Introduction

In late 2019, an acute respiratory disease caused by a novel coronavirus, SARS-CoV-2, emerged in Wuhan, China. The World Health Organization (WHO) named the disease: COVID-19. Within three months, the virus had spread to 114 countries and WHO upgraded the status to pandemic (Bavel et al., 2020; La Rosa et al., 2020). By late June, over 10 million people had been infected worldwide (Johns Hopkins, 2020).

The UK entered a national lockdown on 23 March 2020. In the UK, people also had to adapt the way they work. The introduction of lockdown ensured the public only left their homes for a small number of purposes. Those who were able to work from home, were encouraged to do so. By June, more than one quarter of the UK workforce (~9 million people) had been furloughed through the UK’s Coronavirus Job Retention Scheme (BBC, 2020). However, the resilience of the UK, both in terms of the economy and maintaining a functioning society, depended on essential workers adapting their processes to keep vital services operational (Farquharson et al., 2020).

Essential workers are a substantial proportion of the UK workforce, comprising 26% of working-age women and 18% of working-age men (Farquharson et al., 2020). This includes essential services, from health care to food supply, as well as the provision of clean drinking water and the treatment of wastewater: the latter of which, plays a critical role in mitigating the transmission of infectious diseases (Mallapaty, 2020; Nghiem et al., 2020). When schools closed, childcare became a heightened challenge for essential workers and others. The Institute for Fiscal Studies reported that 42% of essential workers have at least one child and virtually all essential workers with children are either single parents or have a partner in full-time work who cannot easily provide childcare (Farquharson et al., 2020).

This study collates the experiences and perceptions of water sector employees gathered from a questionnaire conducted by the Chartered Institution of Water & Environmental Management (CIWEM) when the UK was in lockdown. Our aim was to analyse the challenges facing the UK water sector from COVID-19, capture best practice and identify learning opportunities to improve resilience. Evidence is presented as descriptive findings. We define resilience using the framework outlined by Butler et al., (2017) in which resilience ‘addresses performance during periods in which the required level of service is not met (i.e. when subject to threats)’.
The intervention framework is based on the measures of mitigation, adaptation, coping and learning. These pillars build resilience and sustainability within the system (Butler et al., 2017).

**Method**

**Panel workshop and survey co-design**

A survey was co-designed by the research team, CIWEM and a panel of sector experts, through an online workshop on 6 May 2020. The research team presented the panel with a high-level goal to capture lessons relating to water sector resilience. With terms of reference and ethics elements described, the experts were invited to share their thoughts on key challenges their organisations had faced. The panel included representatives from seven UK water companies and three consultancies. The experts concluded that a questionnaire should be designed to facilitate an understanding of challenges in a chronological manner, as this would enable outputs to fit within the stages of resilience outlined in Butler et al. (2017). The final survey consisted of 30 questions, with three question modalities: multiple choice (12), Likert scale (3) and open response (15) (Table 1). We sought to find out whether there were any impacts, and therefore, if mitigation (i.e. preparation) and adaptation (i.e. response) was adequate; if there were any consequences (such as changes to wellbeing, or operational failures) in terms of evaluating the coping measures; and if learning could improve the likelihood of being able to successfully respond to threats in the future.

The survey was distributed to CIWEM’s membership and the broader water sector via email and social media platforms between 18.05.2020 and 05.06.2020. The questionnaire reached approximately 8,000 people based on CIWEM’s membership. CIWEM has members from scientific, engineering and environmental backgrounds across a range of organisations including consultancy, research, government and utilities. Therefore, working with CIWEM

