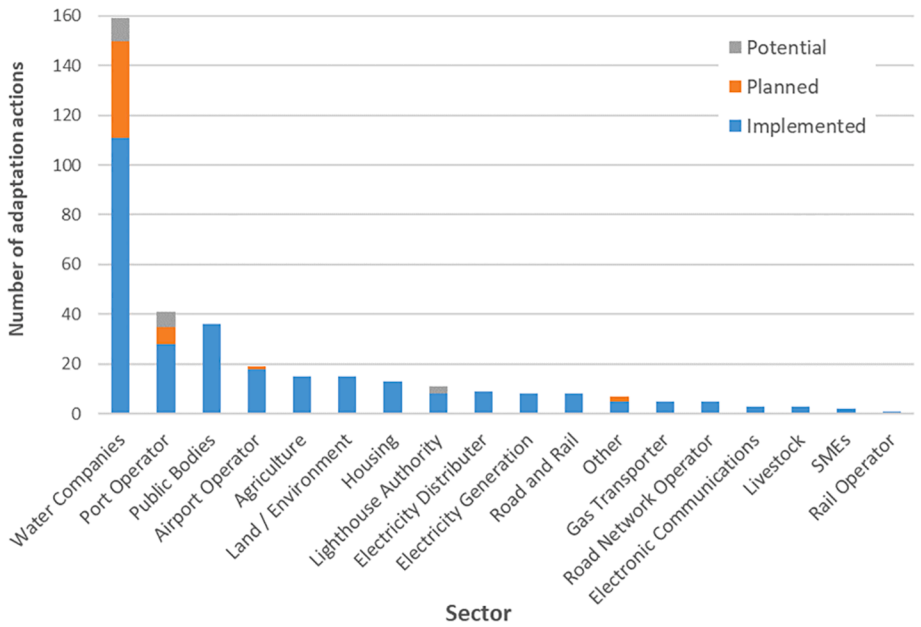

Fig. 2. The number of adaptation actions identified by sector. The blue bars indicate actions reported as implemented; the orange bars indicate actions that are planned to be implemented; and the grey bars reflect actions identified as having future potential.

accounted for 71% of the total number of adaptation actions identified (Fig. 3), with water companies dominating this trend. It has been observed that regulatory frameworks, standards and reporting requirements are key drivers for business adaptation actions (Power et al., 2020). This was apparent in the economically-regulated sectors in the second round ARP reports when assessing adaptation as a whole (Committee on Climate Change, 2017a), and is emphasised again in this study when focusing on adaptation on the ground only. For example, water companies are already required to plan to ensure the resilience of their operations to drought. Likewise, ports have historically adapted to cope with major storms and high winds, including implementation/upgrading of coastal defences, storm warning systems and improved operational health and safety guidelines to respond to such events (Adam et al., 2016).

There is less evidence of adaptive action seen for sectors such as agriculture, housing and road and rail. Agriculture is not covered in the ARP reports, and so only represented here through evidence from four peer-reviewed papers. These include Wreford and Adger (2010), who suggest agriculture is relatively adaptive to current climate variability with a progressive reduction in observed drought- and heatwave-related impacts on production and livestock over time. Hence, widespread autonomous adaptation may be happening on the ground at the farm level, but this may not be captured in peer-reviewed literature. Holman et al., (2021) highlighted limited examples of longer-term adaptive responses within agriculture when looking at the 2018 UK drought, suggesting a tendency towards reactive actions to cope or recover from short-term effects (indicative of actions reported in three of the peer-reviewed papers referenced in the Inventory), rather than considering longer term risk reduction.

The CCRA3 note that Network Rail and national highways agencies have been proactive in implementing adaptation measures on

