Hazelwood Health Study Technical Report

2019-2020 Mental Health and Wellbeing Follow-up Survey

A follow-up to the 2016-2017 Adult Survey investigating the ongoing psychological health of adults who lived in Morwell during the 2014 Hazelwood mine fire

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This report presents a preliminary analysis which has not been submitted to independent peer review. Subsequent scientific manuscripts which undergo independent peer review may vary in their findings or interpretation.

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Abbreviations

ANOVA	Analysis of variance
CATI	Computer-assisted telephone interview
CAWI	Computer-assisted web interview
COPD	Chronic obstructive pulmonary disease
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DHHS	Department of Health and Human Services
HHS	Hazelwood Health Study
IES-R	Impact of Event Scale - Revised
IQR	Inter-quartile range
IRSAD	Index of Relative Socio-economic Advantage and Disadvantage
K10	Kessler 10-item psychological distress scale
LGA	Local Government Area
MICE	Multiple Imputation by Chained Equations
MUHREC	Monash University Research Ethics Committee
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of 2.5 micrometres (thousandths of a millimetre) or less
PTSD	Posttraumatic Stress Disorder
REDCap	Research Electronic Data Capture
95% CI	95% Confidence Interval

Executive Summary

The 2016-2017 Hazelwood Health Study Adult Survey collected information on the health and wellbeing of residents, including mental health, 2.5 years after the 2014 Hazelwood mine fire. One of the primary research questions of the Hazelwood Health Study was to monitor levels of psychological distress within the Morwell community over time. To do this, Morwell residents who participated in the 2016-2017 Adult Survey (round 1 survey) were invited to again participate in the 2019-2020 Mental Health and Wellbeing Follow-up Survey (round 2 survey).

The round 2 survey repeated key measures: (1) current psychological distress specifically associated with the Hazelwood mine fire (IES-R), and (2) current generalised psychological distress (K10). This report focuses on whether psychological distress levels have changed over the intervening three years between survey rounds, whether changes in psychological distress are related to exposure to the 2014 mine fire, and whether the more acute levels of psychological distress observed in the round 1 survey among younger people continue to be evident.

The data collection period for the round 2 survey was from December 2019 to early March 2020. This coincided with the catastrophic bushfire events that impacted south-eastern Australia, which caused significant fire activity elsewhere in Gippsland and periods of widespread smoke haze across the Latrobe Valley. Accordingly, the timing of the round 2 survey also provided the opportunity to consider how longer-term psychological impacts of exposure to an earlier smoke event may present within the context of a subsequent smoke event.

A weighted random sample of Morwell respondents to the round 1 survey were invited to participate in the round 2 survey. In total, 713 people participated in the round 2 survey. The majority of these participants completed the survey online (82.5%), or over the phone (15.8%), with a smaller proportion providing a written response (1.7%).

The current analysis makes use of modelled individual-level exposure to mine fire-related fine particles less than 2.5 thousandths of a mm in diameter ($PM_{2.5}$) completed as part of round 1 analyses. In addition, round 1 survey data were utilised in the analysis to control for key confounders (age, gender, education level, employment, prior physical and mental health). Weighting was applied to account for response bias and missing data compensated for using multiple imputation. Linear mixed-effects regression modelling was implemented to evaluate changes over time in both event-related and general psychological distress, including the association of these changes with levels of $PM_{2.5}$ exposure during the Hazelwood mine fire.

The main finding of the analysis was that, some six years after the 2014 Hazelwood mine fire, there was a continuing relationship between participants' level of exposure to $PM_{2.5}$ during the Hazelwood event and the level of event-related psychological distress that they attributed to that event. For each 10 $\mu g/m^3$ increase in mean daily $PM_{2.5}$ exposure during the 2014 mine fire, there was a 1.1-point increase in IES-R score (at the mean age of the cohort). Furthermore, compared with levels observed in the round 1 survey, event-related psychological distress had increased at the time of the round 2 survey. Higher Hazelwood-related distress was also associated with several key risk factors,

including asthma, COPD, multiple prior traumatic events, and being unemployed or unable to work. Consistent with the round 1 survey analysis, the impact of $PM_{2.5}$ exposure on event-related psychological distress was more severe for younger people, with the effect of $PM_{2.5}$ exposure on IES-R score being, on average, 0.5 points greater with each 10-year decrease in age.

There was evidence that general psychological distress (i.e. not specifically tagged as arising from the mine fire) had also increased, with a 1.8-point rise in K10 scores between the round 1 survey and round 2 survey. However, unlike the IES-R findings, there was no longer any evidence of an association between prior Hazelwood $PM_{2.5}$ exposure and general distress levels. Younger age, along with all other key risk factors, except gender, was associated with increased general distress. Unlike the IES-R findings, there was no evidence that age modified the relationship between exposure and distress level.

The finding that current psychological distress, both event-related and general, had increased over the three years between the two survey rounds contrasts with previous post-disaster studies which have found psychological distress decreasing over time. One possible explanation for this different result is that the 2019-2020 bushfire and smoke event which coincided with the round 2 data collection period may also have had a psychological impact on participants, and hence, an impact on their responses. Regardless, the finding that participants' event-related psychological distress was still associated with their level of $PM_{2.5}$ exposure to an event now six years in the past indicates that the Hazelwood mine fire has had an enduring impact on mental health and wellbeing in the affected community.

Based on this finding, we recommend that public health agencies include warnings that people who have experienced similar events in the past may experience further psychological distress in response to the new event, and that they should seek support if needed. In addition, the finding that multiple risk factors were associated with increased psychological distress, both attributed to the mine fire and in general, suggests that a more nuanced approach be taken to identifying and supporting vulnerable groups. This need for nuanced messaging is reinforced by the finding here, building on the earlier round 1 finding, that younger people may be at greater risk of event-related psychological distress.

A third survey round is planned for 2022, which will yield further insights on how participants are coping eight years after the Hazelwood mine fire event.

1 Introduction

During February and March 2014, a brown coal fire burned in the Morwell open-cut pit adjacent to the Hazelwood Power Station, causing a period of excessive smoke which impacted on Morwell and other localities in the Latrobe Valley region of Victoria, Australia (Luhar et al., 2020). The smoke event continued for 45 days and was unusual in terms of the intensity, duration, and proximity to population centres. In response to community concerns about the potential health impacts of exposure to the smoke, the Victorian State Department of Health and Human Services (DHHS, formerly the Department of Health) determined that it was important to learn from the fire, particularly for:

- the benefit of the local community who were exposed to this smoke, by monitoring any potential long-term health effects; and
- assisting health authorities, environment protection agencies and emergency services to inform and improve future policy and planning in the event of future similar events.

In order to achieve these objectives, the DHHS awarded a tender for a longitudinal health study to a Monash University-led research team with collaborators from Federation University, the University of Tasmania, and others.

The Hazelwood Health Study (HHS) is a program of research with several research streams, each with their own specific aims and objectives. This report represents a cross-stream activity, bringing together the Adult Survey and Psychological Impacts streams, to investigate the longer-term psychological health and wellbeing of Morwell respondents to the 2016-2017 Adult Survey. In addition to repeating key psychological distress measures included in the original survey, the longitudinal follow-up survey also assessed factors associated with recovery in the aftermath of the mine fire, including resilience, social support and community wellbeing.

2 Background

At present, few studies have tracked longer-term mental health and wellbeing in the aftermath of natural disasters, with very little evidence available regarding what longer-term mental health outcomes might be expected following a protracted smoke event. Existing disaster research indicates that levels of psychological distress and cases of post-traumatic stress disorder (PTSD) attributable to an event tend to peak at a time-point within the first year post-event and, from then onwards, begin to decline over time (Norris, Friedman, Watson, et al., 2002). However, psychological health and wellbeing in affected communities may take considerable time to return to the normal range (Norris, Friedman, & Watson, 2002). In follow-up assessments completed at time-points between four- and seven-years post-disaster event, it has been observed that population-wide levels of psychological distress and rates of PTSD were still elevated compared with norms, despite exhibiting a downward trend in intensity over time (Abramson et al., 1996; Bryant et al., 2018; Livanou et al., 2005; North et al., 2011; Paxson et al., 2012). Furthermore, there is evidence that, in some cases, symptoms of psychological distress associated with exposure to a trauma have a delayed onset and may not become apparent until several years after the event (Bonanno et al., 2008; McFarlane, 2010).