| Table 1 Question phrasing, modality and response rate in the COVID-19 Research survey |
|----------------------------------------------------|
| **Question**                                      | **Response type** | **Response rate (%)** |
| Section one: About you                           |                   |                      |
| 1. What is your gender?                          | Multiple choice   | 99.6                |
| 2. What is your job title and department?        | Open response     | 85.1                |
| 3. What type of organisation do you work for?    | Multiple choice   | 99.6                |
| 4. In which region do you work?                  | Multiple choice   | 99.6                |
| 5. Have you had essential worker status at any stage since lockdown? | Multiple choice | 99.2                |
| 6. Please select which best describes your usual work status prior to lockdown | Multiple choice | 99.2                |
| 7. Please select which best describes your current work status since lockdown | Multiple choice | 98.6                |
| 8. I have been able to continue my usual role since lockdown | Likert scale | 99.0                |
| 9. My general productivity has increased since lockdown | Likert scale | 99.0                |
| 10. My general wellbeing has improved since lockdown | Likert scale | 98.6                |
| 11. Are there particular challenges that you have faced as a result of the outbreak that you would like to tell us about? | Open response | 62.0                |
| Section two: About your organisation            |                   |                      |
| 12. What did your organisation do to prepare for lockdown? | Open response | 63.1                |
| 13. How did your organisation respond during lockdown? | Open response | 63.1                |
| 14. Were there any unanticipated challenges during this time? | Open response | 58.1                |
| 15. What are the lessons learnt from preparing for lockdown? | Open response | 53.8                |
| 16. How will your organisation adapt in the medium term? | Open response | 58.8                |
| 17. What challenges might you face in adapting to working practices? | Open response | 57.2                |
| 18. How might this crisis change your future operations? | Open response | 55.8                |
| 19. Do you think we will return to pre-lockdown working practice? | Multiple choice | 66.3                |
| 20. If no, what do you perceive to be the new ‘normal’? | Open response | 46.8                |
| 21. Do you think this crisis will change investment priorities in resilience? | Open response | 58.2                |
| 22. Is more strategic guidance needed to support water companies through this crisis and beyond? | Multiple choice | 64.7                |
| 23. What guidance can regulators provide?        | Open response     | 36.7                |
| 24. Has your organisation noticed a change in customer behaviours during the lockdown? | Multiple choice | 64.5                |
| 25. If yes, what has changed?                    | Open response     | 34.1                |
| 26. Do you think any of the changes identified in Q24 will continue into the future? | Multiple choice | 59.8                |
| 27. Do you think there will be any implications of the lockdown on other aspects of public policy? | Multiple choice | 63.5                |
| 28. What role should collaboration play in addressing future challenges? | Open response | 40.4                |
| 29. Do you think this crisis will change research priorities? | Multiple choice | 61.8                |
| 30. Would you like to share any other thoughts or experiences? | Open response | 19.7                |
offered a unique opportunity to obtain input from a wide range of expertise reflecting the diversity of the sector’s population. The response rate (6.3% of CIWEM members emailed) reflects the large number of participants polled, the broad specialisms of practitioners and the difficult circumstances in which the research was undertaken. Responses were received from various organisations including water and wastewater service providers (WSPs), consultants, contractors, regulators, local authorities, central government and manufacturers. A full list of organisation types and job roles is provided in the Supporting Information (Appendix A). The number of responses received (502) accounts for less than 1% of staff employed in the UK water sector, but the spread of the responses geographically, organisationally and across job types, provides a fair reflection of CIWEM’s membership and a reasonable reflection of the UK water sector’s population (Warwick Institute for Employment Research, 2010; Energy and Utility Skills, 2017). More detail on the demographics of those who completed the survey is provided in the discussion.

**Survey format and question modalities**

This section presents the reasoning behind the question modalities and format in which they were presented. The questionnaire was divided into two sections. Section one sought to profile respondents and ascertain their employment experiences during the COVID-19 lockdown. Section two sought to understand participants’ perceptions of how their organisation had responded to the outbreak, and explore mechanisms for mitigating, adapting, coping and learning from the crisis.

Open responses were analysed using a qualitative data analysis software (Nvivo v.12, QSR International). The response for each question was read repeatedly to allow the familiarisation of the information provided. Question responses were coded using an inductive approach (Johnson and Onwuegbuzie, 2004). The coding process was conducted independently for each individual question. Many comments contained information that could be coded within different codes. The second level of analysis involved understanding the context of the information contained within the codes and identifying themes. This process was conducted by two researchers working independently of one another. The codes identified by each researcher were compared and found to be very similar, providing validation.

There were 52 coded themes (Supporting Information, Appendix B). These themes were ranked by the number of questions they were referenced in. There were 14 questions coded, including all open questions except Q2 (Table 1). Each theme was mentioned in at least one and no more than twelve questions (Supporting Information, Appendix B). The eight most prevalent codes were: Working from home, Communication, Finance, Health and Safety, IT, Health and Wellbeing, Site Work and Climate and Environment. A heatmap (Fig. 1a) was created in R showing how prevalent each theme was for each question. The number of entries in each theme (per question) was counted, then normalised, then plotted and scaled per column. A third component highlights

![Fig. 1. Heatmap showing the relative proportion of eight coded themes (y-axis) in the responses to 14 open survey questions (x-axis). Darker colours represent the most prevalent theme within each question (a). The proportion of responses by men, women, or those who preferred not to disclose to each of the eight themes is shown in (b). [Colour figure can be viewed at wileyonlinelibrary.com]](image-url)
the profile of the respondents for each coded theme. This is presented as a stacked bar chart denoting the proportion of male to female responses within each theme (Fig. 1b). The proportion of male to female responses to the survey was 60.6% M: 38.2% F (with 1.2% preferring not to say).

The remaining questions were multiple choice or Likert scale, enabling participants to express how much they agreed or disagreed with a statement (Supporting Information, Appendix C). All responses were analysed, with no participants omitted from the data set. However, respondents were grouped into subsets for further analysis. These sub-sets included: gender; job function; and essential worker status. Statistical tests were carried out using IBM SPSS statistics 26 (IBM Corp., New York, USA).