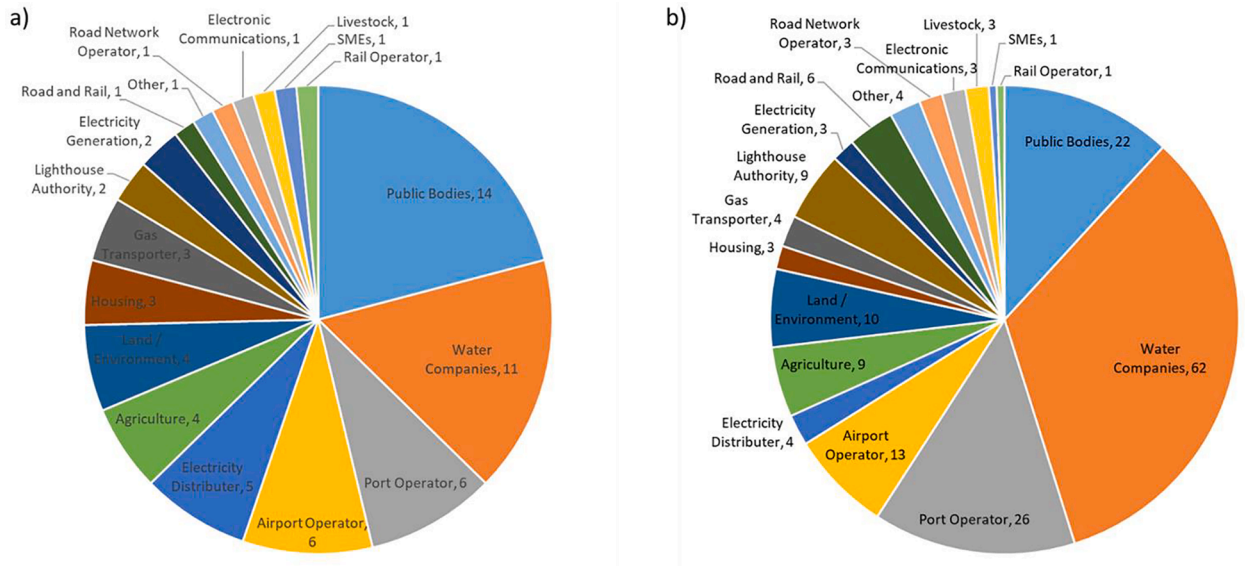

Fig. 3. a) The number of reports and academic papers cited, per sector; and b) the number of different adaptation types identified, per sector.

national networks related to some risks (Jaroszweski et al., 2021). The limited number of actions identified here may reflect that only three ARP reports relate to road and rail; that adaptation to some risks is already well embedded in operations; or as noted for Highways England the implementation of adaptation is related to updating operational procedures and adaptation plans, and so would not be included in this analysis under the definition of adaptation action on the ground (*ibid.*).

Tompkins et al. (2010) also identified far less activity in the transport and agriculture sectors as compared to the water sector, concluding that longer lead-in times for infrastructure investments such as reservoirs may also be a factor in driving activity in some sectors compared to others. At the same time this review also highlights certain sectors, such as water, may now have more incentive to document adaptation, that is absent for other sectors.

Differences also exist across organisations within the same sector in terms of the level and detail of reporting. While there is evidence that the ARP has created climate risk awareness in the majority of responding firms (Jude et al., 2017), differences may reflect the stage of the adaptation planning process achieved, their historical experience of risks and level of projected risks dependent on e.g. their size, business operations and geographical location. Institutional capacity, in terms of resources and finances to allocate to adaptation, will also be a factor as it is suggested that larger companies have the benefit of scale and resources in terms of influencing adaptive behaviour (Power et al., 2020).

To some extent, the larger number of adaptation actions identified for certain sectors in Fig. 2 reflects the number of reports and papers available per sector. However, when the type of adaptation option being implemented is considered, Fig. 3b illustrates that these sectors also have a more diverse portfolio of actions. Water companies list 62 different types of adaptation actions, including water metering, increasing sewer capacity, leakage reductions and investment in property-level flood protection, whilst port operators reported 26 action types, including relocation of assets, installing flood pumps, and operational improvements such as enhanced radar systems.

In total, 134 different types of adaptation action were identified in the Inventory (see Table SM2.3 for a full list). The most common types of adaptation options were flood protection (comprising 12% of all identified actions); leakage reduction (4%); water metering (3%); property-level flood protection (3%); operational improvements[3] (3%); and back-up generators (3%)(Fig. 4).

In terms of the typology of actions, most were categorised as structural/physical, and sub-categorised as engineered and built environment (42%), technological (40%), and ecosystem-based (13%), with fewer examples of social and institutional methods (Fig. 5a). While this suggests a prevalence towards structural and physical interventions at the sectoral level when adapting to climate change, it also reflects the emphasis of this study on evidence of adaptation action on the ground. The Committee on Climate Change (2017a) highlighted that 60% of the second round ARP reports included actions focused on developing their evidence base, while 70% included actions focused on building organisational awareness. Activities that would be defined here as building adaptive capacity and would more likely fall under the institutional and social categories. Furthermore, if the inclusion of grey literature was broadened to include government or local authority reports, then there are likely to be more examples of institutional actions such as economic instruments and laws and regulations. There is evidence of this across high income countries, where a move towards more diversity in terms of the adaptation landscape and mechanisms being implemented has been identified (Lesnikowski et al., 2016).