Most people in disaster-affected communities do not consequently go on to experience problematic levels of psychological distress or develop a psychiatric disorder (Norris et al., 2009). However, those who do typically endure symptoms that persist for years afterwards (Bryant et al., 2018; Fergusson et al., 2014; Norris, Friedman, Watson, et al., 2002). Determining what factors indicate vulnerability and resilience to adverse mental health after a disaster is an emerging research topic with important implications for disaster-response planning. Such research may help to determine the extent and duration of services needed by a community affected by disaster. To date, several risk factors have been associated with poor mental health following disaster, including pre-existing mental health conditions (Stein et al., 2019), having experienced prior trauma (Karam et al., 2014), a recent significant life event (Bryant et al., 2018), unemployment (Bosmans & Van der Velden, 2018), social disengagement (Platt et al., 2016) or having few social supports to draw upon (Galea et al., 2008), and a larger number of dependent children in the household (Abramson et al., 2008).

3 Study aim and research questions

The overall aim of the Hazelwood Health Study Psychological Impacts research stream is to determine whether exposure to smoke from the 2014 Hazelwood coal mine fire is associated with psychological trauma and distress, and to examine factors associated with recovery and resilience in the affected community.

The aims of this *Mental Health and Wellbeing Follow-up Survey* were to:

- Investigate whether levels of psychological distress in adults who were residing in Morwell at the time of the 2014 Hazelwood mine fire have changed in the three years since completing the 2016-2017 Adult Survey (Ikin et al., 2020);
- Explore the potential role of sociodemographic factors, physical health and wellbeing, personal resilience, social support, exposure to prior trauma, and other recent major life events in the onset and maintenance of psychological distress related to the 2014 Hazelwood mine fire; and
- Explore the relationship between individual and community wellbeing and psychological impacts of the 2014 Hazelwood mine fire.

The data collection period for the Mental Health and Wellbeing Follow-Up Survey coincided with the catastrophic bushfire events that impacted south-eastern Australia between September 2019 and March 2020, with significant fire activity elsewhere in Gippsland and periods of widespread smoke haze across the Latrobe Valley. Accordingly, the timing of the survey provided the opportunity to consider how longer-term psychological impacts of exposure to an earlier smoke event may present within the context of a subsequent smoke event.

This is the first of multiple reports that are expected to arise from the Hazelwood Health Study Mental Health and Wellbeing Follow-Up Survey. The aims of the current report are to:

- Evaluate changes in event-related psychological distress and general psychological distress between the 2016-2017 survey and the 2019-2020 follow-up survey;
- Evaluate whether changes in psychological distress are associated with fine particulate matter ($PM_{2.5}$) exposure level during the mine fire event; and
- Compare whether the at-risk group identified in the 2016-2017 survey (young people) were still at higher risk at the time of the 2019-2020 follow-up survey.

Future reporting on survey findings will include consideration of the key factors added to the current survey, including social isolation, loneliness, and resilience, as well as the relationship between personal wellbeing and broader community wellbeing.

4 Human Research Ethics Committee approval

The protocol for the original Hazelwood Health Study Adult Survey was approved by the Monash University Human Research Ethics Committee (MUHREC) on 21 May 2015 (project number 6066). Ethical approval to conduct the Mental Health and Wellbeing Follow-up Survey was granted on 16 October 2019 by the MUHREC (project number 21151).

5 Methods

5.1 Study design

The Mental Health and Wellbeing Follow-up Survey functioned as a longitudinal follow-up assessment of psychological health and wellbeing among participants who completed the HHS Adult Survey conducted between May 2016 and February 2017 (Ikin et al., 2020). While the Adult Survey (hereafter referred to as the round 1 survey) was a wide-ranging survey assessing multiple potential health outcomes, the current round 2 survey was focused specifically on psychological health and wellbeing. Key measures of psychological distress associated with the event (Impact of Events Scale - Revised [IES-R]; Weiss & Marmar, 1997) and general psychological distress (Kessler Psychological Distress Scale [K10]; Kessler et al., 2003) were repeated, allowing us to observe any individual changes in psychological health and wellbeing over the three years between survey rounds in the community most impacted by the Hazelwood mine fire. Additionally, the round 2 survey included newly implemented measures to investigate a broader range of individual and social factors that might contribute to, or otherwise protect against, adverse psychological health in response to the Hazelwood mine fire event.

Data collection in the follow-up survey was conducted between December 2019 and March 2020. Accordingly, the round 2 survey took place approximately three years after the original Adult Survey, and approximately six years after the 2014 Hazelwood mine fire event (February-March 2014).

5.2 Survey piloting

The round 2 survey was piloted with members of two community groups located in towns immediately adjacent to Morwell, with eight people participating in each pilot session. Feedback collated during piloting contributed to optimising accessibility, presentation and clarity of the survey for participants. The pilot groups assisted in testing the functionality of the online survey platform, including the distribution of invitations via email and SMS, weblinks, participant verification procedures and the delivery of reimbursement vouchers.

5.3 Participant eligibility

The sampling frame for the Mental Health and Wellbeing Follow-up Survey was the Morwell participant cohort of the 2016-2017 Adult Survey. Round 1 survey participants were accessed from the Victorian Electoral Commission roll and the survey was open to people who at 31 of March 2014, were aged 18 years or older and residing in Morwell. In total, 3,096 Morwell residents participated in the Adult Survey. From this initial cohort, 3,077 were identified as eligible to be included in weighted random sampling for the Mental Health and Wellbeing Follow-Up Survey. The remaining 19 participants from the cohort were ineligible due to either having died (*n* = 17) or having previously notified the HHS that they did not want to receive further invitations to participate in research (*n* = 2).

A priori power analyses indicated that approximately 450 participants would need to be recruited into the Mental Health and Wellbeing Follow-up Survey to detect a 2-point change in the IES-R scores of participants from round 1 survey to round 2 survey, assuming a standard deviation of 4 points, with at least 90% power using mixed-effects regression analysis. Based on the response rate from the round 1 survey, it was anticipated that the response rate in the Follow-up Survey would be approximately 30%. Accordingly, a weighted random sample of 1,512 participants, stratified by age group at the time of participating in the round 1 survey (categories: Aged <35 Years; Aged 35-65 Years; Aged >65 Years) and level of exposure to $PM_{2.5}$ during the 2014 Hazelwood mine fire period (categories: Low Exposure; Medium Exposure; High Exposure), was drawn from the eligible cohort for an invitation to participate in the Follow-up Survey. Over-sampling of younger participants (age group: <35 years) was adopted to compensate for the lower rate of participation among people in this age group observed in round 1 survey.

5.4 Contact and recruitment

A flowchart of recruitment into the Mental Health and Wellbeing Follow-up Survey is presented in Figure 1. The database of participant contact details maintained by the HHS for longitudinal research was utilised to recruit participants. In the round 1 survey, participants were informed that the HHS was intended to be a longitudinal study of health and wellbeing, with follow-up surveys and health assessments to be conducted in subsequent years. Round 1 survey participants were given the opportunity to provide contact details, including mailing address, mobile telephone number, and email address, to enable them to be invited to participate in future HHS research activities.

A staggered approach was taken to inviting participation into the round 2 survey, starting with email, then SMS, and finally postal approaches (depending on the contact information provided by participants). Within each contact mode, a survey invitation and a reminder were delivered approximately one week apart. Approaches continued in turn, until either a response was received or all six possible attempts (i.e. 2 approaches in each of the three modes) had been made. The invitations delivered via email and SMS included a weblink providing prospective participants direct access to the explanatory statement and online survey, instructions detailing how to arrange an alternative mode of survey completion, and instructions detailing how to opt out of the study. Postal invitations provided the same web links and instructions. In recognition of the time involved in completing the survey, participants were eligible to receive a $25 gift voucher as reimbursement. The reimbursement was delivered as an online e-gift voucher or mailed gift card in accordance with the preference of the participant. Survey responses were collected between December 2019 and March 2020.