Results and discussion

The results and discussion are presented in two parts, aligning with the two sections of the questionnaire. Part one focused on employees’ experiences and is used to assess the impact of the pandemic on those working within the sector. Part two covered employees’ perceptions about their organisation’s response and is used to understand the sector’s preparedness. The two investigations are linked through the responses to Q1-4, which provided a participant profile. The findings from part one and two are evaluated in relation to Butler et al. (2017) to assess the resilience of the sector to a significant threat, such as COVID-19.

The survey was completed by 502 participants. Each question was completed by at least 99 respondents (19.7%), with the first ten receiving the highest response rate (98% ± 5) (Table 1). The mean response rate was 69% ± 23. A one-way ANOVA showed a significant relationship between question modality and response rate (F(2, 27) = 3.354, P = .00003). Unsurprisingly, open questions had fewer responses (53% ± 16) than multiple choice (81% ± 19) or Likert scale questions (99% ± 0.2).

Participant profile

The survey was completed by 304 men (60.6%), 192 women (38.2%) and six who did not disclose their gender (1.2%) (Q1). A profile of the sector’s workforce showed the number employed by UK WSPs was 58,500 (Energy and Utility Skills, 2017). The review highlighted a lack of diversity: less than a fifth (19%) of the sector’s workforce identified as female, compared to 47% across all UK employment sectors (Energy and Utility Skills, 2017). The proportion of women to men completing the survey was 1.5-2 times larger than their representation in the sector. Studies of survey response have shown women are more likely to complete surveys than men (Smith, 2008), suggesting one reason why women were overrepresented.

The survey was completed by participants with a diverse range of jobs (Q2). Twenty job categories were identified, from technicians to managing directors and planners to process scientists (Supporting Information, Appendix A). Engineers were the most prevalent, accounting for 16% of the 427 responses to Q2. Consultants (11.1%), Directors/ Senior Managers (10.7%) and other Managers (8.4%) were all well represented (Supporting Information, Appendix A). Operators (1.4%), Technicians (1.2%) and practical roles such as process scientists (0.9%) were present but underrepresented.

Over a third of responses (196 people) were from consultants and a fifth (98 people) were from WSPs (Q3). The third most represented sector was regulators, accounting for 12.4% (62 people), followed by contractors (4.4%, 22 people) and research organisations (3.6%, 18 people). These five organisations accounted for 79.2% of responses. A full list of organisations is provided in the Supporting Information (Appendix A). Job function, including role and organisation, may influence how much a respondent knows about their organisation and the sector. Therefore, evaluation of Q2 and Q3 is particularly important in assessing free-text responses. The high proportion of managers, directors, team leaders and CEOs (collectively 26%) amongst the respondents implies there is a good level of understanding of organisational response amongst the participants.

There were substantially more responses from England (64%) than other parts of the United Kingdom (Scotland 5.6%, Wales 4.8% and Northern Ireland 2.2%) (Q4). Some reported working nationally throughout the UK (11.6%) or stated they were UK-based but their organisation was international (2.4%). The questionnaire focused on the UK water sector, but 45 contributions (9.0%) were made from respondents in other countries. Some overseas respondents had previously been working on UK/international projects, prior to lockdown. Two respondents (0.4%) did not select a location.

Section one: employee’s experiences

Prior to lockdown, three-quarters of respondents stated they were office workers, 5.4% reported they were site-based and 1.6% identified as mobile operators (Q6). A further 11.2% stated they worked from home, and 8.4% selected ‘other’, splitting their time between office and site. More contractors reported being site-based than regulators (18.2% of contractors compared to 1.6% of regulators) (Fig. 2). A large proportion of WSP employees reported being office-based (82.7%). During lockdown, there was a large shift to working from home (84.2% of respondents) with only 5.5% working in offices, and 2.4% on-site (Fig. 2).
Fig. 2. Regular location for work prior to lockdown (Q6) and during lockdown (Q7) for respondents from the five most prevalent organisation types (consultant, WSPs, regulators, contractors and researchers) and the entire survey population [Colour figure can be viewed at wileyonlinelibrary.com]
Eighty percent of respondents were able to continue their usual role during lockdown (Q8). Fewer contractors reported being able to continue their usual role (59.1%) than consultants (79.1%), WSPs (77.6%), regulators (71%) or researchers (66.7%) (Fig. 3). A Kruskal-Wallis H test, conducted to determine if there was a significant difference in the distribution of Likert scores (Q8) between ‘consultants’ (n = 196), ‘water companies’ (n = 98), ‘regulators’ (n = 62), ‘contractors’ (n = 22) and ‘research organisations’ (n = 18), showed the differences were not statistically significant, $\chi^2(4) = 7.816, P = .126$ (Fig. 3). The large proportion of respondents, across organisations, able to continue their usual pre-lockdown role, suggests that employees were coping.