[3] Changed operations, practices or maintenance regimes. For example, a change to more heat resilient materials used; a change in sludge management practices to increase aeration and reduce odour; or changing operations to place containers at high risk of flooding on concrete plinths.

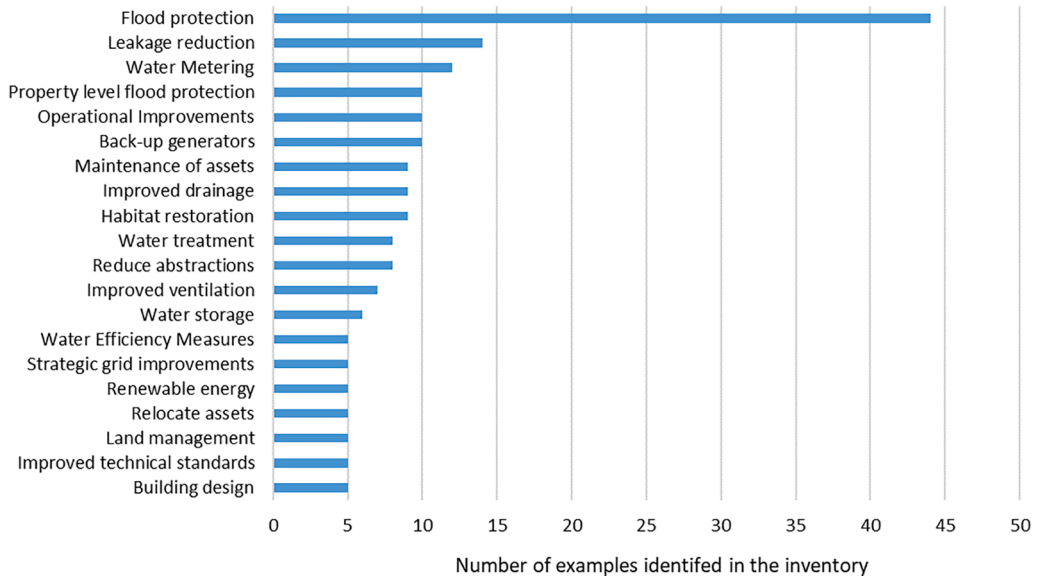

Fig. 4. Summary of the most popular adaptation types implemented, planned, or identified as having potential.

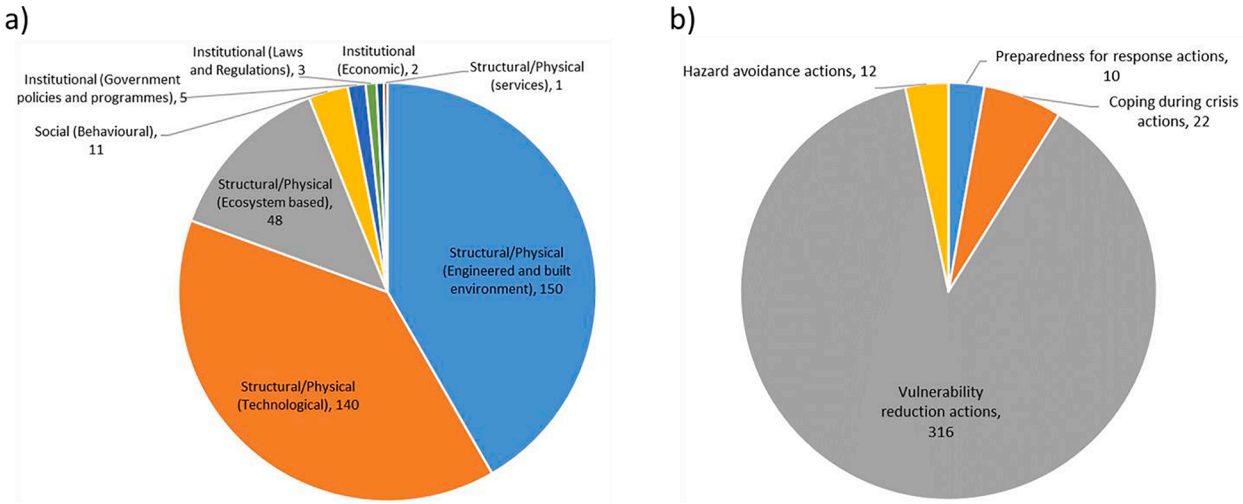

Fig. 5. a) The number of adaptation actions categorised by mechanism (Mimura et al., 2014, Table 14.1); b) The number of adaptation actions categorised by objective (Power et al., 2020).