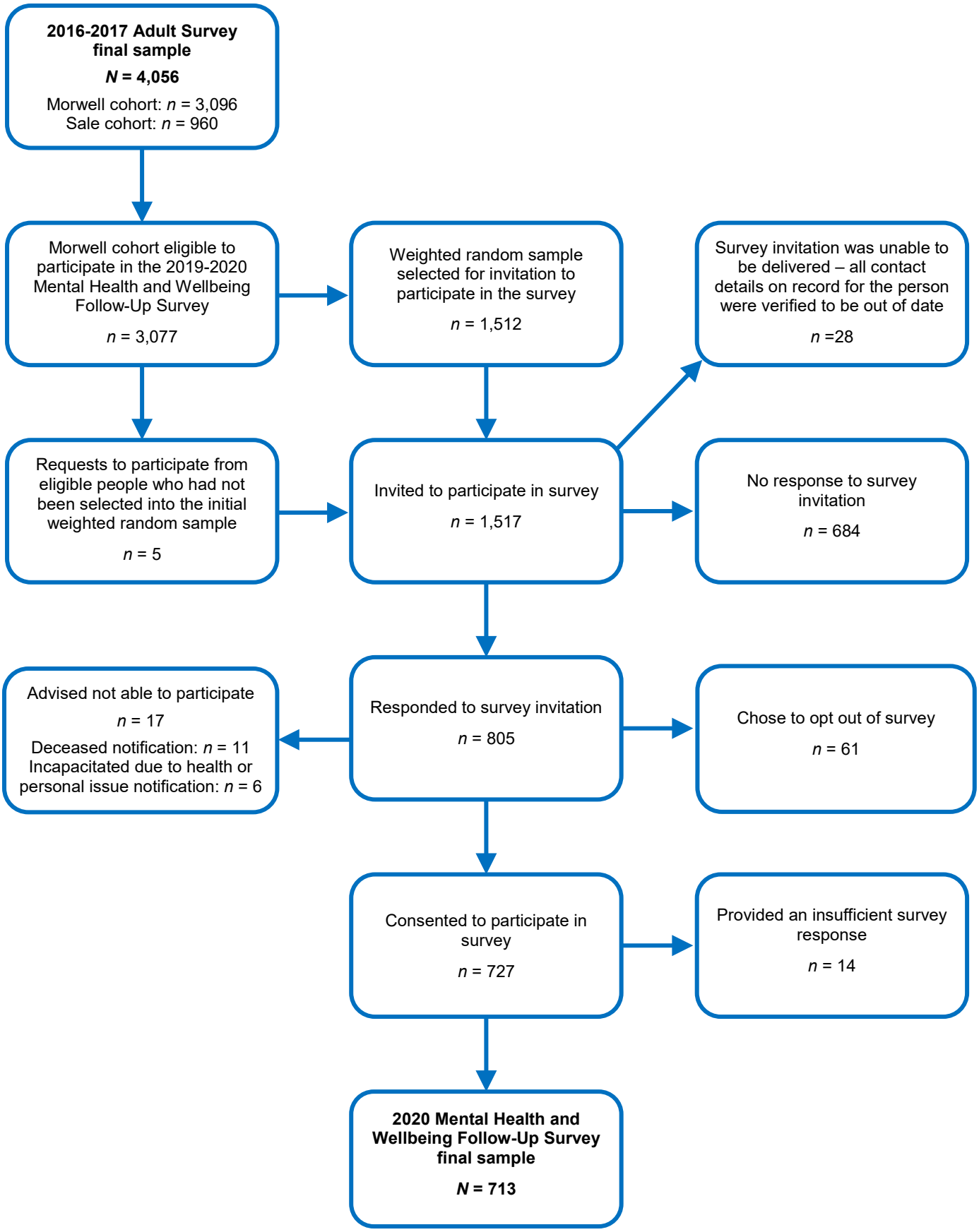

Figure 1. Mental Health and Wellbeing Follow-Up Survey recruitment flowchart

5.5 Final sample

The final sample for the round 2 survey was 713 participants (see Table 1). Of the 1,517 people who were sent an invitation, 17 were unable to participate due to death or incapacity. This equated to a response rate of 48% (713 participants from 1,500 viable invitations). This was well above the anticipated 30% response rate for the survey, and the final sample exceeded the recruitment target of 453 participants. To ensure adequate representation across both age and levels of $PM_{2.5}$ exposure, minimum recruitment numbers in each *Age-by-Exposure stratum* were determined *a priori*. Table 1 shows that each of these stratum targets was exceeded.

Table 1. Mental Health and Wellbeing Follow-up Survey participation grouped by $PM_{2.5}$ exposure and age

	$PM_{2.5}$ exposure level during the 2014 Hazelwood mine fire			
Age at time of round 1 survey	**Low exposure**	**Medium exposure**	**High exposure**	**Total participants**
<35 years	67 (target: 42)	75 (target: 38)	53 (target: 33)	**195 (target: 113)**
35-65 years	131 (target: 73)	120 (target: 82)	126 (target: 75)	**377 (target: 230)**
>65 years	51 (target: 37)	43 (target: 34)	47 (target: 39)	**141 (target: 110)**
Total participants	**249 (target: 152)**	**238 (target: 154)**	**226 (target: 147)**	**713 (target: 453)**

5.6 Survey completion modes

To enhance accessibility and maximise participation, three ways to respond to the Mental Health and Wellbeing Follow-up Survey were offered:

1. *Computer-assisted web interview (CAWI).* This was the primary mode of response to the survey. All electronic survey invitations sent to prospective participants provided direct access to the online survey.
2. *Computer-assisted telephone interview (CATI).* In this mode the survey was conducted over the phone, facilitated by a research team member, at a time convenient to the participant; or
3. *Postal response.* In this mode, a paper version of the survey was sent via postal mail by the research team and the participant mailed back their response.

In summary, 82.5% of participants responded to the survey via CAWI, 15.8% via CATI, and 1.7% via postal response.

5.7 Survey instrument

The round 2 survey involved repeat measurement of IES-R and K10 distress scores, which were implemented in HHS research as the core assessments of psychological health and wellbeing among adults in the aftermath of the 2014 Hazelwood mine fire (Ikin et al., 2020). Demographics and other risk factors which may have changed since the round 1 survey, such as education level, employment status, and self-reported mental health diagnoses, were also repeated in round 2.

In addition, the survey included measures implemented in HHS surveying for the first time. These newly included measures assessed community wellbeing, resilience, recent adverse life-events, social support and loneliness. These instruments and the structure of the Mental Health and Wellbeing Follow-up Survey are presented in Table 2. The survey retained a consistent structure and presentation across CAWI, CATI, and postal formats.

5.8 Data management

The survey database, used to email and SMS survey invitations to participants and to collect data, was managed using the web-based application REDCap (Research Electronic Data Capture) hosted by Monash University (Harris et al., 2019; Harris et al., 2009). Survey data collected by CAWI or CATI were entered directly into the online survey database. Paper survey data were manually entered into the survey database and then cross-checked by a second team member, with any discrepancies reviewed by a third team member to ensure accuracy.

All data were subject to statistical checks for missing, invalid, inconsistent or outlying results. Where such problems were found, decision rules were applied which allowed most records to be 'cleaned'. Where data remained missing after cleaning, methods of imputation were employed as part of the statistical analysis.

Data from the round 2 survey were merged with the previously collected round 1 survey data. This enabled key confounders from round 1, including demographic factors: age, gender, education level, and employment status, as well as health factors: mental health diagnoses, prior cardiac events, prior asthma or chronic obstructive pulmonary disease (COPD) and previous traumatic exposures, to be controlled for in the analysis of round 2 survey outcomes. In the case of mental health diagnoses prior to the 2014 mine fire (hereafter referred to as prior mental health), a question regarding the type and date of clinically diagnosed mental health conditions was included in both survey rounds. As expected, there were some discrepancies between self-reported type and date of prior mental health diagnoses between the two rounds, which likely reflected a change in state (i.e. recovery or recurrence of condition) or change in willingness to self-report a condition. To capture all possible instances of prior mental health diagnoses regardless of type and survey round, we merged the responses to both survey rounds to include any prior mental health diagnosis reported in round 1, and any additional prior mental diagnoses reported in round 2 (Table 2).

Table 2. Mental Health and Wellbeing Follow-Up Survey structure

Sections and measures	Repeated measure	Summary of construct measured and previous HHS findings
Section A: Living and working circumstances		
Current place of residence and contact details	Yes	This item provided an opportunity to verify and update an individual's HHS records, and captured detail of relocation away from Morwell after the 2014 Hazelwood mine fire.
Household composition	No	This item captured information about an individual's current household and living circumstances.
Parental status	No	This item captured information about parenthood and how many dependent children an individual currently had living with them.
Education level	Yes	This repeated item captured change in an individual's attained level of qualification since the round 1 survey.
Employment status	Yes (modified)	This repeated item captured change in an individual's employment circumstances since the round 1 survey. An additional sub-question was included to record job title.
Section B: Current wellbeing in regard to the 2014 Hazelwood mine fire event		
Impact of Events Scale – Revised (IES-R; Weiss & Marmar, 1997)	Yes	The IES-R assessed an individual's level of psychological distress, experienced in specific relation to a traumatic event (in this study: the 2014 Hazelwood mine fire), over the previous week. Event-related psychological distress is a mental health outcome of primary interest in the Hazelwood Health Study.
Section C: Community wellbeing		
(1) Community Wellbeing Index (CWI; Forjaz et al., 2011)	No	The CWI assessed an individual's current level of satisfaction in relation to the community in which they live.
(2) Change in Community Wellbeing - CWI modified to measure change from pre-event (considered retrospectively).		An adaption of the CWI was developed by the research team to additionally assess change in satisfaction in relation to the community since the time immediately before the 2014 Hazelwood mine fire event occurred.
Section D: General health		
Self-Reported Health Survey (SF-12): General health item (Ware et al., 1996)	Yes	The General Health item of the SF-12 assessed an individual's perception of their overall quality of health.
Patient Health Questionnaire (PHQ-15; Kroenke et al., 2002)	No	The PHQ-15 assessed an individual's level of somatic symptomology. Somatisation is the tendency to experience and communicate psychological distress in the form of physical symptoms.
Self-report of clinician diagnosed mental health conditions	Yes	This item assesses whether an individual has ever been diagnosed with a mental health condition and, if so when this occurred in relation to the 2014 Hazelwood mine fire. Mental health diagnoses are a mental health outcome of primary interest in the Hazelwood Health Study.
Section E: General wellbeing		