Questions 9 and 10 asked about changes to productivity and wellbeing during the lockdown. The survey population’s productivity and wellbeing were normally distributed. When gender differences were examined, a fifth of women saw an increase in productivity compared to a quarter of men (Fig. 4a). Conversely, more women (37%) saw a decrease in productivity compared to men (33%) (Fig. 4a). A Mann-Whitney U test was run to determine if there were significant differences in productivity between men and women during the lockdown. There was no statistically significant difference in the median values, $U = 27,295, z = -1.297, P = .195$. More women saw a decrease in wellbeing (39%) than men (32%, Q10) but this too was not statistically significant (Fig. 4b). A Mann-Whitney U test revealed there was no statistically significant difference in the median values for wellbeing between men and women, $U = 27,030, z = -1.472, P = .141$. This is likely due to each individual coping with and adapting to the pandemic in different ways. Individuals were subject to different challenges: some may have had significant childcare responsibilities, whereas others may have struggled with isolation. Respondents reported negative and positive impacts, each of which may have counteracted any significant deviations in wellbeing and positivity.

Differences in productivity and wellbeing were evaluated between essential workers and other non-essential staff. Essential workers were more likely to report an increase in productivity (30% of essential workers) than non-essential workers (19% of non-essential workers). This highlights the ability of essential workers to proceed with tasks when everyday obstacles (e.g. traffic, routine administrative tasks, etc.) are lessened. Non-essential workers reported the largest decrease (42%) in productivity (Fig. 4c). A similar trend was observed for wellbeing: essential workers had the largest improvement (29%) in wellbeing (Fig. 4d). Those who were unsure whether they were an essential worker had the largest decrease (47%) in wellbeing (Fig. 4d). A Kruskal-Wallis H test was run to determine if there was a significant difference in wellbeing between: ‘essential workers’ (n = 183), ‘non-essential workers’ (n = 301) and those ‘not sure’ of their status (n = 15). Median Likert scores were higher in those that answered ‘yes’ and ‘no’ (median value = ‘neutral’) than those who were ‘not sure’ (median value = ‘negative’), but differences were not statistically significant, $\chi^2(2) = 3.929, P = .140$. These moderate differences suggest that uncertainty, perhaps through poor communication, can impact wellbeing.

Section two: employees’ perceptions of organisational response

The second part of the questionnaire focused on the respondents’ perspectives on their organisation’s response to the outbreak. The eight themes presented in the heatmap (Fig. 1) are used to frame the discussion.
Working from home

‘Working from home’ (WFH) was the most prevalent theme in the survey responses with 771 individual mentions across 12 of the 14 open-response questions (Supporting Information, Appendix B). WFH was most frequently mentioned in the middle part of the survey, accounting for one-third of responses to Q11, 12, 16, 18 and 20 (Fig. 1a). These questions focused on the challenges employees had faced (Q11), what their organisation had done to prepare and mitigate the threat (Q12), how their organisation might adapt in the medium term (Q16), as well as a longer term outlook on future operations (Q18) and what might become the new normal (Q20).

The majority of survey respondents (58%) did not expect a return to pre-lockdown working practice (Q19). Consultants and those working for WSPs were twice as likely to think normal working practices will return after the COVID-19 lockdown, than regulators or researchers (12% of contractors and 10% of WSPs, compared to 6% of regulators and 5% of researchers). There was a perception that WFH would remain for a long period of time, with some regulators and consultants stating it may become the norm or business as usual (Q16). Some discussed this adaptation further with suggestions of how this might be realised in practice: they are currently looking at rota for employees to come into the office, without having everyone in at the same time (Q16, Q20). Participants perceived there would be a change in attitudes and perceptions regarding WFH with it being considered more acceptable. One consultant said, The workplace will become more flexible; we’ve proven we can all still deliver whilst based from different locations and working different hours (Q18). This demonstrates that generally, the workforce was able to adapt well to the new situation.

WFH was identified as the main form of adaptation (Q16), a large part of the new normal (Q20), but also, a significant challenge (Q17). Though WFH is expected to play a large part in working practices going forward, many participants associated issues such as loneliness, isolation and reduced motivation with WFH. Some stated that not everyone can work from home, and it can be motivationally draining (Q17). The importance of good communication channels to make sure those not based in offices are sufficiently included in day-to-day operations was also raised (Q17). Participants commented on the physical aspects of returning to work. A third of responses to Q17 related to how the physical office environment might change. Participants perceived that, with the shift to WFH, offices would only be used for occasional and necessary face-to-face meetings. They suggested there may be smaller offices, fewer staff, or the potential closure of office locations. One
Communication

Communication was mentioned 237 times in 12 questions. It was a broad theme that was raised in relation to the effectiveness of an organisations’ response (Q13 and 15), as well as the important role it will play in the strategic guidance (Q23) and collaboration (Q28) needed to support recovery from the outbreak. Communication accounted for 14% of the responses to Q13, with participants noting how their organisations had adapted to ensure the volume, quality and clarity of communications met the needs of their employees, with additional communications from senior leaders down to line managers and the signposting of additional support (Q13). Honest, consistent and direct communication was perceived to be essential, to ensure people did not misinterpret and spread misinformation within organisations, to avoid confusion and to enable good planning. Participants perceived that it was important to stay in touch, share information and listen to staff who may be experiencing different personal circumstances as a mechanism for coping (Q15).