Fig. 5b highlights that if actions are categorised based on their behavioural objective, then vulnerability reduction actions dominate (88% of total adaptive actions identified), followed by fewer examples of actions for coping during the crisis (6%), preparedness for response actions (3%) and hazard avoidance actions (3%). This reflects the findings of Power et al., (2020) that vulnerability reduction actions were seen to be most prevalent across a range of sectors, households, individuals and communities. Also, broader findings of Preston et al., (2011) who found that most identified adaptation actions on the ground aimed to reduce risk, rather than bearing climate losses e.g. through managed retreat or relocation of assets (for a breakdown of actions per typology and sector see Table SM2.4).

Reporting on the timescale of implemented or planned actions varied across the reports and literature reviewed. When considering adaptation action on the ground, most reports simply stated if actions had been implemented, were planned or highlighted those that had potential (Fig. 2), others listed the actions as implemented and ongoing but with no specific dates, while reports from seven sectors included specific details of the start date or start and end dates of actions. For those seven sectors, and organisations within them, Fig. 6 provides a broad summary highlighting the limited reporting of timescales.

For water companies, implementation timeframes of specific actions were reflective of the 5-year reporting cycles of Water Resource Management Plans (WRMP) and their longer 25-year planning period (Water UK, 2016). Public bodies encompass a wide range of organisations (Table SM2.2). The examples which detailed timings mainly suggested start and end dates between 2008 and

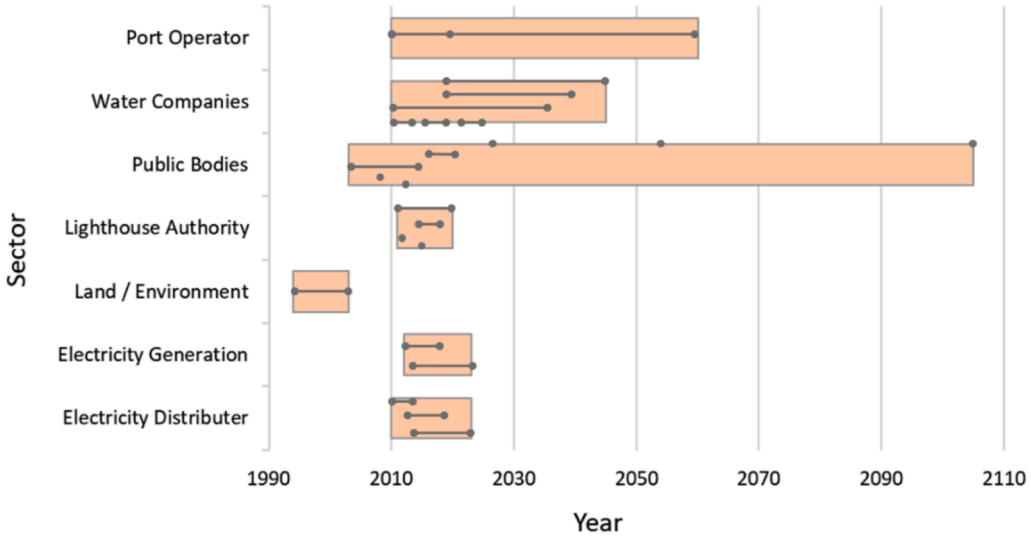

Fig. 6. Summary of reported timeframes for the implementation of adaptation on the ground for seven sectors. The orange bars represent the extent of dates reported, whilst the grey bars/dots reflect the start and end dates, or start dates, reported for specific actions.