Sections and measures	Repeated measure	Summary of construct measured and previous HHS findings
Kessler Psychological Distress Scale (K10; Kessler et al., 2003)	Yes	The K10 assessed an individual's level of psychological distress, experienced in a general sense, over the previous four weeks. General psychological distress is a mental health outcome of primary interest in the Hazelwood Health Study.
2-item Connor-Davidson Resilience Scale (CD-RISC2; Vaishnavi et al., 2007)	No	The CD-RISC2 assessed personal resilience, being an individual's capacity to adapt and recover when they encounter adversity.
Section F: Recent life-events		
List of Traumatic Experiences Questionnaire (LTE-Q; Brugha et al., 1985)	No	The LTE-Q assessed potentially difficult or adverse personal circumstances that an individual may have experienced over the previous 12 months.
Section G: Social support		
Duke Social Support Index (DSSI-11; Koenig et al., 1993)	No	The DSSI-11 assessed an individual's levels of engagement with available support within their family and social network.
Center for Epidemiologic Studies Depression Scale (CES-D): Loneliness Item (Radloff, 1977)	No	The CES-D loneliness item assessed an individual's level of loneliness experienced over the previous week.

Note: As this report provides a preliminary analysis of key changes between the two survey rounds, the variables added to the round 2 survey have not been included in the analysis. Future cross-sectional analysis will detail how differences in exposure to the mine fire impact on these new measures.

5.9 Assessment of $PM_{2.5}$ exposure during the mine fire period

Due to a lack of ground-level-monitor air pollution measurements, particularly at the start of the mine fire period, retrospective modelling was carried out by the CSIRO Oceans & Atmosphere to obtain estimates of spatial and temporal $PM_{2.5}$ exposure related to the Hazelwood mine fire. A detailed description of the approach to modelling $PM_{2.5}$ exposure has been published elsewhere (see Luhar et al., 2020). The modelled $PM_{2.5}$ exposure data were then mapped onto the participant's self-reported time-location diaries for the mine fire period, completed as a component of the round 1 survey, to obtain each participant's level of mine-fire related $PM_{2.5}$ exposure during the event (Ikin et al., 2020). For the purposes of the current analysis, exposure was grouped into three categories, *Low Exposure*, *Medium Exposure*, and *High Exposure*, based on tertiles of mean daily $PM_{2.5}$ exposure of all Morwell round 1 survey participants during the mine fire event. This equated to mean daily $PM_{2.5}$ exposure levels of: <8.56 $\mu g/m^3$ for the Low Exposure group, 8.56 $\mu g/m^3$ to 14.15 $\mu g/m^3$ for the Medium Exposure group, and >14.15 $\mu g/m^3$ for the High Exposure group.

5.10 Statistical analyses

Statistical analysis and data transformations were performed using Stata version 16 (Stata Corporation, College Station, Texas 2019).

5.10.1 Assessment of response bias

Possible response (attrition) bias was evaluated based on characteristics of all 1,517 participants sampled for the round 2 survey (collected as a part of the earlier round 1 survey). Probit regression models were used to identify factors associated with responding to the round 2 survey versus not responding. The set of factors identified included age, gender, education level, marital status, exposure to the mine fire and smoking status, as well as the Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) score. An inverse probability weight was developed using a probit regression model for non-response which included this set of factors. The final response weight was calculated as the inverse of the predicted probability of responding to the survey multiplied by the overall response rate (also known as balancing weight). All further analyses were conducted using weighted methods of estimation.

5.10.2 Imputation for missing values

Missing data in the round 2 survey varied between 1-2% for demographic variables and was approximately 3% for the total scores of multi-scaled instruments analysed in this report. To obtain more accurate estimates, multiple-imputation (MI) procedures (Rubin, 1987) were incorporated in the analysis using the ICE package (Royston & White, 2011), which was used in conjunction with Stata's inbuilt MI procedures. The imputation was implemented using chained equations and twenty datasets were imputed. Individual items in the multi-scaled instruments were imputed with user-written imputation equations to reduce the chance of multicollinearity, and the subscale and total scores imputed passively from the combination of imputed (where required) and observed item scores.

5.10.3 Descriptive analysis

Categorical variables were presented as counts and weighted percentages. Continuous variables were presented as weighted means and weighted standard deviations, or weighted medians and weighted inter-quartile ranges (IQR) if skewed. Differences in demographic characteristics and health-related risk factors were compared between participants in different PM2.5 exposure groups using weighted Pearson chi-squared tests for categorical measures, and weighted analysis of variance (ANOVA) for continuous outcomes. When the distribution of a continuous variable was found to be heavily skewed, the data were log-transformed. Distributions of psychological distress scores in the round 1 and 2 surveys were visualised using boxplots.

5.10.4 Mixed-effects modelling

Linear mixed-effects regression models were implemented to evaluate changes over time in (1) event-related psychological distress (IES-R score), and (2) generalised psychological distress (K10 score), and the association of these changes with $PM_{2.5}$ exposure during the 2014 Hazelwood mine fire. To incorporate the multiple imputation, the mixed-effects models were run on each of the 20 imputed datasets and the results combined using Rubin's rules (Rubin, 1987). Mixed-effects modelling allows for the correlated structure of repeated-measures data. Accordingly, this modelling facilitated a comparison of IES-R scores and K10 scores in the round 2 survey with corresponding scores in the round 1 survey to determine whether levels of psychological distress have changed over the approximately 3 years between study rounds, and whether outcomes differed across the three levels of $PM_{2.5}$ exposure. Mean $PM_{2.5}$ exposure was included in the regression models as a continuous variable. A binary time variable (round 1 survey = 0; round 2 survey= 1) was included to estimate average within-participant change in psychological distress across the two study rounds. An interaction between $PM_{2.5}$ exposure and the time variable was tested to evaluate whether any change in psychological distress between the two study rounds varied by $PM_{2.5}$ exposure level.

As previous Adult Survey results suggested that younger people were more vulnerable to experiencing subsequent psychological distress related to their level of $PM_{2.5}$ exposure during the mine fire event (Broder et al., 2020), an interaction between age and $PM_{2.5}$ exposure was evaluated, and the interaction was also assessed for any change by survey round using a three-way interaction. In addition to age, other covariates adjusted for in the regression models were gender, self-reported mental health diagnoses prior to 2014, self-reported cardiac events, diagnosed asthma, diagnosed COPD, number of traumatic life events experienced, education, and employment.

5.10.5 Sensitivity analysis

Sensitivity analysis was conducted using un-imputed and un-weighted mixed-effects regression models to evaluate the impact of multiple imputation and response weighting on estimated effects. As IES-R and K10 scores both have a right-skewed distribution, mixed-effects modelling was carried out on the log-transformed outcome data to assess whether similar outcomes to the main results would be evident.

6 Results

6.1 Sample description

Table 3 presents participant characteristics by $PM_{2.5}$ exposure group for each survey round. The profiles for highest education level and employment were similar in the two survey rounds. Approximately one-third of the cohort reported having an asthma diagnosis, and slightly over 4% reported having a COPD diagnosis. A notable difference between the two study rounds is that a higher proportion of participants reported having fair or poor health at the time of second round, and that by that time there were no longer clear differences in self-reported general health status between the $PM_{2.5}$ exposure groups.

As shown in Figure 2, scores on both the IES-R and K10 had increased at the round 2 survey compared with corresponding scores from the round 1 survey, with the change in scores evident across all $PM_{2.5}$ exposure groups. The median IES-R score increased by 2 points in the low exposure group, by 4 points in the medium exposure group, and by 6 points in the high exposure group (see Table A1 in the appendix).