One-third of responses to Q22 suggested more strategic guidance was needed to support WSPs (Q22). However, the majority of responses to this question (56%) were not sure and therefore it is likely responses were knowledge-dependent and affected by job function (i.e. role and organisation). Profile analysis supports this; employees of water companies, contractors to the water sector and research organisations were more likely (32% ± 5) to answer yes than local authorities and central government (17% ± 5) (Q22). Of those who selected ‘yes’ (Q22), open responses focused on a need for more guidance on compliance and understanding around regulations, penalties and rewards (Q23). A WSP employee noted that some AMP7 year one targets may be missed as the enabling work is impacted by lockdown and social distancing rules. Regulators need to be quick and clear in declaring their position on how they will assess compliance with targets. Others questioned how this [i.e. the effects of COVID] will impact Outcome Delivery Incentives (ODIs) moving forward, if it will impact incentives and penalties and what measures are to be put in place to protect the water industry from footing additional costs. A senior water quality manager noted that guidance was required on delaying investigations and schemes where statutory deadlines are specified, suggesting this is further complicated by Brexit uncertainty. One consultant questioned how non-emergency, routine assessment regulatory visits would take place if restrictions are in place, suggesting that increased use of satellite or drone photography could replace or enhance ground checking and surveillance. These comments demonstrated a shift from how the individual was coping with how the sector was coping with the challenges of the pandemic.

Participants also noted the importance of communication within collaboration, stating this would be a vital part of recovering from the outbreak. One respondent noted that communicating [with] and involving stakeholders results in a clearer understanding of the issue and can result in an ‘out of the box’ solution. Others commented that collaboration needs to play a major role and that evidence from the lockdown period has clearly demonstrated that, via collaboration, outcomes have been achieved in incredibly short timescales (Q28). Participants saw opportunities to learn from the outbreak, suggesting greater collaboration across the sector, and between sectors, could help to address current and future challenges, encourage innovation and develop effective contingency plans to recover from the outbreak. One WSP employee proposed, I think the water industry (as a whole) should have an agreed to, and publicly published, strategy for how it will deal with and respond to a pandemic in future.

Finance

Finance was mentioned 169 times in 12 questions. This theme spanned three key areas: the impact on individuals, the cost burden on WSPs and the impact on future investment priorities. Participants discussed the financial impacts they would experience in Q11. There did not appear to be any gender differences; with financial impacts accounting for 5.4% of male responses and 5% of female responses (Q11). However, all comments, except one, were made by consultants. Both men and women referred to having to...
furlough staff as well as expressing concern over their own job security, there is great uncertainty about my role and whether I will be made redundant at the end of this. Some consultants noted their staff had to be idle without salary. Others commented on how they were coping, stating they were unable to deliver the work that forms the majority of my income, or that they had taken a pay reduction (Q11). One respondent stated, I am determined not to panic about business matters until absolutely necessary. My clients are struggling to pay outstanding invoices and I have no idea what will happen in coming weeks …. The financial impact on individuals, with regard to furlough, pay cuts and job security, was mentioned again in Q13 and 14. Communicating the changing information on the furlough scheme created confusion within some organisations. This was compounded by uncertainty regarding eligibility and how communication could be maintained with furloughed employees when the rules did not allow this.

There were implications of a potential cost burden on WSPs due to: increased treatment costs arising from a changing wastewater load; and decreased revenue from changes to water consumption shifting from metred commercial establishments to primarily unmetered domestic properties (Q24). One participant identified the disposal of excess milk – occurring after demand from restaurants and cafés rapidly decreased in lockdown, meaning dairy farms and suppliers had to dispose of vast quantities (Drury, 2020) – which increased load at wastewater treatment works. They noted the implication that this would have on the cost of treatment, particularly when considered with a potential reduction in revenue, due to increased water use in unmetered homes and reduced water use in metered commercial establishments. It will be important to evaluate (i) how severe these changes were, in terms of frequency, magnitude or duration and (ii) exactly how the WSPs dealt with such changes, to assess whether the coping mechanisms implemented would be adequate in future scenarios, which could be prolonged or occur alongside multiple threats. One WSP employee noted that there seems to be a distinct lack of help from other sectors for water. She argued that there should be more support provided to the water industry for example; subsidised energy bills, or rules not allowing providers to charge more because of tariff changes, when the lower usage is directly caused by COVID-19 (Q11). She added, the additional costs hit by the sector will undoubtedly cause delays in improving our water network due to reductions we have had to make to new enhancements, suggesting this will result in higher bills for customers.