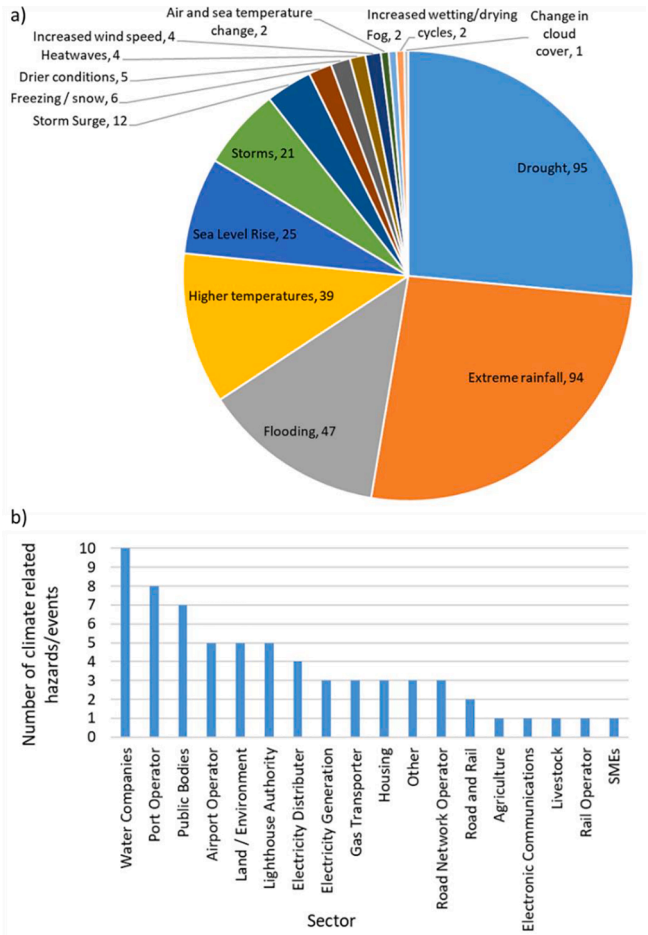

Fig. 7. a) The number of adaptation options implemented in response to different climate-related hazards and events (note, terminology used for classifying hazards/events reflects that used within the reports/peer reviewed literature); and b) the number of climate related hazards/events resulting in adaptation action on the ground per sector.

2021, however other actions included coastal realignment and retreat at Fairbourne, Wales. The current position until 2025 is to hold the line, with a shift to managed realignment up to 2055 and then no active intervention up to 2105 (Buser, 2020). This reflects the need for a longer-term planning view in the coastal context, particularly given that the need for realignment and retreat over the coming decades is likely to be widespread (Committee on Climate Change, 2018). Other longer-term actions included tree management actions alongside rivers and canals by port operator The Port of London Authority, with actions planned over the next 10–50 years (Port of London Authority, 2015).

However, many of the examples are short-term and operational. The Land/Environment sector reflects e.g., habitat restoration, documented in peer-reviewed papers as occurring between 1994 and 2003. This is not to say that longer-term risks are not being considered, as timings are reflective of the limited reporting on the implementation of actions only, and not the period in which the risk will be addressed. For example, modernising a lighthouse to use solar power to reduce the risk of power outages during a storm may be relatively quick to implement and adequate to cope with longer-term impacts specific to this risk. Other risks may require longer-term and flexible adaptation strategies. For example, many of the nuclear power plants in the UK, which are all situated on the coast or tidal estuaries, are concerned about erosion and flooding from sea-level rise by the 2080 s (Dawson et al., 2016). Given their long life cycle, which could extend to the 22nd century for new build, and uncertainties over this timeframe, adaptation strategies such as flexibility to retrofit or risk-adverse (i.e. high) protection levels will be crucial in dealing with risks in the longer-term (Wilby et al., 2011, Simm et al., 2021).

The Inventory also reviewed drivers of adaptive action in the UK context, in terms of the type of climate hazard or risk addressed. As well as differences in the maturity and capacity of the reporting organisations, regulatory requirements, and the number of reporting sectors, the perceived vulnerability to different climate-related hazards and events, and the types of risk faced, may also influence the level of adaptation action on the ground and depth of reporting. Based on the hazards defined by reporting organisations, 76% of identified adaptation actions were implemented in response to drought (26%), extreme rainfall (26%), flooding (13%) and higher temperatures (11%) (Fig. 7a).

Water companies reported adaptation action in relation to ten different climate-related hazards/events (Fig. 7b), whilst port operators, public bodies and airport operators reported adaptation actions on the ground in response to eight, seven, and five different climate-related hazards/events respectively, reflective of sectoral trends seen in Fig. 3. This could reflect the broader climate sensitive nature of certain sectors, but also their enhanced maturity in dealing with related risks in practice. Other sectors may also face similar myriad risks but may be in an earlier stage of identifying less prominent risks, enhancing their adaptive capacity and planning for future action.

In terms of specific risks identified, these were more diverse for water companies, public bodies, port operators, lighthouse authorities and airport operators, including service failure; risks to public and private water supplies; damage to property; damage to infrastructure; reduced water quality; change in biodiversity and habitat; and loss of power supplies (Table SM2.5 summarises key risks per sector).