Table 3. Participant characteristics by $PM_{2.5}$ exposure group at each study round

Parameters[1, 2]	Round 1 (2016-2017 Adult Survey) Low exposure N = 249	Medium exposure N = 238	High exposure N = 226	*p*-value	Round 2 (2019-2020 Mental Health and Wellbeing Survey) Low exposure N = 249	Medium exposure N = 238	High exposure N = 226	*p*-value
Age, mean (SD)	52.1 (17.6)	48.3 (18.5)	52.1 (17.1)	0.08	55.4 (17.6)[2]	51.6 (18.6)	55.4 (17.1)	0.08
Female,	145 (56%)	128 (52%)	118 (50%)	0.51				
Highest education level								
Secondary up to year 10	54 (27%)	64 (33%)	38 (20%)	0.01	54 (27%)[2]	57 (28%)	35 (17%)	0.06
Secondary year 11-12	48 (21%)	59 (26%)	57 (27%)		48 (21%)	48 (21%)	60 (30%)	
Certificate, university or other tertiary institute	142 (52%)	108 (41%)	128 (53%)		143 (52%)	128 (50%)	124 (53%)	
Employment								
Paid employment	137 (51%)	126 (49%)	130 (52%)	0.23	136 (50%)	126 (49%)	120 (50%)	0.25
Other (student/volunteer/home-duties/retired)	86 (40%)	69 (34%)	67 (34%)		88 (40%)	70 (33%)	73 (37%)	
Unemployed/unable to work	23 (9%)	38 (17%)	29 (13%)		24 (10%)	39 (17%)	27 (12%)	
General health								
Excellent/Very good	117 (44%)	99 (39%)	89 (37%)	0.05	79 (31%)	65 (26%)	58 (27%)	0.75
Good	91 (37%)	76 (31%)	73 (32%)		78 (33%)	78 (33%)	71 (31%)	
Fair/Poor	41 (19%)	63 (30%)	63 (31%)		82 (36%)	83 (40%)	83 (42%)	
Asthma[3]	77 (30%)	75 (32%)	60 (27%)	0.58				
COPD[3]	9 (4%)	10 (6%)	12 (7%)	0.45				
Cardiac events[3]	41 (19%)	40 (19%)	44 (20%)	0.94				
Anxiety prior to 2014[4]	60 (23%)	61 (27%)	57 (26%)	0.64				
Depression prior to 2014[4]	57 (23%)	56 (24%)	64 (30%)	0.29				
PTSD prior to 2014[4]	12 (4%)	11 (5%)	13 (5%)	0.92				
Any mental health diagnosis prior to 2014[4]	78 (31%)	76 (33%)	81 (37%)	0.44				
Number of traumatic life events[3]								
None	84 (33%)	83 (34%)	63 (27%)	0.06				
One	60 (24%)	50 (20%)	37 (17%)					
Multiple	105 (43%)	102 (46%)	125 (56%)					

[1] Missing data (%) were as follows: Age and gender had no missing values; education was missing for 15 (2.1%) of participants in round 1, 16 (2.2%) in round 2; employment was missing for 8 (1.1%) in round 1, 10 (1.4%) in round 2; general health was missing for 1 (0.1%) in round 1, 36 (5.1%) in round 2; asthma was missing for 2 (0.3%); COPD and cardiac events had no missing values; anxiety was missing for 2 (0.3%); depression was missing 2 (0.3%); PTSD was missing 3 (0.4%); any mental health condition had none missing; and traumatic life events was missing 4 (0.6%).

[2] Statistics presented are number (weighted %) and weighted mean (SD) with weighted chi-square tests performed for categorical variables and weighted ANOVA for continuous variables

[3] Only collected in round 1 survey

[4] Includes anyone reporting a prior diagnosis in either round 1 or round 2.

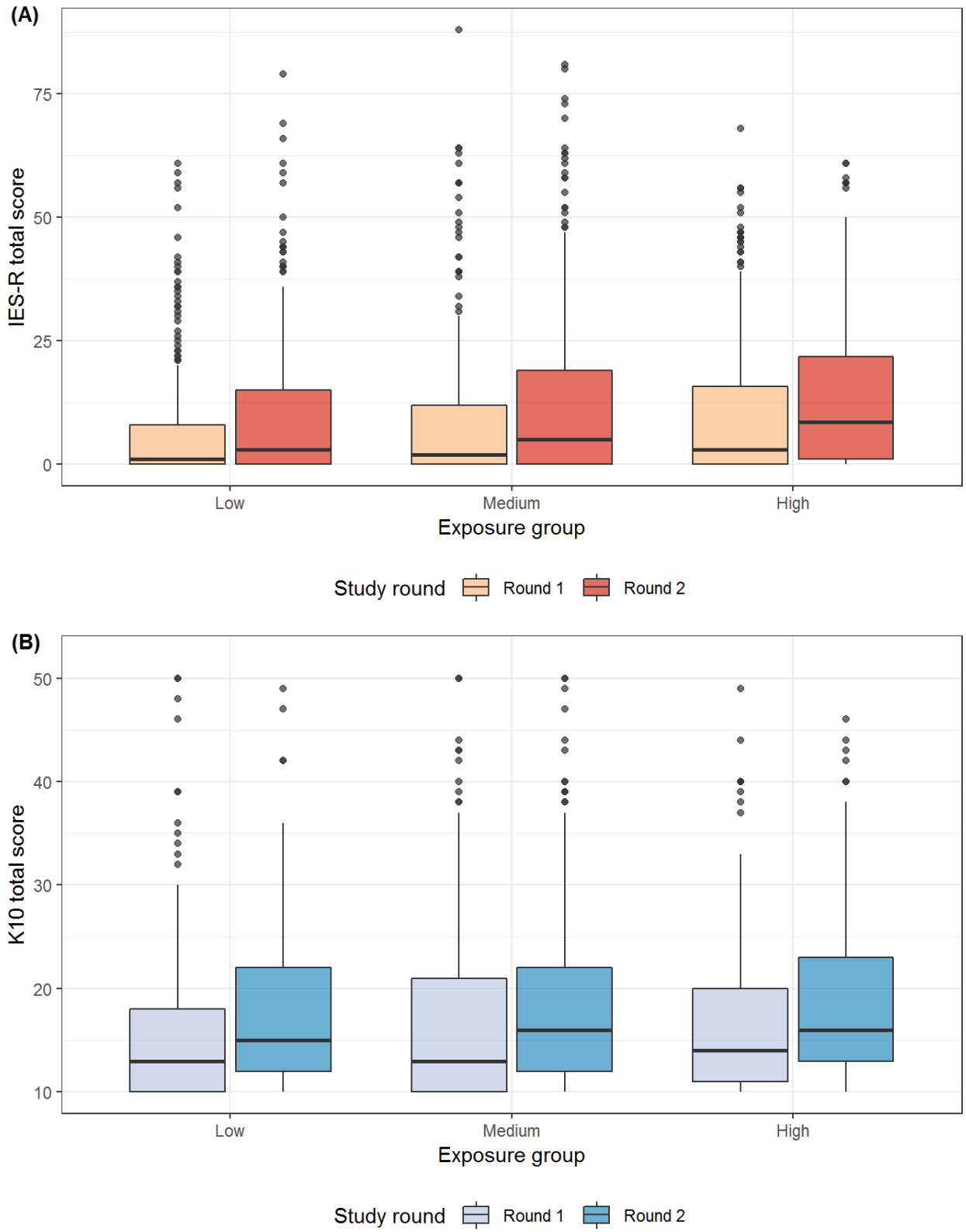

Figure 2. Distributions of IES-R and K10 scores by $PM_{2.5}$ exposure group at each study round

6.2 Changes in psychological distress over time

6.2.1 Change in event-related psychological distress (IES-R results)

Table 4 presents the results of the final linear mixed-effects model with event-related psychological distress (IES-R score) as the outcome of interest. After adjusting for mean $PM_{2.5}$ exposure and round 1 confounders, participants' IES-R total scores increased on average by 2.6 points (95% CI: 1.2 to 3.9 points) between the two survey rounds. For each 10 µg/m^3 increase in mean $PM_{2.5}$ exposure, there was an estimated 1.1-point increase in IES-R score (95% CI: 0.1 to 2.0 points) at the cohort mean age during the mine fire, 47 years. For other ages, consistent with the round 1 Adult Survey results (Broder et al., 2020), the exposure-outcome association was stronger among younger people. The age-dependence of the exposure-outcome association, illustrated for ages 35, 45 and 65 years, is presented in Figure 3. The effect of age can be summarised from the estimated model as follows: with each 10-year decrease in age the impact of mean $PM_{2.5}$ exposure on IES-R score increased on average by 0.5 points (95% CI: 0.01 to 1.1 points). This means that for every 10 µg/m^3 increase in average daily mine fire related $PM_{2.5}$ exposure, IES-R scores were estimated to increase by 2.1 points on average for participants aged 27 years at the time of the mine fire, and by 1.6 points for participants aged 37 years at the time, compared with a more modest increase of 0.5 points for participants aged 57 years at the time.

No evidence was found that the amount of change in IES-R score between round 1 and 2 differed by $PM_{2.5}$ exposure level (p = 0.48 for the interaction between $PM_{2.5}$ exposure and survey round). Accordingly, this interaction term was not included in the final model presented in Table 4.