Later in the questionnaire, the financial implications of COVID-19 were evaluated in terms of investment priorities in resilience (Q21) and research (Q29). Finance was a key theme in Q21, accounting for a fifth of responses ranging from the perceived lack of future investment and concern over not being seen as a priority. Participants raised the possibility of an economic downturn or the introduction of austerity measures, with participants commenting on reduced workload, reduced investment in the infrastructure, cancellation of projects and redundancies (Q21). One quarter of participants acknowledged it was likely that centralized research funding would be reallocated to medical research, to support the development of COVID-19 treatments and/or a vaccine. However, some highlighted opportunities to innovate out of this crisis including a WSP employee who thought there would be greater interest in characterisation of sewage to influence public health policy and a consultant who referred to current research on early viral detection through sewage effluent monitoring (Mao et al., 2020; Medema et al., 2020; N-WESP, 2020) (Q29). Others noted a need to do more with less, a focus on remote operation and monitoring and suggested that low cost nature-based solutions could gain more traction as the benefits of a system that self-manages become more apparent (Q29).

These responses demonstrated there are many opportunities for learning from the outbreak, from the generation of new knowledge to the sharing of exemplars and the availability of novel data sets which can facilitate reflection on current best practice.

**Health and safety**

Health and Safety (H&S) was referred to 193 times in 11 questions. Some participants perceived their organisation’s response to the outbreak demonstrated a good level of resilience; others perceived it highlighted the need for increased learning and awareness (Q21). This was particularly pertinent in Q12 and 13, where respondents were split between those who thought their organisation was well prepared for an emergency on the scale of COVID-19 and those who believe their organisations did not respond at all. This could simply be due to a lack of knowledge, related to job function, or it could evidence a need to create more effective communication strategies.

In response to, what did your organisation do to prepare for lockdown?, five respondents commented little or not a lot and twenty responded nothing (Q12). These responses may suggest that mitigation mechanisms were not present or could be a lack of understanding due to the job role. Most comments referred to IT and WFH, but there were 76 comments addressing H&S. This included health and safety briefings, the purchase of additional PPE and face masks (7 comments), the updating of risk assessments (eight comments) and social distancing (11 comments). A technical director commented that their consultancy, set up emergency committee of senior management, office staff provided with PPE and hand sanitisers up to the point
when the office closed (Q12). Mitigation is typically used to refer to long-term actions to prepare for and reduce the impact of, a threat (Butler et al., 2017). Responses to Q12 were primarily rapid reactionary responses and targeted actions, such as the provision of hand sanitizer/wipes in the office, increased emphasis on ‘correct hand washing or the closure of offices (Q12) This demonstrates how the organisation adapted, in the short term, to remain open. However, some respondents did refer to mitigation measures such as contingency plans and well documented and rehearsed crisis plans (Q12). There was also an acknowledgement that shared learning in preparing for Brexit had enabled them to act quickly (Q12). The key topics in Q13, relating to H&S, were office closures (12 comments) and social distancing (10 comments), with one consultant noting their organisation had a very proactive response to safe working procedures (Q13).

H&S continued to be a minor theme throughout the survey. PPE, risk assessments and social distancing were all referred to as mechanisms for adapting in the medium term (Q16). Some referred to new risk assessments, and H&S procedures, and identified that it might be necessary for staff to wear masks at work and for specific COVID PPE to be provided to field staff or those required to do site visits (Q16). In Q23, relating to guidance from regulators, the comments on H&S broadened. A senior scientist commented they would like more confidence about the implications of infectious disease to their operations and health and safety and the impact on the environment. A local planning authority engineer stated they wanted to see safer guidelines on services and a consultant asked for guidance on Safe Operation of assets & uninterrupted services to customers with safe delivery to not to spread the covid19 (Q23). Finally, there was an acknowledgement of the cost of implementing safe working practices, with a network strategy manager asking for reassurance that penalties will be relaxed for some years as we will be behind in capital investment programmes and may need more funding to accommodate safe working (Q23).

**IT issues**

IT issues were the second most referenced theme with 417 individual comments. However, these were spread over 10 questions and were concentrated in Q11 (Are there particular challenges that you have faced as a result of the outbreak?) and the first part of section two (Q12-15). Men were more likely to report IT issues than women (Fig. 1b); accounting for 23% of male responses versus 17% of female responses in Q11. These issues included internet connectivity, screen size, video call fatigue and access to appropriate corporate networks and software. A regulator commented, Physical home working arrangements, i.e. laptop, furniture, are not suitable for long-term working. Connectivity to IT systems has been variable and at times non-existent due to number of users. Number of telecoms has increased significantly (Q11).

IT issues accounted for one quarter of responses to Q12, What did your organisation do to prepare for lockdown? (117 comments) including remote access and provision of IT equipment. IT was a key theme in Q14 which asked about unanticipated challenges, though these were largely experienced at the start of lockdown and resolved as the crisis progressed. It was perceived that there was not enough capacity in the system to cope with large numbers of people working from home. The speed at which this decision was made meant that preparations for remote working were not completed in time. One participant noted that remote working IT systems (which I had been using prior to the lockdown) did not have enough capacity when more people started working from home. This caused prolonged intermittent loss of access to networks for many weeks (Q14).