As noted in Section 2.2, however, it is not possible to accurately ascertain where climate change adaptation actions are solely addressing threats posed by anthropogenic climate change or responding to longer-term trends deriving from climate variability or other socio-economic factors. There were 58 (16%) cases that specifically highlighted adaptation actions had been implemented in response to an extreme weather event or incident. These reflected a wide range of climate-related hazards/events and risks: half were identified in the ARP reports and half from peer-reviewed literature (Table SM2.4). Examples included, improved insulation of pipes at a water treatment plant to reduce risks of freezing following the cold winter of 2010–2011; raising sub-stations above ground level following storms and flooding in January 2014; and installation of property-level flood protection following incidents in 2001, 2003 and 2007.

Some aspects were difficult to consistently record and quantify such as the identified or anticipated outcomes of the adaptation. Whilst most actions identified aimed to reduce vulnerability (Fig. 5b), most reports only provided generalised descriptions of expected benefits, such as building resilience, delivering cost savings or reducing demand for water. There was also less evidence of adaptation challenges or barriers that may have been faced and/or overcome. Only 18 (5%) cases included details on challenges or barriers, including:

i) *Data availability and uncertainties* - validation of model projections to real life situations is difficult. Uncertainties were flagged by some organisations as an overarching barrier to action, for example in relation to wind projections. At the broader level, reliance on climate change models to understand risks can be seen as a key barrier to action (Biesbroek et al., 2013) where even large organisations may face difficulties in interpreting the volume and complexity of technical data available (Pitt, 2008).
ii) *Interrelated risks* - flood protection could be installed but other contributing factors, such as local ditches and waterways being blocked were outside the remit of the organisation.
iii) *Regulatory* - options for relocation of sites were dependent on the flexibility of local planning regulations.
iv) *Financial* - the organisation could not devote resources to the completion of actions.
v) *Trade-offs* - changing irrigation practice to prioritise certain crops at the farm-level could lead to substantial yield and quality impacts on remaining crops.

As the focus of this study was on evidence of adaptation on the ground, with most actions already implemented, it may be that barriers and challenges have been overcome, or alternative actions were excluded for these reasons.

4. Discussion and conclusions

The key aim of this study was to identify and assess *if* and *how* adaptation action was occurring on the ground in the UK through a systematic review of literature. While the Inventory presented here cannot claim to capture all adaptation action in the UK, it illustrates that for the sub-set of sectors identified there is good evidence of significant cross-sectoral and sector-specific adaptation actions being implemented. In total, 360 examples of adaptation on the ground were identified, comprising 134 different types of adaptation action.

Whilst Tompkins et al., (2010) and Lorenz et al., (2019) highlighted the dominance of the public sector in the UK when identifying adaptation activity, these actions were primarily focused on building adaptive capacity with limited examples of implemented action on the ground. Compared to these earlier reviews, this study highlights (1) an increase in evidence of adaptation action on the ground; and (2) this includes private sector organisations such as water companies and port operators as well as the public sector. Whilst a detailed analysis of driving factors is beyond the scope of this paper, this suggests that in addition to top-down legislative mechanisms, regulatory frameworks and reporting requirements, bottom-up action, such as the growing recognition of climate change as a business risk (Jude et al., 2017), and enhanced collaboration with regulators, banks, investors and insurers may also be driving action. Although others suggest there is limited evidence of risk awareness affecting investment decisions beyond e.g. water companies (Surminski, 2021). Other factors that may be driving adaptation action on the ground could also include emerging knowledge, availability of new funding related to e.g., nature-based solutions, and changing organisational standards.

Both within and across sectors, individual organisations in the UK are at different stages of the adaptation cycle, defined by the UNFCCC (2021) as comprising four general components: the assessment of impacts, vulnerability and risks; planning for adaptation; implementation of adaptation; and the monitoring and evaluation of adaptation. This status may reflect (1) the organisation's historical experience of managing natural climate variability and risks and their sensitivity to climate; (2) the projected severity and type of risks organisations may face in the future; (3) the specific role and directives of the organisation; (4) institutional capacity in terms of resources and finances to allocate to adaptation; and (5) any regulatory frameworks, standards or reporting requirements they may face. Organisations appear to be responding in both a reactive and anticipatory manner. Given the limited data on the timing of implemented and planned actions, it is hard to assess if they are addressing the longer-term implications of climate change and the degree of proactiveness. There is only limited evidence in the reports assessed that organisations are starting to actively plan for longer-term incremental or flexible adaptation pathways that may be required (Fig. 6). However, as a first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate variability (IPCC, 2014), this action is still crucial.