Other risk factors in the round 1 survey that were associated with an increase in IES-R score in round 2 were self-reported diagnosis of asthma, self-reported COPD, having had multiple traumatic events, and being unemployed or unable to work. Having a certificate or tertiary qualification was observed to have a protective association with IES-R score in comparison with having an education level up to Year 10. There was no association between IES-R score and having experienced a cardiac event or having been diagnosed with a mental health condition prior to 2014.

6.2.2 Change in general psychological distress (K10 results)

Table 5 shows the results of the final linear mixed-effects model with general psychological distress (K10 score) as the outcome of interest. Similar to the event-related psychological distress findings, after adjusting for $PM_{2.5}$ exposure and confounders, there was an increase in general psychological distress in the round 2 survey (a mean increase in K10 scores of 1.8; 95% CI: 1.2 to 2.4). However, $PM_{2.5}$ exposure was no longer associated with K10 scores in round 2. Furthermore, there was no evidence of differential exposure-response associations by age and study round (p = 0.61 for the interaction between age and $PM_{2.5}$ exposure, and p = 0.56 for the interaction between study round and $PM_{2.5}$ exposure).

There was strong evidence for an association between age and K10, with K10 decreasing on average by 0.9 points (95% CI: 0.5 to 1.4) for every 10-year increase in age. The K10 scores for participants who reported having had a prior mental health condition were found to be, on average, 3.9 points higher (95% CI: 2.7 to 5.1). Other round 1 risk factors associated with an increase in K10 score at round 2 were having an asthma diagnosis, having a COPD diagnosis, having experienced one or more traumatic life events, and being unemployed or unable to work. Having a higher education level was associated with a decrease in K10 score.

Table 4. Linear mixed-effects model results for IES-R total scores

Risk factors	IES-R total score	
	Coefficient (95% CI)	***p*-value**
Mean exposure to mine fire related $PM_{2.5}$ (per 10 µg/m³; at the mean age during the mine fire of 47 years)[1]	1.1 (0.1, 2.0)	0.031
Survey round (0 = round 1; 1 = round 2)	2.6 (1.2, 3.9)	<0.001
Age during the mine fire (per 10 years; at an exposure level of 10 µg/m³)[2]	0.3 (-0.6, 1.2)	0.55
Interaction between exposure and age[3]	-0.5 (-1.0, -0.01)	0.045
Mental health conditions prior to 2014	1.0 (-1.4, 3.5)	0.40
Male	0.3 (-1.8, 2.3)	0.78
Cardiac event pre/post 2014[4]	1.4 (-1.9, 4.7)	0.40
Asthma diagnosed pre/post 2014[4]	2.5 (0.2, 4.9)	0.036
COPD diagnosed pre/post 2014[4]	7.6 (1.0, 14.2)	0.023
Number of traumatic life events[4]		
None	Reference	
One	1.3 (-1.4, 4.0)	0.34
Multiple	4.2 (1.7, 6.7)	0.001
Education level at each survey[4]		
Secondary up to year 10	Reference	
Secondary year 11-12	-3.2 (-7.0, 0.6)	0.10
Certificate, university or other tertiary institute degree	-5.4 (-8.4, -2.4)	<0.001
Employment at each survey[4]		
Paid employment (FT, PT, self-employed)	Reference	
Other (student/volunteer/home-duties/retired)	1.8 (-1.3, 4.8)	0.25
Unemployed/unable to work	5.8 (1.8, 9.9)	0.005

[1] Mean $PM_{2.5}$ exposure variable was centred at 10 µg/m³ and divided by 10 to give exposure units per 10 µg/m³

[2] Age during coalmine fire was centred at the mean (47 years) and divided by 10 to give age per 10 years

[3] The increase in the exposure effect per each 10-year increase in age

[4] Round 1 covariates. Coefficients were estimated from multivariate weighted mixed-effects regression with missing data imputed using chained equations

Table 5. Linear mixed-effects model results for K10 scores

Risk factors	K10 score Coefficient (95% CI)	*p*-value
Mean exposure to mine fire related $PM_{2.5}$ (per 10 µg/m³; at the mean age during the mine fire of 47 years)[1]	0.2 (-0.3, 0.6)	0.47
Survey round (0 = round 1; 1 = round 2)	1.8 (1.2, 2.4)	<0.001
Age during mine fire (per 10 years; at an exposure level of 10 µg/m³) [2]	-0.9 (-1.4, -0.5)	<0.001
Mental health conditions prior to 2014	3.9 (2.7, 5.1)	<0.001
Male	-0.6 (-1.6, 0.4)	0.25
Cardiac event pre/post 2014[3]	1.4 (-0.03, 2.8)	0.06
Asthma diagnosed pre/post 2014[3]	1.3 (0.1, 2.4)	0.029
COPD diagnosed pre/post 2014[3]	3.4 (0.8, 6.1)	0.012
Number of traumatic life events[3]		
None	Reference	
One	2.5 (1.0, 3.9)	<0.001
Multiple	3.0 (1.9, 4.2)	<0.001
Education level at each survey[3]		
Secondary up to year 10	Reference	
Secondary year 11-12	-1.4 (-3.0, 0.3)	0.10
Certificate, university or other tertiary institute degree	-2.3 (-3.6, -0.9)	<0.001
Employment at each survey[3]		
Paid employment (FT, PT, self-employed)	Reference	
Other (student/volunteer/home-duties/retired)	1.0 (-0.4, 2.3)	0.15
Unemployed/unable to work	4.7 (2.6, 6.7)	<0.001

[1] Mean $PM_{2.5}$ exposure variable was centred at 10 µg/m³ and divided by 10 to give exposure units per 10 µg/m³

[2] Age during coalmine fire was centred at the mean (47 years) and divided by 10 to give age per 10 years

[3] Round 1 covariates. Coefficients were estimated from multivariate weighted mixed-effects regression with missing data imputed using chained equations

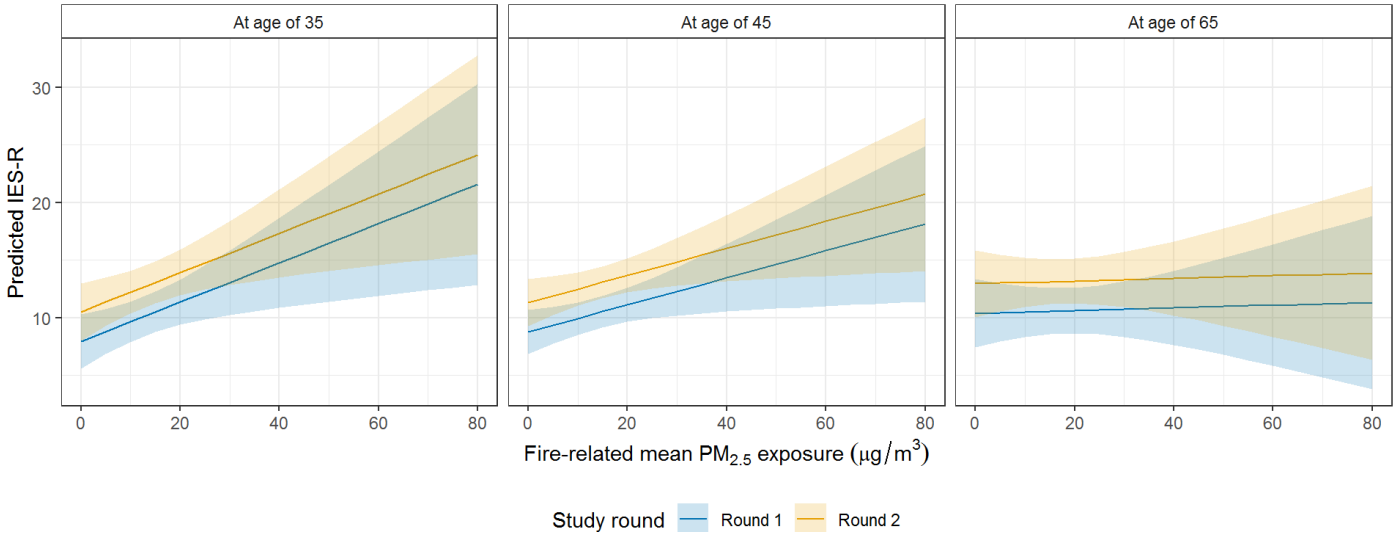

Figure 3. Illustration of the estimated age-dependence of the association between mine-fire $PM_{2.5}$ exposure and event-related psychological distress

6.3 Sensitivity analysis

Sensitivity analyses are presented in Tables A2 and A3 of the appendix, and consisted of results from: (1) imputed and unweighted mixed-effects regression models, (2) unimputed and unweighted mixed-effects regression models, and (3) unimputed and unweighted mixed-effects regressions with log-transformed outcome variables. For both IES-R and K10, the findings were consistent across all models, suggesting the robustness of our conclusions. It should be noted that the values of coefficients estimated from log-transformed outcomes are not directly comparable with values from other models; here we are looking to see if similar conclusions can be drawn about the associations seen in Tables 4 and 5.