Connectivity was also perceived to be a challenge due to slow internet connections, broadband speed and bandwidth capacity. Participants commented that servers were overloaded at the start of lockdown and increased usage resulted in slow and unreliable server connections, restricting access to projects. There were difficulties obtaining laptops and IT equipment to enable employees to work effectively from home. A WSP employee noted, the volume of staff needing laptops/licences to be able to work from home, was a mammoth task to get everyone set up and ready to work from home (Q14).

**Health and wellbeing**

Health and wellbeing was mentioned 194 times across 10 questions. There were gender differences in response. Women were more likely to refer to care responsibilities than men, accounting for 31% of female responses compared to 13% of male responses to Q11 (Are there particular challenges that you have faced as a result of the outbreak?) However, whilst care responsibilities were raised as a considerable challenge that individuals had faced; care was only mentioned ten times (3.4% of responses) in Q17 (What challenges might you face in adapting working practices?). This could be linked to the perception that children would return to full-time education and care responsibilities may return to normal for working parents. Both women and men referred to isolation, a lack of social interaction and missing face-to-face contact as a particular challenge they had to cope with during the outbreak. However, this was reported much more frequently by women (18% of female responses) than men (8% of male responses) (Q11). Other
studies have reported a decline in mental well-being during the COVID-19 pandemic (Etheridge and Spantig, 2020). Etheridge and Spantig found that the decline is twice as large for women as men and whilst differences in family and caring responsibilities contribute to this, it is predominantly a function of social factors (Etheridge and Spantig, 2020). Conversely, men were four times more likely to refer to their physical health than women, commenting, my health has deteriorated, owing to the lack of activity and I’m finding it difficult to replace my daily cycle commute with exercise (Q11). Five people referred to anxiety and depression (Q11). Both men and women commented on increased headaches, tiredness, and referred to technology fatigue (Q11).

Yet, there were positive outcomes across the sector. A regulator commented on how their organisation had excelled in regard to employee wellbeing during lockdown (Q13), whilst a WSP employee said their organisation had been championing mental health and wellbeing awareness, and a consultant noted an adaptation in the introduction of mental health awareness seminars (Q13). There was an acknowledgement that the outbreak had changed participants’ work-life balance. One stated, There have been some good things to this lockdown. Spending more time with family and a reminder that the pace of life is too fast and a consultant reflected, cutting to a 4-day working week and spending more time with the family has improved my life quality. More widely this should be an opportunity for society to evaluate its priorities (Q30).

Site work and operations

Site work was counted 116 times across eight questions and was most prevalent in Q17. Challenges with site work were raised more frequently by men (66%) than women (32%) or those who did not disclose their gender (2%) (Fig. 1b). Site-specific issues raised in Q14 included difficulties maintaining social distancing, accessing appropriate PPE and securing key worker status to ensure site access. A lack of toilet facilities for field workers was also raised. Operational challenges included: a sudden change to sampling capabilities, a risk of lab staff shortage and changes in consumption patterns due to reduced commuting, leading to hard to forecast demand patterns. The slightly higher overall water supply demand with people working from home more was also noted to be exacerbated by hot and dry weather during mid-May (Q14). Challenges raised by site workers for returning to work included travel limitations locally (to and between sites) and nationally, where a lack of overnight accommodation is a major constraint to UK-wide work. This was a key concern during lockdown, when travel was restricted, but is unlikely to be a continued challenge, unless local or national lockdowns are reintroduced. Managing social distancing and visitors to site, however, will require measures of adaptation in the medium term (Q17).

Whilst not directly coded as ‘site work’, changes observed in customer behaviours (Q24) relate to the operational and site-based elements of the sector. Ten percent of the survey population reported there had been no direct impact on water and wastewater operations during the lockdown (Q24), whilst 164 participants (33%) provided responses that covered project delays, decreased workload, sewer blockages and water quality and demand implications. Customer behaviour inevitably means different things to different participants. Twenty four participants referred to an increase in domestic water consumption, as a direct impact of more people being at home (Q25). Demand patterns were considerably altered for some, with one participant noting that demand was higher due to more customers not commuting out of our area. Others reported that peak water demand is later during the day and that there was little difference in the daily demand patterns of weekdays and weekends. This was echoed by another participant: peak water usage (which was in the mornings) now constant throughout the day and commuter towns where less water was used are now seeing much more household water usage, so distribution and demand is changing. A water strategy team leader referred to the implications of the toilet paper shortage in the early stages of lockdown, when people flushed other things down the toilet which resulted in blockages as a coping mechanism, whilst a contractor referred to more wipes blocking the inlet screens at some wastewater treatment plants and suggested this might be because people are more likely to use them at home, rather than at work (Q25).