The methodology used to build the Inventory is based on evidence obtained from a systematic review of peer-reviewed literature and a review of the second round ARP reports. Following such an approach provides useful insights but challenges are also apparent. There will be many instances of adaptation on the ground that are not documented in ways that are included in this review. One example where adaptation is almost certainly unrepresented is coastal flooding. Haigh et al. (2020; 2016) noted a decline in the impacts of coastal flood events reflecting widespread adaptation across better warning systems/preparedness, codes/standards and upgraded defences including allowance for climate change. However, neither the ARP reports nor literature systematically capture this past adaptation effort in detail.

Whilst the methodology is designed to be reproducible and supportive of further extensions in the future, the interpretation of text describing adaptation action plans can raise questions. Even with a structured methodology, interpretation of text descriptions in reports/papers involves a degree of subjectivity, particularly where limited detail is provided. There is also the potential for double counting as the same adaptation actions may be reported by multiple organisations, across sectors, or included within multiple academic papers (Tompkins et al., 2018). Additionally, as noted above, results may also be biased by the quantity and quality of sectoral reports and peer-reviewed literature available.

The very small number (21) of peer-reviewed papers identified may reflect methodological limitations of the systematic peer-review. For example, the focus on terminology related to 'adaptation' and 'climate change', 'variability', and 'extremes' (see Table SM1.2). The framing of actions by different actors and academics across sectors and disciplines can differ substantially. Actions, whilst beneficial, may be designed to serve other objectives not directly driven or attributable to climate change or may be integrated into other policies focused on risk reduction, such as actions related to flood prevention, water management or urban planning (Ford et al., 2013, Aguiar et al., 2018). Consequently, actions may be framed in ways that are not captured by this systematic review. One option to address this in future research is to expand the method to capture other related terminology e.g., 'risk management' and 'reduction' as in Berrang-Ford et al., (2021), or 'prevention' or 'planning'.

Secondly, the small number of peer-reviewed papers identified could reflect a broader disconnect between academia and public and private sectors, in that academics are not often embedded in the institutions that are actively investing and carrying out actions (Sietsma et al., 2021). As such findings from such case studies may be harder to monitor, evaluate and reflect upon within the academic sphere. This is not surprising given the different motivations of academics publishing papers. Focusing on new and innovative adaptation case studies has novelty, such as examples of coastal realignment and retreat at Fairbourne, Wales (reported in section 3.3), but there will be much less incentive to document more common adaptation practices.

In contrast to peer-reviewed literature, grey literature provides a key source of information, suggesting that this type of material will be key for adaptation inventories, in the UK and also beyond. The ARP reports were found to be beneficial as they avoid some of the previously highlighted identification issues, given the specific focus of the reports on detailing adaptation actions to address climate-related risks, which may encourage a more consistent framing of actions across sectors. This reflects broader conceptual thinking by including all adaptation measures, whether they are primarily or solely focused on addressing climate change or not (Grüneis et al., 2018). This framing is extended to capture evidence from peer-reviewed papers, with this dual approach addressing the call of Lorenz et al. (2019) to identify and consider the role of all adaptation actors, beyond central government. Both public and

private sector organisations are included, whilst the peer-reviewed papers captured additional sectors and evidence of behavioural actions from an individual and household perspective. This adds to previous evidence on the current position of climate-sensitive private sectors and, as highlighted above, suggests that in the UK there is motivation and momentum in adaptation on the ground by these actors.

The results highlight the sectors where there is less evidence of adaptation on the ground, for example for road and rail and agriculture (discussed in section 3.3). It may be that actions are occurring but are not being considered by academics; or where sectors are considered are not appropriately reported in the ARP reports. Other gaps include limited focus on small and medium-sized enterprises (SMEs), non-governmental organisations (NGOs), and community-based organisations (CBOs). Climate change has been raised as a major concern for small and medium-sized enterprises, which often have lower adaptive capacity than larger counterparts and are less prepared and protected (Surminski et al., 2018). As noted in section 3.3 above, this can result in an information bias towards larger organisations that do record and share information. The CCRA3 highlight the discrepancy in information available between SMEs and larger companies as a serious and urgent knowledge gap (Surminski, 2021). Future actions to facilitate greater disclosure from SMEs, NGOs and CBOs on adaptation, and the review of such reports, will be essential to understanding where and what adaptation is happening on the ground in these sectors and the success of such actions.