7 Discussion

7.1 Summary of the main findings

The main finding of the study is that there was a continuing relationship between participants' level of exposure to $PM_{2.5}$ during the 2014 Hazelwood mine fire event, and their level of psychological distress attributed to that event six years on. At the mean age of the cohort, for each 10 µg/m^3 increase in mean daily $PM_{2.5}$ exposure, there was a 1.1-point increase in IES-R score. This increase in event-related psychological distress level was consistent with the round 1 Adult Survey results, where a 1.0-point increase was found for the same 10 µg/m^3 increase in $PM_{2.5}$ exposure (Broder et al., 2020). In addition, psychological distress associated with the 2014 Hazelwood mine fire event had increased over the time that had passed between survey rounds. On average, IES-R scores increased by 2.6-points from the first to the second survey. Higher event-related psychological distress was also associated with other key risk factors, including asthma, COPD, multiple prior traumatic events, and being unemployed or unable to work. Consistent with the round 1 analysis (Broder et al., 2020), the impact of $PM_{2.5}$ exposure on IES-R scores was stronger in younger people, with scoring increasing by 0.5 points with each 10-year decrease in age.

In addition to measuring distress associated with the event, we also measured general distress in the past month (using the K10 scale) in both survey rounds. There was evidence that general distress levels also increased, with a 1.8-point rise between round 1 and 2. However, unlike the IES-R findings, there was no evidence of an association between mine fire $PM_{2.5}$ exposure and general distress levels. Younger age, along with all other key risk factors except gender, were associated with increased general distress. Again, unlike the IES-R findings, there was no interaction between age and $PM_{2.5}$ exposure.

An increase in the levels of both event-related and general psychological distress over time is a finding that contrasts with other post-disaster studies. Studies following the Ash Wednesday (McFarlane et al., 1997) and Black Saturday fires (Bryant et al., 2014) have reported psychological distress levels decreasing over time. Importantly then, it would appear that our findings should be considered within the context of the timing of the survey, which coincided with the 2019-2020 bushfire season that had a catastrophic impact in some regions of south-eastern Australia. While the fires in Victoria were primarily restricted to East Gippsland and the closest major fires were approximately 150 km from

Morwell, the resultant smoke from the fires was widespread, with 43 smoke health alerts issued for the region or for the whole of Victoria during the fire period (Inspector-General for Emergency Management, 2020). We know anecdotally from comments made by some participants who were interviewed over the phone that the 2019-2020 bushfires brought back thoughts of the Hazelwood event. Given that the round 1 survey was completed during a relatively mild summer with minimal fire activity, whilst the round 2 survey was completed during an extremely active fire season which resulted in considerable local smoke exposure, it seems plausible that the increase in distress levels observed from round 1 to round 2 on both the IES-R and K10 may be due, in some part, to the contrasting background circumstances at the time of each survey.

Regardless, the finding that there was still a clear relationship between $PM_{2.5}$ exposure level and scoring on the IES-R six years after the Hazelwood event suggests that people's level of exposure to the earlier Hazelwood event has influenced their psychological response during a current event. The lack of a relationship between $PM_{2.5}$ exposure level and general distress may be because the association between exposure and general distress was not as strong as that with event-related distress, and so the smaller sample size for the current analysis (713 participants compared with the original Morwell cohort of 3,096 participants), would have reduced our power to detect an exposure effect.

7.2 Strengths and weaknesses of the research

This research has several key strengths. In contrast to previous air pollution studies which generally rely on population-level pollution data, the current analysis utilised individual level $PM_{2.5}$ exposure data generated by coupling modelled $PM_{2.5}$ distribution with participants' time-location diaries. This measure of exposure was largely free from the influence of the individual's perception of the exposure (Glass & Sim, 2006).

There are, however, several limitations to this research. There is potential for recall bias in the time-location diary information provided by participants, particularly given that this information was collected more than two years after the mine fire (Coughlin, 1990). Additionally, some sampling bias (participation or selection) might still be present even after the weighting of the sample to ensure adequate representation in terms of age and exposure level, and the application of response weightings in the statistical analyses.

In addition, the coincidental timing of the survey, which overlapped with a major fire and smoke event, means that the round 2 survey responses are likely to have been influenced to some degree by background circumstances, rather than being an unsullied measure of ongoing psychological impacts resulting from exposure to smoke from the Hazelwood mine fire. Given the survey was launched without foreknowledge of the impending fire and smoke event, we did not attempt to capture information on our participants' level of exposure to the 2019-2020 fire and smoke event. However, as most participants were still residing in Morwell, it is likely that there was little variation in smoke exposure between participants during the round 2 survey period. Importantly, while the influence of the 2019-2020 fire and smoke event makes it challenging to gain a clear picture of mental health trajectories following on from the Hazelwood event, it sheds particular light on the potential of prior exposures to influence how people respond to a current event.

8 Conclusions

The key message from the analysis presented in this report is that higher levels of exposure to the Hazelwood mine fire were associated with reporting higher psychological distress levels in relation to the event some six years later. This finding highlights the importance of considering the impacts of prior events when planning the public health response to new events. Based on this finding, we recommend that public health agencies include warnings that people who have experienced similar events in the past may experience increased psychological distress in response to the new event and that they should seek support if needed. In addition, the finding that multiple risk factors were associated with increased psychological distress, both attributed to the mine fire and in general, suggests that a more nuanced approach be taken to identifying and supporting vulnerable groups. This need for nuanced messaging is reinforced by the finding here, building on the earlier round 1 finding, that younger people may be more at risk of event-related psychological distress.

The possible impact of the recent fire/smoke event on participant responses in the follow-up survey limits our capacity to draw conclusions about the ongoing mental health trajectory for study participants, other than to say that a prior event impacted on how participants responded during a new event that shared some similar characteristics. Importantly, a further round of the survey is planned in 2022, which will yield insights on how participants are coping eight years after the Hazelwood mine fire event and the longitudinal trajectory of their mental health.

It should also be noted that the current analysis did not include consideration of the new factors included in the follow-up survey, such as resilience, social isolation, and community wellbeing. These will be considered in upcoming reports and scientific publications. By focusing on changes in psychological distress within the community, rather than delving into the complicated interplay of risk factors, we think that this report provides more straightforward findings which will be of interest to the community, and also to public health professionals, who will be able to draw on them when responding to future events.

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10 Appendix

Table A1. Distribution of IES-R and K10 scores by exposure group and study round

Psychological distress measures	Round 1 (2016-2017 Adult Survey)				Round 2 (2019-2020 Mental Health and Wellbeing Survey)			
	Low exposure N = 249	Moderate exposure N = 238	High exposure N = 226	*p*-value	Low exposure N = 249	Moderate exposure N = 238	High exposure N = 226	*p*-value
	Mean (SD) [2]	**Mean (SD)**	**Mean (SD)**		**Mean (SD)** [2]	**Mean (SD)**	**Mean (SD)**	
IES-R total score	7.5 (13.1)	10.4 (16.3)	11.3 (15.6)	0.028	10.4 (15.5)	14.1 (18.6)	13.5 (14.7)	0.048
Intrusion	3.0 (5.0)	4.1 (6.3)	4.7 (6.3)	0.006	4.3 (6.2)	5.9 (7.5)	5.8 (6.1)	0.022
Avoidance	2.6 (4.7)	3.7 (6.1)	4.0 (5.7)	0.036	3.5 (5.4)	4.7 (6.5)	4.9 (5.3)	0.022
Hyperarousal	2.3 (4.5)	2.8 (4.8)	2.9 (4.8)	0.47	2.7 (4.7)	3.6 (5.6)	3.0 (4.4)	0.26
K10 total score	16.0 (7.9)	17.4 (8.7)	16.9 (7.5)	0.24	17.8 (7.9)	18.9 (8.7)	19.0 (8.1)	0.24
	Median (IOR) [2]	**Median (IQR)**	**Median (IQR)**		**Median (IOR)** [2]	**Median (IQR)**	**Median (IQR)**	
IES-R total score	1 (0-8)	2 (0-14)	3 (0-16)	0.015	3 (0-15)	6 (1-21)	9 (1-22)	0.005
Intrusion	1 (0-4)	1(0-7)	2 (0-7)	0.005	1 (0-6)	3 (0-8)	4(0-10)	0.006
Avoidance	0 (0-3)	0 (0-5)	1 (0-6)	0.031	1 (0-5)	2 (0-7)	3 (0-8)	0.005
Hyperarousal	0 (0-2)	0 (0-3)	0 (0-4)	0.27	0 (0-3)	1 (0-5)	1 (0-5)	0.20
K10 total score	13 (10-19)	14 (10-21)	14 (11-20)	0.18	15 (12-22)	16 (12-23)	16 (13-23)	0.20

[1] Missing data (%) were as follows: for each IES-R item missing observations ranged from 0.6% to 1.7% of study sample (713) in round 1 and 0% to 1.1% in round 2; IES-R total was missing values for 32 participants (4.5%) in round 1 and 22 (3.1%) in round 2; IES-R Intrusion was missing for 21 (3.0%) in round 1 and 10 (1.4%) in round 2; IES-R Avoidance was missing for 26 (3.7%) in round 1 and 18 (2.5%) in round 2; IES-R Hyperarousal was missing for 13 (1.8%) in round 1 and 9 (1.3%) in round 2. Missing observations for K10 items ranged from 0.7% to 1.1% in round 1 and 1.8% to 2.4% in round 2; K10 was missing 14 (2.0%) in round 1 and 19 (2.7%) in round 2.