Climate and environment

Climate and the environment were referred to 54 times across eight questions and were the only theme which had an equal gender split, despite the much higher proportion of men completing the survey (Fig. 1b). This theme focused on the environmental impact of fewer people commuting into offices as more people WFH. In Q20, on expectations for a new normal, a WSP employee commented more opportunities to work from home meaning less vehicles on the road and less energy used causing a lower carbon impact, and a regulator stated, More of a focus on the environment… reduction in car use, less polluting activities, and helping to meet carbon emission targets for climate change (we can only hope…). Anecdotally, one respondent referred to lower air pollution concerns locally in Q11.

In Q28, participants identified complex and multifaceted environmental challenges, such as climate change, which
could benefit from open and inclusive collaboration to deliver effective solutions. Collaboration was said to be singly one of the most effective ways of addressing this and future challenges. To collaborate is to share ideas and burdens, and as we are all in this together, to not work together would be detrimental (Q28). This was reiterated in the final part of the survey (Q30), which due to the nature of the question had a huge range of answers. However, climate and environment was one of the most frequently mentioned issues along with wellbeing and government handling of the pandemic (each of which accounted for 5% of responses). One participant suggested there was a ... Need to consider change in water use patterns (diurnal and longer term) when more people are spending longer at home (Q30). Whilst some individuals reported the environmental benefits realised during lockdown (Q11, 20) and globally, the rate at which Earth’s resources are consumed declined sharply this year (Earth Overshoot Day, n.d.), environmental challenges are still a pressing concern. Those that responded on climate, pushed for the future of the sector – and the recovery from the COVID19 outbreak – to prioritise climate change and the environment: Climate change should be addressed in the recovery programme and that the circular economy should be embraced when the economy is already being disrupted (Q30).

Conclusions

This exploratory study was conducted rapidly in difficult circumstances. However, a key set of findings on the sector’s resilience to a threat, such as COVID-19, are presented using the intervention framework of Butler et al. (2017), acknowledging that the relationship between the four terms (mitigation, adaptation, coping and learning) at the individual, organisation and sector level is complex.

(2) Adaptation

Adaptations are adjustments that are carried out in response to threats to minimize consequences (Butler et al., 2017). These actions may be taken before, during, or after a disruptive event. Adaptations to reduce the impact of the COVID-19 on the water sector included working from home, social distancing and the use of increased PPE. Many participants quickly and successfully adapted to a new way of working, with eighty-four percent of the sector working from home. However, there were many challenges in adapting: some (largely site-based) work was impracticable; working from home increased employee’s sense of isolation; and IT infrastructure was initially inadequate to support such high levels of remote working.

(3) Coping

Coping describes the action taken to reduce the effects of an impact on a recipient (Butler et al., 2017). Coping was experienced at both an individual and sector level. Participants reported positive and negative consequences of the outbreak, which made it difficult to ascertain a definitive change to wellbeing, productivity and mental health. IT issues, childcare and social isolation made it harder for individuals to cope. Good communication and signposting of additional support helped to address this. Eighty percent of respondents felt able to continue their usual role, which indicates coping mechanisms were effective in reducing the impact of the pandemic on individuals. At the sector level, coping involved the ability to meet increased potable water demand and prevent widespread sewer blockages from the use of non-flushable items due to toilet paper shortages.

(4) Learning

Learning is relevant to all sections of the resilience framework and does not address specific threats, impacts or consequences. Learning seeks to embed new knowledge in best practice (Butler et al., 2017). The lessons learned from the outbreak relate to the importance of robust IT systems, good communication and new approaches to collaboration. Future crisis plans should transcend organisational boundaries to prepare for prolonged crises of international magnitude, such as the COVID-19 pandemic. The development of such plans should be collaborative, across multiple sectors and factor in the likelihood of multiple threats occurring simultaneously, such as those relating to climate and the environment. There is, unsurprisingly, a need for increased learning and awareness of the health and safety implications of COVID-19 and this is likely to
be iterative. With regard to working from home, the crisis demonstrated the effectiveness of this way of working and the benefits to the environment of less travel. There is still room for learning to inform how we can overcome the challenges of social isolation and novel approaches to collaborative or practical working while staff are largely remote from each other.

Further study
We recommend further investigations to explore these findings within the UK and global water sectors. Semi-structured interviews with water companies will add clarity, at a strategic level, to what the sector did to mitigate the threat of a pandemic and what planning was carried out to assess the vulnerability of water systems to such threats. Furthermore, this could help to identify whether any other large-scale threats were experienced during the outbreak and what impact this had on a company’s ability to respond. We are interested in exploring specifically how water consumption changed during the COVID-19 lockdown and the mechanisms water companies deployed to cope. We would like to investigate whether changes are temporary or if demand patterns are likely to remain changed, as we recover from the lockdown, and what the implications of this may be for operational resilience and security of supply. Finally, the research team has initiated a survey with the International Water Association, seeking to explore the impact of the pandemic on intermittent water supply at a global level. This will help to identify similarities and differences in responses in developed and developing countries and facilitate knowledge transfer.

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Data availability statement
The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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