Given the above limitations and recommendations, it is concluded that the current Inventory is likely to underestimate the true number of implemented adaptation actions in the UK, and does not yet capture the full diversity of actions or sectors where they occur. However, the Inventory is intended as an evolving database. Recommendations to address limitations noted above would include having the reports and papers independently reviewed and inputted using the same framework, to allow for the degree of subjectivity to be quantified. In the future, it will also be important to document evidence more widely across public and private sectors to distinguish between reporting gaps and adaptation action gaps. As a first step, this could be achieved by (1) using additional search terms/criteria to expand the systematic review and capture further papers that may have been overlooked; and (2) expanding the methodology to capture any organisations not currently covered who submitted first round ARP reports and updated evidence currently being published under the third round ARP. Additionally, an online literature search could be tailored to gathering evidence, documented using the same framework, from grey literature on key areas that are not currently well represented here, such as agriculture and public investment in flood adaptation. This review suggest grey material will be a primary source of information on adaptation. Whilst this could become a large task, automated approaches such as machine-learning, which can use algorithms to 'learn' relevant synonyms for adaptation-relevant terms and identify appropriate material could also be used to enhance the comprehensiveness of the coverage (Sietsma et al., 2021). Likewise, the method could be expanded to the use of surveys or interviews to capture evidence directly from organisations.

The review also alludes to ways in which the information captured under the ARP process itself could be improved. For example, requesting more detailed information from organisations on the specific timings of actions reported. Given our current understanding of barriers to adaptation is limited (Biesbroek et al., 2013) further guidelines to request and support the documentation of these aspects within future ARP reports could be beneficial in terms of knowledge sharing, including where barriers have been overcome. Expanding the invitation to voluntarily report to other sectors and organisations, using the same reporting framework, would be highly beneficial. This would also support recent recommendations made in the CCRA3 (Climate Change Committee, 2021) for further information on adaptation in practice, including calls for regular systematic surveys on the uptake of adaptation practices by agriculture and adaptation reporting by businesses, both of which could also help capture more autonomous adaptation practices.

More understanding of what adaptation is happening in practice, where, and by who, will be a precondition to the monitoring and evaluation of these actions within the adaptation policy cycle (Ebrey et al., 2021, Tompkins et al., 2018, Wang et al., 2018). However, the question of how adaptation action reported translates into outcomes, in terms of risk reduction, is less clear. There is limited information available on the assessment of outcomes, which tends to be more generalised and quantitative, making the effectiveness of reported actions hard to measure (UNEP, 2021, Power et al., 2018, Committee on Climate Change, 2017a). Hence, more objective or independent assessments of the successes and failures of adaptation actions in terms of actual outcomes, both from a short and longer-term perspective, are clearly required. However, the Inventory does provide a benchmark for key climate-sensitive sectors from which adaptation tracking, using systematic and consistent criteria, could be evaluated and compared over time and across regions/sectors in the future (Lorenz et al., 2019, Ford et al., 2015, Ford and Berrang-Ford, 2016). Better tracking and monitoring of progress will be a prerequisite to strengthening future ambition commitments within the Paris Agreement (Tompkins et al., 2018).

Furthermore, in contrast to the varied reporting, language, formatting, and accessibility of individual sector reports and academic papers, the Inventory provides a consistent and easily searchable database that will continue to evolve in terms of its functionality. It can provide evidence on the specific type/s of adaptation implemented on the ground by e.g., sector, climate related hazard/event or risk, as well as providing more detailed insights into the specific examples of action being implemented. This has the potential to help inform UK-based decision-making by providing a mechanism to help identify, review and share the potential of a multitude of adaptation actions that are technically, economically, and politically feasible, as evidenced through their implementation elsewhere (de Bruin et al., 2009). The added value in terms of sharing case studies and learning from best practice has already been highlighted by organisations involved in the ARP process in the UK (Street et al., 2017), and through the Inventory could be expanded to other organisations and regions.

At the broader level, there is clear stakeholder demand for the assessment of existing adaptation options and outcomes to help take advantage of potential opportunities (Wang et al., 2018), needs which transcend national boundaries. As such, there could be similar benefits seen from the dissemination of lessons learned and best practice at the international level. While the Global Stocktake aims to enhance the implementation of adaptation action it cannot do this directly, but could indirectly contribute by distilling national level information on adaptation actions implemented and lessons learned (Christiansen et al., 2020, Kato and Ellis, 2016). By defining

adaptation action on the ground, reviewing evidence of adaptation action, and synthesising findings in a consistent and comparable manner, the UK Adaptation Inventory provides a first step in this direction.

Declaration of Competing Interest

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

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crm.2022.100430.

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