[2] Statistics presented are weighted mean (SD) and weighted median (IQR). Statistical tests performed: weighted ANOVA when mean (SD) is reported; and weighted ANOVA with log transformed outcome when median (IQR) is reported

Table A2. Sensitivity analysis of linear mixed-effects model results for IES-R total scores

Risk factors	Imputed & unweighted		Unimputed & unweighted		Log transformed	
	Coefficient (95% CI)	*p*-value	Coefficient (95% CI)	*p*-value	Coefficient (95% CI)	*p*-value
Mean exposure to mine fire related $PM_{2.5}$ (per 10 µg/m³; at the mean age during the mine fire of 47 years)[1]	1.1 (0.2, 2.1)	0.016	1.1 (0.1, 2.0)	0.026	0.15 (0.06, 0.24)	0.001
Survey round (0 = round 1; 1 = round 2)	2.6 (1.4, 3.8)	<0.001	2.7 (1.5, 3.9)	<0.001	0.34 (0.24, 0.44)	<0.001
Age during the mine fire (per 10 years; at an exposure level of 10 µg/m³) [2]	0.5 (-0.4, 1.4)	0.251	0.5 (-0.4, 1.4)	0.301	0.07 (-0.01, 0.14)	0.079
Interaction between exposure and age[3]	-0.5 (-1.0, 0.0)	0.050	-0.5 (-1.0, 0.0)	0.065	-0.05 (-0.11, -0.00)	0.048
Mental health conditions prior to 2014	1.3 (-1.0, 3.6)	0.260	1.6 (-0.6, 3.9)	0.151	0.17 (-0.03, 0.37)	0.099
Male	-0.03 (-2.0, 1.9)	0.974	0.3 (-1.6, 2.3)	0.747	-0.01 (-0.19, 0.16)	0.878
Cardiac event pre/post 2014[4]	0.7 (-2.2, 3.7)	0.620	0.2 (-2.7, 3.2)	0.886	-0.05 (-0.30, 0.20)	0.694
Asthma diagnosed pre/post 2014[4]	2.0 (-0.2, 4.2)	0.079	1.2 (-1.0, 3.4)	0.298	0.18 (-0.02, 0.37)	0.076
COPD diagnosed pre/post 2014[4]	8.4 (1.9, 14.9)	0.012	10.0 (3.2, 16.8)	0.004	0.59 (0.12, 1.07)	0.015
Number of traumatic life events[4]						
None	Reference		Reference		Reference	
One	1.1 (-1.4, 3.6)	0.400	0.9 (-1.7, 3.5)	0.499	0.13 (-0.12, 0.38)	0.309
Multiple	3.9 (1.5, 6.2)	0.001	3.8 (1.4, 6.1)	0.002	0.43 (0.22, 0.65)	<0.001
Education level at each survey[4]						
Secondary up to year 10	Reference		Reference		Reference	
Secondary year 11-12	-3.2 (-7.0, 0.5)	0.089	-2.5 (-6.2, 1.2)	0.178	-0.20 (-0.49, 0.10)	0.189
Certificate, university or other tertiary institute degree	-5.3 (-8.3,-2.2)	<0.001	-4.6 (-7.7, -1.5)	0.003	-0.33 (-0.58, -0.08)	0.010
Employment at each survey[4]						
Paid employment (FT, PT, self-employed)	Reference		Reference		Reference	
Other (student/volunteer/home-duties/retired)	1.4 (-1.5, 4.2)	0.352	1.3 (-1.5, 4.2)	0.360	0.09 (-0.15, 0.33)	0.464
Unemployed/unable to work	5.9 (2.0, 9.8)	0.003	5.7 (1.9, 9.5)	0.003	0.34 (0.09, 0.71)	0.011

[1] Mean $PM_{2.5}$ exposure variable was centred at 10 µg/m³ and divided by 10 to give exposure units per 10 µg/m³ ;
[2] Age during coalmine fire was centred at the mean (47 years) and divided by 10 to give age per 10 years ;
[3] The increase in the exposure effect per each 10-year increase in age;
[4] Round 1 covariates

Table A3. Sensitivity analysis of linear mixed-effects model results for K10 scores

Risk factors	Imputed & unweighted Coefficient (95% CI)	*p*-value	Unimputed & unweighted Coefficient (95% CI)	*p*-value	Log transformed Coefficient (95% CI)	*p*-value
Mean exposure to mine fire related $PM_{2.5}$ (per 10 µg/m³; at the mean age during the mine fire of 47 years)[1]	0.2 (-0.2, 0.7)	0.31	0.2 (-0.2, 0.6)	0.39	0.01 (-0.01, 0.03)	0.24
Survey round (0 = round 1; 1 = round 2)	1.8 (1.2, 2.3)	<0.001	1.8 (1.2, 2.3)	<0.001	0.10 (0.07, 0.13)	<0.001
Age during mine fire (per 10 years; at an exposure level of 10 µg/m³) [2]	-0.9 (-1.3, -0.5)	<0.001	-1.0 (-1.4, -0.6)	<0.001	-0.05(-0.06, -0.03)	<0.001
Mental health conditions prior to 2014	4.2 (3.0, 5.3)	<0.001	4.5 (3.4, 5.6)	<0.001	0.22 (0.17, 0.27)	<0.001
Male	-0.5 (-1.5, 0.4)	0.28	-0.3 (-1.2, 0.7)	0.55	-0.02 (-0.06, 0.03)	0.44
Cardiac event pre/post 2014[3]	0.9 (-0.4, 2.3)	0.17	1.0 (-0.4, 2.4)	0.15	0.05 (-0.02, 0.11)	0.16
Asthma diagnosed pre/post 2014[3]	1.0 (-0.1, 2.0)	0.08	0.7 (-0.3, 1.8)	0.17	0.04 (-0.01, 0.09)	0.12
COPD diagnosed pre/post 2014[3]	3.8 (1.0, 6.5)	0.007	3.9 (1.1, 6.7)	0.007	0.16 (0.04, 0.28)	0.009
Number of traumatic life events[3]						
None	Reference		Reference		Reference	
One	2.5 (1.1, 3.8)	<0.001	2.6 (1.2, 3.9)	<0.001	0.13 (0.06, 0.19)	<0.001
Multiple	3.0 (1.9, 4.1)	<0.001	2.9 (1.8, 4.0)	<0.001	0.16 (0.11, 0.21)	<0.001
Education level at each survey[3]						
Secondary up to year 10	Reference		Reference		Reference	
Secondary year 11-12	-1.6 (-3.3, 0.1)	0.06	-1.5 (-3.1, 0.1)	0.08	-0.06 (-0.13, 0.01)	0.11
Certificate, university or other tertiary institute degree	-2.3 (-3.7, -0.9)	<0.001	-2.2 (-3.5, -0.8)	0.002	-0.10 (-0.16, -0.04)	0.002
Employment at each survey[3]						
Paid employment (FT, PT, self-employed)	Reference		Reference		Reference	
Other (student/volunteer/home-duties/retired)	0.9 (-0.4, 2.2)	0.16	0.9 (-0.4, 2.2)	0.17	0.05 (-0.01, 0.11)	0.14
Unemployed/unable to work	4.6 (2.6, 6.6)	<0.001	4.5 (2.6, 6.5)	<0.001	0.19 (0.11, 0.28)	<0.001

[1] Mean $PM_{2.5}$ exposure variable was centred at 10 µg/m³ and divided by 10 to give exposure units per 10 µg/m³

[2] Age during coalmine fire was centred at the mean (47 years) and divided by 10 to give age per 10 years

[3] Round 1 covariates.

11 Document History

Version number	Date approved	Approved by	Brief description
1.0		Senior Project Manager	Submitted to DHHS